Local Risk Factors for Implant Therapy

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Purpose: *The aim of this review was to determine the effect of several potential local risk factors on implant survival and success (primary outcomes) as well as on mucosal recession, bleeding on probing, and proximal marginal bone loss (secondary outcomes).* ***Materials and Methods:*** *A comprehensive review of the literature was conducted. The selection of publications reporting on human clinical studies was based on predetermined inclusion criteria and was agreed upon by three reviewers. After title and abstract screening of 2,681 publications obtained from the search, 19 articles were deemed to be relevant to the topic and the search criteria.* ***Results:*** *Limited data show that when an implant is placed within 3 mm of the neighboring tooth, proximal bone is at risk. The data regarding the placement of implants into infected sites are still insufficient, but studies have shown that this may be possible. Soft tissue thickness has not been shown to be a risk factor in implant survival. There is also no evidence to support a relationship between the width of keratinized tissue and implant survival. No studies were found that directly related bone density to implant survival. Implant stability was also difficult to examine due to the lack of validated stability measures.* ***Discussion and Conclusion:*** *One critical factor that faced the group during the review of the literature and interpretation of the data was the multifactorial nature of implant therapy. This makes isolation of specific risk factors difficult. Conclusions are limited by the current lack of quality clinical trials in this area.* Int J Oral Maxillofac Implants 2009;24(suppl):28–38

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The use of dental implants to aid in the support of restorations replacing missing teeth has been reported in the literature dating back to the early 1960s.[1–3] Historically, dental implant treatments have had mixed results with regard to survival of the implants and prostheses. The past two decades have seen continual efforts by manufacturers, researchers, and clinicians to improve the success of implant treatment outcomes through evolution in implant designs, materials, and clinical procedures.

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In today's practice, the clinician and patient often evaluate the treatment success of dental implants with reference to duration of function and ultimate esthetic result. When implant failures occur, they are categorized as either early or late, defined as occurring prior to or at abutment connection (early), or after occlusal loading (late).[4,5] The factors involved in the failures at these time points often are not related. Early failures often are associated with a disruption that occurs during the initial healing phase, leading to fibrous scar tissue formation between the implant surface and the surrounding bone.[6] This scar tissue formation can allow epithelial downgrowth to occur, which can lead to implant mobility and eventual implant failure. Late failures are often influenced by a combination of factors, including the microbial environment and prosthetic rehabilitation. In recent years, diagnosis, planning, and clinical techniques that highlight potential risk factors and introduce methods to improve the outcomes of implant osseointegration and restoration have moved to the forefront of educational demands.

Several factors have been shown to have a potential influence on the incidence of dental implant success.[4,7] These factors can be divided into local and systemic risk factors, which may be influential in the early or late phase of implant therapy. A *risk factor* is a characteristic statistically associated with, although

not necessarily causally related to, an increased risk of morbidity or mortality, according to *Stedman's Medical Dictionary*. It is important to understand that this is a statistical relationship and to emphasize that a risk factor does not imply causation. The scope of this paper is the examination of local risk factors in implant dentistry. A *local risk factor* is any situation that could pose a risk to successful osseointegration and restoration of a dental implant at the level of the implant site and surrounding teeth. It would be advantageous for the clinician to be able to identify the role local risk factors play prior to the initiation of treatment, so that the end result is optimal for a given situation.

The placement of dental implants adjacent to natural teeth requires careful measurement of the available restorative space, bone, and proximal root positions. Utilization of a dental implant that encroaches on the adjacent periodontal apparatus or root surface could lead to complications affecting the peri-implant hard and soft tissues, the dental implant, and/or the tooth, resulting in esthetic compromise and loss of the implant or the adjacent tooth.[8] Therefore, careful consideration of available bone coupled with the implant dimension and insertion position is needed to prevent such occurrences. While numerous studies support the use of dental implants in single-tooth rehabilitation, there is little information available on structures adjacent to single-tooth implants.[9] For example, how close can an implant be placed to an adjacent root without causing significant bone loss and subsequent compromise of interdental papillae?

In response to increasing demands to streamline patient care and maximize available bone once condemned teeth are extracted, clinicians have successfully introduced immediate placement of dental implants into the clinical protocol.[10–14] In addition, numerous clinical studies have demonstrated that immediate implant placement into extraction sockets is a successful and predictable clinical method.[12,15–16] As clinicians' experience with immediate implants has increased, questions have arisen regarding whether implants placed into debrided infected sites would show similar outcomes when compared to native sites. At present, data regarding the outcome of implant placement into sites with periapical lesions in humans are scarce.[17]

One of the primary clinical outcomes of implant placement is primary stability, ie, rigid fixation of the implant with the host bone cavity and absence of micromotion.[18–20] There has been limited investigation of the factors that influence primary stability or of its predictability at different sites in the jawbone. The degree of primary stability after implant placement has been related to bone quality, bone volume, implant design, patient characteristics, and surgical technique, among other factors.[21,22] Since many of these factors are present during placement of an implant, it is difficult to isolate the influence of primary stability alone. Various methods have been used to objectively assess the stability of the bone-implant interface at the time of insertion and throughout the osseointegration period, but none have been validated.[23]

With the ever-increasing demands regarding esthetic outcomes with implant therapy, the behavior of the peri-implant soft tissue is at the forefront of discussions. The gingival biotype has often been used to describe soft tissue thickness in a bucco-lingual dimension, and perhaps in the future this will become a more accepted term.[24,25] Soft tissue thickness is an important factor when considering the esthetic zone. Esthetic success is different from dental implant success, the definition of which is still under discussion. The presence of an adequate zone of keratinized mucosa has also been discussed as essential for esthetic success and the long-term survival of dental implants. Lang and Löe[26] have defined an adequate zone of keratinized mucosa as having ≥ 2 mm of masticatory gingiva with ≥ 1 mm of attached gingiva. These different types of tissue may differ in their resistance to bacterial infection, especially at the complex implant-mucosa interface. Few studies have examined the relationship between the width of keratinized mucosa and the health of the peri-implant tissues.[27–30]

While there is literature to support the direct influence some local risk factors may have on implant survival or success, there are also several factors that are anecdotally quoted as having an impact on implant therapy. It is the ongoing task of healthcare professionals to seek evidence-based knowledge such that the highest standard of care can be provided to their patients.

OBJECTIVES

The aim of this review was to determine the effect of several potential local risk factors on implant survival and success (primary outcomes) as well as on mucosal recession, bleeding on probing, and proximal marginal bone loss (secondary outcomes). The following local risk factors were considered: interdental space, infected sites, soft tissue thickness, width of keratinized soft tissue, bone density, and implant stability. It must be noted that this does not represent a comprehensive list of all the local factors related to implant therapy. Other papers within this consensus report address the topic of bone quantity.

As with any study involving the oral cavity, oral hygiene is a key variable. There is substantial evi-

dence that poor oral hygiene is associated with peri-implant disease.[31,32] The authors felt that it was not within the scope of this review to examine this association in any further detail.

The following list highlights the primary and secondary outcome measures that were utilized in this review. The primary outcomes were implant survival and implant success, and all definitions of implant survival and success described in the included studies were considered. However, when there was a lack of consensus regarding a set of universally accepted success criteria, the following clinical and radiographic criteria proposed by Albrektsson et al[33] and adapted by Buser et al[34] and Karoussis et al[35] were used to define implant success:

- Absence of mobility[34]
- Absence of persistent subjective complaints (pain, foreign-body sensation, and/or dysesthesia)[34]
- Absence of recurrent peri-implant infection with suppuration[34]
- Absence of a continuous radiolucency around the implant[34]
- No pocket probing depth (PPD) > 5 mm[36]
- No PPD ≥ 5 mm and no bleeding on probing[36]
- Annual vertical bone loss after the first year of service not exceeding 0.2 mm (mesially or distally)[33,37]

Several secondary outcomes were also considered. These included mucosal recession, bleeding on probing, and proximal marginal bone loss. Although these outcomes individually were not directly related to implant survival or success, they were determined to be significant when considering outcomes in the esthetic zone.

MATERIALS AND METHODS

Search Strategy

Prior to commencing an electronic search, it was necessary to determine the key local risk factors in implant dentistry. Through a group discussion drawing on published articles, textbooks, and clinical experience, the authors generated a list of local risk factors. Once the list had been compiled, an electronic search was performed utilizing MEDLINE (via PubMed) from 1991 through June 2008. The search key words utilized were: (*dental implant* OR *implant*) AND: *local risk factor, risk factor, anatomy, infection, endodontic failure, implant failure, ridge atrophy, hard tissue, soft tissue, bone quality, bone quantity, biotype, success, Periotest,* and *Osstell.* Limits applied during the search were *English*, *dental,* and *clinical journals*.

Hand searching was performed for all offline journals, including *The International Journal of Periodontics & Restorative Dentistry, Journal of Oral and Maxillofacial Surgery, Journal of Oral Implantology, Implant Dentistry, Journal of Periodontology,* and *Dental Clinics of North America*, as well as for bibliographies of articles relevant to the topic.

The search was restricted to clinical trials utilizing conventional and immediate placement and loading protocols for dental implant therapy. Only studies reporting implant and prosthesis survival and/or success outcomes and the secondary outcomes (mucosal recession, bleeding on probing, and peri-implant marginal bone loss) after 12 or more months were included. All levels of the hierarchy of evidence, except for expert opinion, were included. For case reports, only studies with 10 or more patients were included.

Data Extraction

Three reviewers (WM, EL, and AN) independently screened the titles and abstracts of the articles collected from the initial search. After title and abstract screening of 2,681 publications obtained from the search, 189 were selected for full text reading. The selected publications in electronic format (when available) were imported into a reference managing software (EndNote X.0.2 for Macintosh) and distributed to the reviewers. Discrepancies were resolved by discussion. Nineteen articles were deemed to be relevant to the topic and the search criteria.

RESULTS

Interdental Space

According to the inclusion criteria, six papers were found that reported on the effects of implant placement on the proximal marginal bone loss of adjacent teeth (Table 1). Of the six papers found, none were prospective controlled clinical trials or randomized controlled trials; all were prospective clinical trials. Two of the six prospective clinical trials reported on the influence of implant placement on the marginal bone levels of adjacent teeth based on available interdental space. In all of the studies, the cementoenamel junction (CEJ) to the alveolar crest of the tooth surface facing the implant was used as a reference point for measurements. When available, the survival and success rates of the implants and the adjacent teeth were reported.[38–42]

Esposito et al[38] performed a prospective clinical trial of marginal bone loss at tooth surfaces adjacent to single machined-surface implants. A total of 58 adults with 71 implants were followed up to 3 years after restoration. Specified distances were measured,

Table 1 Reported Mean Marginal Bone Loss (MMBL) at Adjacent Teeth at Pre- and Postloading Visits

Study	Study type	Patients/ implants	Location	Preloading	Postloading	Notes
Esposito et al (1993)[38]	PCT	58/71	53 anterior 18 posterior	x = 0.97 ± 1.09 mm	x = 0.32 ± 0.58 mm y = 1	No failures, machined implants
Johnson and Persson (2000)[39]	PCT	76/78	21 anterior 57 posterior	NA	x = 0.3 ± 0.9 mm y = 3	1 failure, machined and rough-surfaced implants
Krennmair et al (2003)[40]	PCT	78/78	27 anterior 51 posterior	NA	xa = 1.6 ± 0.6 mm xp = 0.4 ± 0.3 mm *P* < .05 y = 3	1 failure, no loss of adjacent teeth, rough-surfaced implants
Gotfredsen (2004)[42]	PCT	20/20	18 anterior 2 posterior	xe = 0.13 ± 0.58 mm x = 0.57 ± 0.48 mm	xe = 0.35 ± 0.45 mm x = 0.22 ± 0.38 mm y = 5	No failures, rough-surfaced implants
Cardaropoli et al (2006)[41]	PCT	11/11	11 anterior	x = 0.2 ± 1.1 mm	x = 0.4 ± 0.9 mm y = 1	No failures, machined implants

PCT = prospective clinical trial; x = MMBL at adjacent teeth; xe = MMBL when implants placed in extraction sockets; xa = MMBL at adjacent teeth in anterior locations; xp = MMBL in posterior locations; y = years.

as were marginal bone levels around implants and tooth surfaces in magnified standardized intraoral radiographs. The results showed a loss of marginal bone support at tooth surfaces adjacent to inserted implants during the interval between preoperative examination and crown delivery (mean 0.97 mm, SD 1.09 mm) that exceeded the loss during subsequent years (mean 0.32 mm, SD 0.58 mm). The largest bone loss was observed when implants were placed next to maxillary lateral incisors (mean 1.40 mm, SD 1.46 mm). A strong correlation was found between bone loss at adjacent teeth and a horizontal distance from implant body to tooth of < 3 mm ($P = .0001$). With decreasing distance the bone loss increased, especially in the maxillary incisor region. The authors reported an implant survival rate of 100%.

Another prospective clinical trial by Krennmair et al[40] analyzed the status of teeth adjacent to single-tooth dental implants placed in anterior (27 implants) and posterior (51 implants) regions of the mouth. Seventy-eight single-tooth implants and 148 adjacent teeth were followed for a mean of 58 months, including evaluation of implant survival rate and proximal bone loss. Radiographic bone loss was determined from orthopantomograms and/or radiographs based on the paralleling technique and by comparing the primary postoperative radiograph with the most recent one. The differences in proximal bone crest height between implant placement and follow-up were calculated, and the amount of bone height loss was compared between anterior and posterior regions. The authors reported one implant failure and no loss of adjacent teeth over the evaluation period, for a 99% success rate. There was a significant horizontal distance from the implant edge to the adjacent teeth between the anterior (mean 1.5 mm, SD 0.6 mm) and posterior (mean 2.8 mm, SD 0.8 mm; $P < .05$) regions. There was also a significant difference in proximal crestal bone loss when anterior (mean 1.6 mm, SD 1.0 mm) and posterior (mean 0.4 mm, SD 0.3 mm; $P < .05$) regions were compared. A multivariate regression analysis showed a significant influence of the horizontal distance on the proximal bone loss in the anterior region (correlation 0.676; $P = .0032$), but not in the posterior region (correlation 0.05; $P = .29$).[40]

Johnson and Persson[39] conducted a prospective clinical trial evaluating marginal bone levels around machined implants and hydroxyapatite-coated implants and their neighboring teeth over a 3-year period. At machined surface sites, there was a statistically significant change in marginal bone height between baseline and 1 year ($P < .01$), with the radiographic bone levels showing a 1-year mean loss of 0.6 mm (SD 0.1 mm) on the mesial surface and 0.7 mm (SD 0.2 mm) on the distal surface of the adjacent teeth. There was no significant change in marginal bone levels between years 1 and 2, years 1 and 3, or years 2 and 3. The authors reported a 3-year survival rate of 98.3%.

Gotfredsen[42] conducted a 5-year prospective clinical trial of 20 patients who received single-tooth implants placed into extraction sockets after 4 weeks of healing (group A; n = 10) and healed sites, 12 weeks postextraction (group B; n = 10). An implant survival rate of 100% over a period of 5 years was reported. At crown placement, the mean marginal bone loss on neighboring teeth was 0.13 mm (SD 0.58 mm) in group A and 0.57 mm (SD 0.48 mm) in group B, which represented a significant correlation between the groups. After 5 years, the mean loss of

marginal bone on neighboring teeth was 0.35 mm (SD 0.45 mm) for group A and 0.22 mm (SD 0.38 mm) for group B, with no significant correlation.

Cardaropoli et al[41] conducted a prospective clinical trial to evaluate dimensional alterations of the peri-implant tissues of eleven single-implant restorations from the time of placement to 1 year postloading. Radiographic measurements of proximal bone levels on the neighboring teeth were performed at crown placement and at 1 year postloading. The mean radiographic interproximal bone level was 1.9 mm (SD 1.1 mm) at the time of second-stage surgery, increased to 2.1 mm (SD 1.1 mm) at the time of crown placement, and was 2.5 mm (SD 0.8 mm) at the 1-year follow-up ($P > .05$). The authors reported no implant failures during the study period.

Infected Sites

For the purpose of this review, an *infected site* is defined as one exhibiting signs or symptoms of pain, periapical radiolucency, fistula, suppuration, or a combination of these. The search identified two papers (one prospective controlled clinical trial, one prospective clinical trial) that examined the survival outcomes of implants placed into infected sites utilizing immediate implant placement. One prospective randomized clinical trial was also identified that provided implant success rates on immediate and delayed implant placement into infected sites.

Siegenthaler et al[17] examined the survival of immediate implants that replaced teeth exhibiting periapical pathology. In this prospective controlled clinical trial, one group of 17 patients was treated with immediate implant placement in order to replace teeth that exhibited periapical pathology, while the control group of 17 patients had immediate implant placement in sites with no pathology. The authors defined the inclusion criteria for the test group on the basis that the tooth to be extracted and replaced by an implant exhibited periapical pathology, with signs or symptoms including pain, periapical radiolucency > 1 mm, fistula, suppuration, or a combination. One surgeon carried out a standard surgical protocol: upon removal of the tooth, the site was carefully debrided of all granulation tissue and carefully rinsed. Upon achieving primary stability with implant positioning, guided bone regeneration with a deproteinized bovine bone mineral (Bio-Oss spongosia particles, Geistlich) was applied to the horizontal deficit between the implant surface and bone wall and then covered with a resorbable collagen membrane (Bio-Gide, Geistlich). Implants were allowed to heal in both transmucosal and semisubmerged positions. Patients were prescribed a 5-day regimen of penicillin (Clamoxyl 750 mg tid) and diclofenac (Voltarene 50 mg bid). Implants were loaded after 3 months. Five patients were removed from the study (four test and one control) due to the inability to obtain primary stability of the implant during placement. The remaining difference between the test and control group numbers was not statistically significant based on a Fisher exact test. The remaining implants showed a 100% survival rate at 12 months. The authors concluded, within the confines of their study, that when primary stability is achieved for implants placed into extraction sockets exhibiting periapical pathology, there is no statistical difference in survival or complication rates versus those implants placed in sites of removed pathology.

Villa et al[43] examined immediate and early function of implants placed in the extraction sockets of maxillary infected teeth. The pilot study followed 33 patients over one year who had implants placed in infected extraction sites by one surgeon. The authors defined the infected teeth as possessing clinical or radiographic evidence of advanced endodontic and periodontal lesions or root fracture judged to be no longer recoverable and unable to support a fixed prosthesis. The surgical protocol included complete debridement of the extraction socket and placement of the dental implant with primary stability. Grafting was performed to fill socket deficits greater than 1 mm with autogenous bone (when possible) or a demineralized bovine bone (Bio-Oss). Various reasons for tooth extraction were reported: periodontal (n = 55), endodontic (n = 15), and root fracture (n = 6). Implants were placed utilizing various surgical techniques (47 flap elevation, 29 flapless) based on the clinical presentation. Implants were distributed in the maxilla into single sites (n = 12), and multiple sites for partial (n = 9) and complete (n = 12) reconstruction. Seventy-six implants were placed directly into infected sites, while 24 were placed in sites without pathology. Provisional prostheses were placed within 36 hours of the surgery; 20 were in occlusal function and 14 remained out of occlusal contact. An implant was classified as surviving if *(1)* it fulfilled its purported function, *(2)* it was stable when tested individually, *(3)* no pain or signs of infection were detected during clinical examination, and *(4)* no radiographic signs of peri-implant pathology were observed. The author reported a 1-year overall survival rate of 97.4%, with 97.9% in sites with flap elevation and 96.6% in sites with flapless surgery.

With regard to delayed placement into previously infected sites, Lindeboom et al[44] carried out a prospective randomized trial on 50 patients with 50 implants followed up for 1 year. Patients with a tooth demonstrating radiographic signs of chronic apical periodontitis were randomized into two groups (n =

Table 2 Reported Bleeding on Probing (BOP) and Mean Alveolar Bone Loss in Relation to Keratinized Mucosa

Study	Study type	Patients/ implants	Implants/width of keratinized mucosa	BOP	Mean alveolar bone loss
Bouri et al (2008)[30]	Cross-sectional	76/200	A 110/≥ 2 mm B 90/< 2 mm	*B > A (P < .01)	*B > A (P < .001)
Wennström et al (1994)[28]	Cross-sectional	39/171	A 108/≥ 2 mm B 63/< 2 mm	B > A	Not examined
Chung et al (2006)[29]	Retrospective cross-sectional	69/339	A 225/≥ 2 mm B 84/< 2 mm	Not examined	A = B

*Statistically significant.

25 each): *(1)* immediate placement (IP) and *(2)* delayed placement (DP), 3 months post extraction. Primary stability at the time of implant placement was an inclusion criterion for the study. In the IP group, implants were placed following thorough degranulation of the socket, and bone augmentation utilizing ground corticocancellous bone harvested from the trigonum retromolar or chin regions was performed to cover the buccal surface and implant. A bioresorbable collagen membrane (Bio-Gide) was placed to cover the graft and implant. In the DP group, implant placement was carried out after 12 weeks of healing. All implants were submerged and allowed to heal without loading for 6 months. Implant success criteria included: no clinical implant mobility at second-stage surgical procedures or follow-up evaluations, no radiographic evidence of peri-implant radiolucency, no signs or symptoms of infection, and no bone loss in excess of the bone loss criteria reported by Albrektsson et al.[33] Thirty-two implants were placed in the anterior maxilla and 18 implants in the premolar region. Every patient required augmentation of the buccal bone (autograft) at the time of implant placement. Cumulative implant success rates after 6 months were 92% in the IP group and 100% in the DP group. At the 1-year follow-up, all implants remained in function.

Soft Tissue Thickness

During data extraction, there were no papers found that reported a correlation between soft tissue thickness and implant survival, so the secondary outcome measure of mucosal recession was used. There were several studies found that evaluated mucosal recession around dental implants over various time periods, but unfortunately they were not correlated with soft tissue thickness at the time of implant placement.[17,41,43–48] One paper was identified that described this secondary outcome related to soft tissue thickness at the time of implant placement.

Evans and Chen[49] examined esthetic outcomes of immediately placed implants. They evaluated the outcome of implants placed by gingival biotype. They classified the biotype as being either thick or thin according to criteria referenced by Müller et al.[24] For a thin tissue biotype, a periodontal probe could be seen through the gingival tissue of the labial sulcus; for a thick biotype, a periodontal probe was not visible. Of the 42 patients in their study, 24 were classified as having a thin biotype. They demonstrated slightly greater mucosal recession than those classified as having the thick tissue biotype (1.0 ± 0.9 mm vs 0.7 ± 0.57 mm, respectively); however, this was not statistically significant (P = .187). Facial tissue recession of 1 mm or greater was measured in 40.5% sites; those with a thin tissue biotype had a greater frequency of recession of 1 mm or more (45.8%) compared with thick sites (33.3%). If the implants were also located toward the facial aspect, 85.7% of thin biotypes had recession compared with 66.7% of thick biotypes.

Width of Keratinized Soft Tissue

In this review of the literature, no studies were found that directly related the width of keratinized tissue to implant survival. Therefore, secondary outcomes (bleeding on probing, marginal bone loss) were evaluated as they related to the width of keratinized tissue. A summary of these findings can be found in Table 2.

Bouri et al[30] performed a cross-sectional study of 76 patients with 200 implants that had been restored for a minimum of 12 months to determine whether the width of keratinized mucosa around dental implants has an effect on the health of the surrounding soft and hard tissues. One hundred ten implants (group A) were found to have ≥ 2 mm of keratinized tissue and 90 implants (group B) had < 2 mm. Multivariable logistic and linear regression analyses were used to examine whether the width of keratinized tissue is independently associated with bleeding on probing and mean alveolar bone loss. The findings showed implants in group B to have significantly more bleeding on probing than implants in group A (odds ratio 2.37; 95% CI 1.04–5.83). Implants in group B also showed significantly higher mean alveolar bone loss than implants in group A; however, this was based on comparisons of nonstandardized radiographs.

In a clinical investigation, Wennström et al[28] evaluated the soft tissue conditions around implants in relation to the width of masticatory mucosa. They found that although 61% of 171 implants in their study had no attached mucosa adjacent to the implant, this did not appear to have a detrimental effect on the plaque control or the peri-implant health of the tissue when measured by bleeding on probing. They concluded that a lack of an attached portion of masticatory mucosa did not compromise the maintenance of health of the peri-implant soft tissue.

In a retrospective cross-sectional clinical study of 69 patients from two centers, Chung et al[29] investigated the relationship between the presence or absence of keratinized mucosa and the long-term maintenance of 339 endosseous root-form implants with different surfaces. Probing depths and radiographic evaluation were recorded. They found inflammation and plaque accumulation to be statistically higher in keratinized and attached mucosa widths < 2 mm, whereas the absence of adequate keratinized/attached mucosa had little or no impact on alveolar bone level.

Roos-Jansåker et al[50] performed a longitudinal clinical study looking at 218 patients and 999 implants with a follow-up of 9 to 14 years postrestoration, in which they attempted to determine the factors that allowed development of peri-implant lesions. They defined mucositis as sites with a probing depth ≥ 4 mm and bleeding on probing. The bleeding scores were divided into three categories: 0% to 20%, 21% to 60%, 61% to 100%. They reported that the amount of keratinized mucosa was significantly associated with mucositis ($P = .008$ multivariate) as well as a bone level loss of ≥ 3 threads ($P = .03$ multivariate).

Bone Density

During the data extraction, no studies were found that directly related bone density to implant survival or success.

Implant Stability

A number of obstacles were encountered in reviewing the literature on implant stability and survival. Most important was the lack of objective measures of implant stability.

Esposito et al[51] performed a thorough review of the literature, which included randomized controlled trials looking at implant success rates in immediate, early, and conventionally loaded root-form implants. They concluded that a high degree of primary implant stability seems to be one of the prerequisites for successful immediate/early loading.

Orenstein et al[52] conducted a prospective multicenter clinical study of 3,111 implants in 800 patients in which they evaluated the 3-year postplacement survival of 89 implants (HA-coated) that exhibited clinical mobility at the time of placement. Mobility was assessed during the surgical procedure by gently applying pressure to the implant to see if it could be depressed or rotated. The degree of and/or reason(s) for mobility were not documented. The use and type of augmentation material at the time of surgery, if any, were documented. Survival was defined as clinically stable and free of associated pain and/or infection. Survival rates were reported for two periods: from placement to 36 months and from prosthetic loading to 36 months. The latter eliminated early failures and resulted in higher survival rates. Implant survival was 78.8% from placement to loading and 95.9% from prosthetic loading to 36 months. Implant mobility at placement was significantly related to 3-year survival ($P < .001$).

Although the following papers may not deal with implant survival directly, they are mentioned below because they provide information on the currently available methods for measuring implant stability.

Molly[53] performed a review of the literature to evaluate bone density and primary stability in implant therapy. The search included publications from 1988 to January 2006, which resulted in a total of 24 articles that met the inclusion criteria. Four systems were used to measure primary implant stability. The author concluded that there was no evidence that the Periotest (Medizintechnik, Gulden) device provided any means of defining primary stability or that any single measurement provided any predictive value of implant outcome. The Osstell (Integration Diagnostics) device uses resonance frequency association to measure implant stability, and again the author concluded that there was no evidence to support a single measurement having any predictive value for implant outcome. Osseocare (Nobel Biocare) provides a measure of insertion torque, and again there was no evidence that this provided a valid means of defining primary stability. The lack of any correlation of radiofrequency analysis (RFA) to insertion torque has also been confirmed by other authors.[54]

Radiofrequency analysis has been shown to have some use when comparing measurements of the same implant over a period of time and implants of the same system. Balshi et al[55] evaluated 344 Brånemark implants (Nobel Biocare) that were immediately loaded. They looked at radiofrequency measurements taken at the time of implant placement and 30, 60, and 90 days following surgery. They found that RFA measurements showed a decrease in bone-implant stability in the first month which then increased over the second and third months. While a critical value for primary implant stability cannot be determined, information from implant stability measurements taken in

the postsurgical phase may be useful in identifying some of the factors that influence implant survival, such as bone quality and loading protocols.

Turkyilmaz et al[56] performed a clinical study evaluating 108 patients with 230 implant sites in which presurgery bone density was evaluated from a computed tomography (CT) scan, insertion torque was recorded using the Osseocare machine, and primary implant stability was measured using radiofrequency measurements from the Osstell machine. The authors found statistically significant correlations between the radiofrequency values and bone density and insertion torque values. They concluded that the use of a preoperative CT might help predict primary implant stability prior to implant insertion.

DISCUSSION

This review was one of four with the task of determining risk factors in implant therapy in preparation for the International Team for Implantology Consensus Conference in Stuttgart, Germany. The groups were assigned one of four topics: *(1)* systemic, *(2)* local, *(3)* smoking and periodontitis, and *(4)* mechanical and technical risk factors. Verification of these risk factors can be beneficial for treatment planning, establishing treatment protocols, and potentially improving clinical outcomes. The challenge of the review process was collecting enough information to generate appreciable conclusions. Most studies had retrospective or prospective designs that lacked controls, whereas case studies had short follow-up periods and limited numbers of subjects. Another concern faced in interpreting the data was that different implant success criteria were used, complicating the comparison and compilation of the results.

One critical factor that faced our group during the review of the literature and interpretation of the data was implant design. There is a lack of comparative information on the influence of current and past implant designs (implant body, thread pitch, surface characteristics, prosthetic connection, length and diameter) on clinical outcomes in variable clinical situations.

Interdental Space

When exploring the available interdental space as a local risk factor in implant dentistry, the reviewers attempted to determine the time point at which the position of the dental implant influenced the bone crest on the teeth adjacent to the implant. This is an important risk factor, as several implant-body dimensions are commercially available and selection of the improper size implant for a given interdental space can have a negative effect on the support for the interdental papillae, potentially leading to a negative esthetic result. Esposito et al[38] reported a strong correlation between bone loss at adjacent teeth and the horizontal distance of the implant body to the tooth when this was < 3 mm ($P = .0001$). It must be emphasized that their study examined the radiographic parameters of bone loss, which cannot evaluate the true position of the periodontal attachment on the root surface. Their study also did not evaluate the connective tissue attachment, which may be of greater clinical significance in the esthetic zone. Based on these outcomes, there is a need for clinical and histologic studies that evaluate the conditions of the teeth adjacent to implants more thoroughly. The implants that were placed had 4.1-mm platforms, and the authors reported the strongest correlation for marginal bone loss in the lateral incisor position, where the horizontal distance between the implant body and the adjacent tooth was at a minimum. However, the authors reported that this reduced distance could explain only 17% of the variation of bone loss. In a similar study, Krennmair et al[40] also reported significant differences in the proximal crestal bone loss between the anterior and posterior regions of the mouth, and that the horizontal distance significantly influenced the proximal bone loss in the anterior region. Based on their outcomes, the authors encouraged utilization of papilla-protecting surgical methods in cases in which a narrow horizontal distance is to be expected. Lekholm and Jemt[57] considered patients with a horizontal gap of 7 mm or more to be routine cases, whereas gaps of 5 to 6 mm should be regarded as the minimal space for standard 4.1-mm implant platforms. It would be worthwhile to examine the smaller-diameter implants (3.0 to 3.5 mm) available on the market in these limited interdental space situations.

Infected Sites

Several studies have shown the placement of implants into fresh extraction sockets to be a successful and predictable procedure.[10–16] Although this procedure has gained in popularity, several factors continue to play an important role in its success, including surgical technique, achieving primary stability, and augmentation when necessary. Varying indications for immediate implant placement have moved into the forefront of implant dentistry, one of the most popular being placement in infected sites. Data regarding the outcome of implant placement in sites with periapical lesions in humans remain scarce.[17] A question that arose during this review process was whether placement of an implant into an infected, debrided site could pose a local risk to implant success or survival.

In an animal study using histomorphometric analysis of implants immediately placed into sites

with periapical pathology versus control sites, no significant difference was found in the percentage of bone-to-implant contact between the two groups.[58] Hence, it was concluded that in the animal model, periapically infected sites are not contraindicated for immediate implant placement.

The three reviewed papers[17,43,44] reported survival rates ranging from 92% to 100% at 12 months. While the follow-up time was short, the authors of the current proceedings felt that the survival rates were comparable to results reported in noninfected sites.[59–69] Based on this review, we stress that at a minimum, this procedure requires sites to be completely debrided and implant placement to have achieved primary stability to offer the potential for osseointegration and subsequent implant survival. Further long-term controlled clinical trials are needed to investigate this approach.

Soft Tissue Thickness

Our search did not identify sufficient evidence to make firm conclusions with regard to soft tissue as a risk factor in implant therapy. In terms of tissue quality, it was noted that there was an increased risk of recession where a thin tissue biotype was present.[49] However, recession is a multifactorial condition that is also dependent on bone present and the three-dimensional position of the implant. More studies were identified relating to the quantity of soft tissue; however, conflicting evidence exists as to whether the presence of keratinized, attached mucosa is essential for maintenance of health of peri-implant soft tissue.[17,41,43–48]

Width of Keratinized Soft Tissue

This review was unable to find a relationship between the width of keratinized soft tissue and implant survival. It is often recommended that implants be surrounded by keratinized tissue to improve their long-term prognosis. Many authors strongly advocate techniques to increase the width of keratinized tissue; however, there is no evidence to support this.[29] In fact, other studies have shown that the presence of keratinized tissue around an implant is not essential for maintenance of peri-implant health.[28] Until a high-quality trial is performed, there will continue to be controversy over whether the presence of keratinized tissue surrounding an implant is a prerequisite for long-term implant survival.

Bone Density

A number of limitations should be taken into account when reviewing the literature on bone density. Molly[53] highlighted this challenge in a review paper examining bone density and primary implant stability. The author reported that bone quality is often referred to in the literature as bone density, but this cannot be taken for granted because many factors are important when discussing bone quality—among them, metabolism, cell turnover, mineralization, maturation, intercellular matrix, and vascularity. Each of these factors may have an influence on implant outcomes. It has also been highlighted that the "gold standard" for bone density measurement is a histologic and morphometric analysis.[53] The utility of the currently available measurements of bone density for the prediction of implant success has not been assessed. This makes isolation of bone density as a risk factor for implant therapy difficult.

Bone quality has been studied in the implant literature; it includes a classification by Lekholm and Zarb[70] that was introduced more than 20 years ago and is still widely used. It categorizes the quality and quantity of bone in different groups based on the amount of cortical and cancellous bone at the implant site. This assessment employs a radiographic and clinical analysis resulting in a scale from 1 to 4. In view of the highly subjective nature of this classification, studies have utilized bone density in an effort to quantify the bone. However, an evaluation of the literature demonstrates that there is an obvious need for standardization of bone density in order to evaluate implant outcomes.

Implant Stability

There is currently no validated measure of implant stability. Various methods to measure implant stability have been described, such as subjective evaluation,[52] resonance frequency analysis,[71] and insertion torque.[72] However, as Molly[53] discussed, there is no evidence that these methods can be used to define primary stability or that any single measurement provides any predictive value of implant outcome. The primary stability of the implant at placement will remain a critical factor in the survival of an implant, but until there is an accurate and reproducible measure of implant stability, the critical level needed to ensure implant survival will be undefined.

CONCLUSIONS

Limited data (2 PCT) exist evaluating the available interdental space as a risk factor for implant survival. Two clinical studies (both prospective clinical trials) show that as the proximity of the implant to the neighboring tooth decreases (< 3 mm), the proximal bone loss at adjacent teeth could increase following implant placement.

There is evidence regarding the placement of dental implants into infected sites exhibiting apical

pathology. Two clinical trials (one prospective randomized clinical trial and one prospective randomized trial) have shown survival rates greater than 92% when the implants were placed in debrided sockets and had primary stability.

There is no evidence supporting soft tissue thickness as a risk factor in implant survival. While the secondary outcome of mucosal recession is important, there was no significant correlation with tissue thickness and recession around dental implants (retrospective clinical study).

In a recent systematic review, methods of assessing bone density and implant stability were not validated and therefore these factors cannot be linked with implant survival.

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