Crestal Bone Loss and Oral Implants

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ABSTRACT

Background: A consensus meeting was arranged to critically analyze whether the high figures of peri-implantitis at machined implants that recently have been reported in the literature are valid also for modern implants.

Purpose: The aims of this paper were to present the outcomes from the consensus meeting and to evaluate recent long-term clinical studies on modern implants with regard to frequency of peri-implant infection.

Materials and Methods: Ten different studies of three modern implant brands of moderately rough surfaces with 10-year or longer follow-up times were found through a PubMed and manual search.

Results: It was concluded that bleeding on probing or probing depths are weak indicators of crestal bone loss (CBL); that CBL occurs for many other reasons than infection; that implant-, clinician-, and patient-related factors contribute to CBL; and that modern oral implants outperform older devices. Based on a literature search, the frequency of implants with reported peri-implant infection and significant bone loss leading to implant removal or other surgical intervention was on average 2.7% during 7 to 16 years of function.

Conclusion: The summed frequency of peri-implantitis and implant failure is commonly less than 5% over 10 years of follow-up for modern implants when using established protocols.

KEY WORDS: bone, crestal bone loss, implant

INTRODUCTION

Recently, reports have been published in the literature with a seemingly never-ending increase of crestal bone loss around commonly used oral implants. At first, figures of 6.6[1] and 12.2%[2] of placed implants suffering from peri-implantitis were published. Thereafter, other reports claimed frequencies of 28,[3] 47,[4] and more than 56%[5] of all patients being affected. These widely varying figures depend on whether evaluations are performed at the implant or patient level, but in addition different definitions of what is to be regarded "peri-implantitis" vary considerably. The most generous definition suggests infection to be the main cause for all bone loss occurring after the implant's first year in situ.[5] These various reports have led to the publication of widely cited consensus statements,[6] apparently regarding the alarming reports as scientific facts rather than unproven hypotheses.

One reason for the alarming figures may be that periodontal principles have been applied on oral implants. The dentogingival complex consists of highly differentiated and specialized tissues, while the oral implant-tissue interface is the result of a foreign body reaction to biocompatible materials. From this perspective, the two entities cannot be directly compared. For instance, although infection may be the most likely explanation for bone loss around teeth, crestal bone loss around implants may occur for many reasons, that is, the response to healing and function. In the implant situation, Koka and Zarb[7] recently questioned whether peri-implantitis is a disease entity at all. These authors refuted the bacterial implications and suggested terms such as osseoinsufficiency or osseoseparation to describe problematic implants. Furthermore, it has been observed that common periodontal indices such as

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bleeding on probing and probing depth have no correlation to marginal bone loss around implants.[8]

The alarming figures of implant problems reported by some authors are indeed different from the perspectives of many other independent researchers with a long-term clinical experience with different implant systems. From our perspective, implant treatment offers a very positive long-term clinical outcome, but our assumption would need to be backed up by published evidence in long-term studies, which is one of the aims of the present paper. However, we recognize that implant sites may become infected and show suppuration and significant crestal bone loss, which needs therapeutic intervention. However, at the level of knowledge we have today, 50 years after the advent of osseointegration, "peri-implantitis" is not at all a major, but quite a minor, problem, in the range of 1 to 2% of modern implants at 10 years. Having said this, we naturally realize that what seems a minor statistical problem for us may be a major problem for the few patients with problematic implants, which certainly would call for continuing work with improvements of implant therapy.

MATERIALS AND METHODS

We decided to initiate a consensus meeting ourselves to critically analyze the long-term outcome of oral implants as well as to investigate the reasons for failure and crestal bone loss. We sent out invitations to key opinion leaders representing different clinical disciplines and with documented clinical experience from different implant systems. Nine colleagues accepted the invitation, which together with the three authors and initiators of this meeting constituted a consensus group to decide whether there is a major problem of implant usage or not. The group consisted of five periodontists, four prosthodontists, two oral surgeons, and one physician, seven of which from Europe, four from USA, and one from Australia. In addition, scientific reporters were invited to present review papers on different subjects such as the long-term outcome of oral implants, reasons for marginal bone loss, and radiological aspects of crestal bone evaluations. This group of authors included one Chinese, one Japanese, one North American, and one European contributor that were invited to the meeting but not represented in the consensus jury. One of the papers submitted to the meeting is published in this issue of *Clinical Implant Dentistry and Related Research*.[9,10] The Estepona consensus meeting was sponsored by five major oral implant suppliers.*

RESULTS

In the development phase of modern implant dentistry, two implant designs clearly dominated. These original implants were the turned, minimally rough titanium surface[11] and the coated, rough titanium plasma sprayed surface.[12] In the 1990s, researchers started to examine alternative implant surfaces produced by sandblasting or gritblasting, acid etching, and combinations thereof.[13,14] As a result, various new surfaces emerged, which were characterized by a moderately rough surface topography. These modern implant surfaces dominate the market today.[15] Modern implants have demonstrated significantly improved clinical results in comparison to old, turned ("machined") devices, if any challenging conditions apply. Challenging conditions include patient smoking,[16] the use of short implants,[17] rapid or direct loading,[18] maxillary implants,[9] or implants placed in irradiated[19] or grafted[20] beds. Due to such documented advantages, Friberg and Jemt,[21] who reported the clinical results achieved at the so-called Brånemark Clinic where osseointegrated oral implants have been used over the last 35 years, noticed a sharp drop in failure rate following the introduction of modern implants, in this case a shift from turned Brånemark implants over to TiUnite implants, indicative that clinical improvements depend on the novel implants and not on a learning curve of the clinicians. Jungner and colleagues[22] in their 5-year study reported 99.4% survival of one hundred fifty-four TiUnite implants compared with 94.7% survival of one hundred thirty-three turned implants, but mixed materials including many mandibular cases with implants placed between the mental foramina seldom display any statistically significant difference between the two types of implants, a fact reported also by Balshe and colleagues.[17] For adequate statistical power, implants in various compromised situations must be analyzed and compared separately.

Such clinical results point to a much more complicated scenario behind crestal bone loss around implants than that all bone loss can be explained by infection or

*Sponsoring companies of the Estepona consensus meeting, here gratefully acknowledged were Astra Tech (Sweden), Biomet 3i (USA), Dentsply (Germany), Straumann (Switzerland), and Nobel Biocare (Switzerland).

overload. In reality, numerous different factors are behind a response such as late (after the passage of the first year) crestal bone loss.[23] The Estepona consensus[24,25] reported that crestal bone loss may occur due to many other reasons than infection. Implant-, clinician-, and patient-related factors, as well as foreign body reactions, may contribute to crestal bone loss,[26] indeed factors found important for long-term success of osseointegration already more than 30 years ago.[27] This multifactorial background to crestal bone loss was further discussed in one of our consensus papers.[9] The so-called healing adaptation theory[26] or combined factor syndrome[9] explains crestal bone loss to be due to a combination of implant factors, clinical handling, and patient factors. The theory recognizes known and published problems with numerous implant designs of varying roughness levels and threaded or unthreaded[11] designs; the coupling between failures and marginal bone loss dependent on the clinician[28,29] as well as on patient factors may be those genetically or environmentally derived.[9] In fact, these factors have since long been known and attended to in clinical practice; nobody would recommend the clinical novice to treat the difficult patient with poor quality and quantity of bone – these are combined factors between poor surgery and a poor patient bed. May so-called overloading play a role as well? Certainly, overloading due to poor prosthetics may be coupled to implant- or patient-related factors and we will have a clinical problem at hand, leading to marginal bone loss or even implant failure with time. Having said this, the threat to the bone may be due to strain rather than stress[30]; bone is reacting with remodeling to loads put upon it and, therefore, cantilevered situations with more loads may be easily compensated by the body natural defense to make more bone. Hence, a dangerous strain situation may not follow all strong-loading situations. Bone adapts to loads/strains according to Wolff's law; hence, what is overload/dangerous strain in one patient may be a safe load level in the next.

If combined factors explain marginal bone loss, what is the mechanism? It was recognized by the delegates that inflammation is the fundamental mechanism that initiates and propagates bone resorption, although there may be other actions involved as well, for instance, in age-related atrophy. However, inflammation can be triggered by many factors. At the consensus meeting, we discussed implant displacement and microfractures, leading to an inflammatory response as one possibility. Peri-implantitis defined as infection/suppuration and significant crestal bone resorption is another one but in fact found only in a few per cent of long-term followed up patients as seen by the delegates of our consensus meeting and may in most (if not all) cases be a secondary rather than a primary phenomenon.[9] One, in the literature quite neglected, reason for marginal bone loss is the foreign body reaction that may remain totally aseptic but still cause crestal bone loss due to an inflammatory response. One practical example is the presence of excess cement at the submucosal crown margins. If such cement particles remain in the submucosal tissues, crestal bone resorption may follow with time due to a foreign body reaction – it is not at all surprising that clinicians who have perceived bacteria as the incriminated reason for all types of marginal bone loss observed have found no positive outcome of staining for a dangerous microflora,[9] instead the problem is an aseptic one and easily remedied by simply removing the foreign bodies in question.[31]

We find one of the present consensus statements to be the most important of them all; modern implants offer successful outcomes with high predictability and a series of 10-year publications that we discussed at our gathering pointed very clearly to a positive outcome of more than 95% of all implants; and modern surfaces present greater levels of success compared with old implants (Figure 1). Purulent infection with significant crestal bone loss represents rare observations provided control of relevant factors such as the implant design, the clinicians responsible for treatment, and, when possible, the patient receiving it (Figure 2). The full

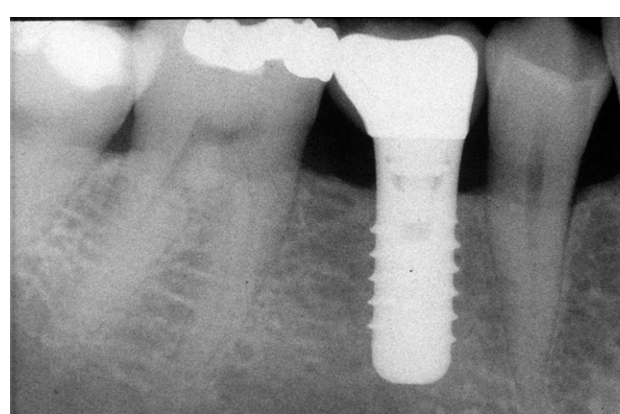

Figure 1 Excellent 10-year results of SLA implants have been reported, here with a typical case of maintained bone levels without any signs of clinical problems.

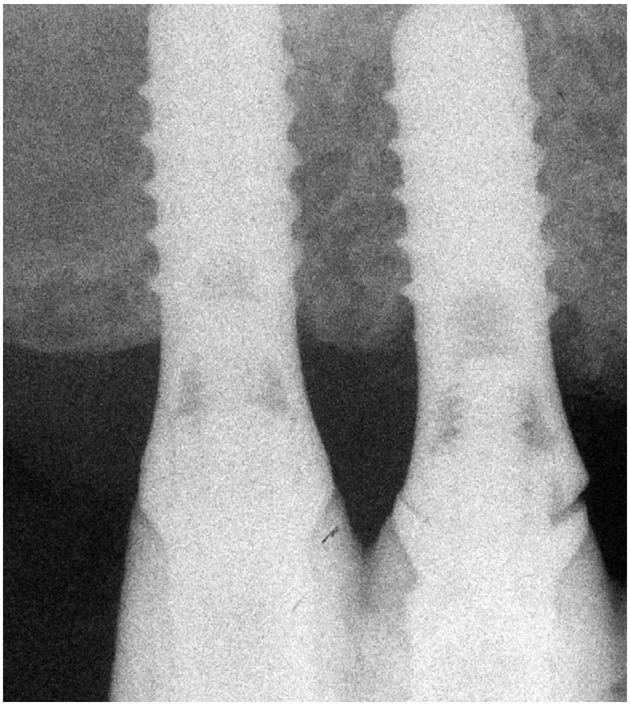

Figure 2 With SLA implants, one study of five hundred eleven implants reported only 0.4% of ongoing peri-implantitis problems at 10 years. This is one such case with a typical semilunar bone loss at the mesial implant.

consensus statement from our meeting has been published in *International Journal of Prosthodontics* and *International Journal of Oral and Maxillofacial Implants* of 2012 and is published in this issue of *Clinical Implant Dentistry and Related Research* with the names of the 12 participating clinical scientists in the list of authors.[25] This consensus stands in stark contrast to previously published alarming reports stating very high levels of peri-implantitis.[1,2,5] The reasons for this substantial discrepancy in interpreting the clinical reality may depend on different factors such as occupational bias, failure to realize that peri-implantitis in all probability mainly is a secondary problem,[10] and/or the fact that the implants analyzed by the referred colleagues were only turned ones, not modern oral implant designs.

Ten different 10-year studies of three modern implant designs, all with a moderately rough surface, were found in a PubMed and manual search: The Astra TioBlast implant ($n = 5$ studies), the TiUnite implant ($n = 3$ studies), and the SLA implant ($n = 2$ studies). A brief review of these 10 studies, some of which were discussed at the Estepona meeting,[25] will be presented here.

10-Year or More Reports of TioBlast Implants

Gotfredsen[32] published a 10-year prospective study of single maxillary implants in 20 consecutive patients, all placed at different times after tooth extraction. Survival rate was 100% at 10 years and crestal bone loss was <1 mm on average. One patient lost more than 1.5 mm of marginal bone. One implant (2.5%) was diagnosed with peri-implantitis.

Mertens and colleagues[33] placed 94 maxillary implants in 17 edentulous patients. Survival rate at 11 years of follow-up was 96.8% as three implants were lost in one and the same patient. Mean crestal bone loss was 0.88 mm; however, two patients with altogether seven implants displayed a crestal bone loss of >3.2 mm. Two implants (2.5%) were diagnosed to have "peri-implantitis."

Vroom and colleagues[34] placed 40 Astra TioBlast implants in a prospective mandibular study to support a bar construction. Survival rate at 12 years was 100% and crestal bone loss was between −0.2 and +0.01 mm. No cases of "peri-implant" infections were reported.

Al-Nawas and colleagues[35] placed five hundred sixteen TioBlast implants that were followed up between 7 and 15 years. Survival rate in this study was only 89.7%; however, it must be noted that 23 implants were placed postirradiation and a further 64 implants were irradiated after insertion. In one hundred fifty-three implants, a bone augmentation procedure was conducted prior to implantation. In addition, a total of one hundred thirteen implants were lost to follow-up. The authors reported that a total of 18 implants (3.4%) had been removed due to peri-implant infection. Although this study is of interest, it is very difficult to compare with other studies because only a relatively small proportion of the implants were placed under normal conditions and adequately followed up for 10 years.

Jacobs and colleagues[36] placed 50 Astra TioBlast implants of which none failed over 10 to 16 years of follow-up. Mean crestal bone loss was −1.15 to +1.51(SD 0.45) mm at 15 years after loading at which time 24 implants were followed up. The authors noted that the marginal bone level changed <0.5 mm after the first year of implant placement. No cases of peri-implant infections were mentioned in the paper (Figure 3).

10-Year or More Reports of TiUnite Implants

Degidi and colleagues[37] placed two hundred ten implants of which one hundred seventy-two had been

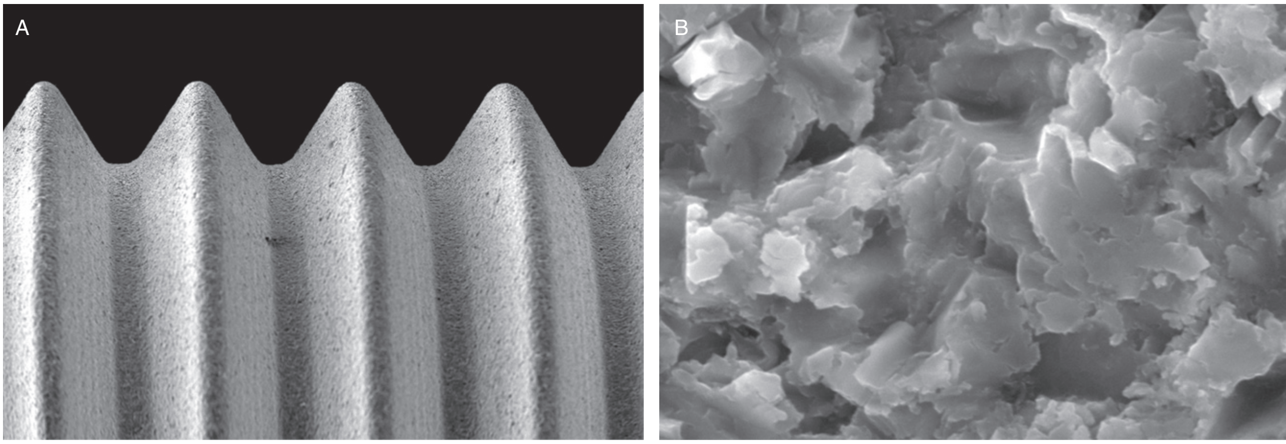

Figure 3 The Astra TioBlast, a design with excellent clinical results with very few implants diagnosed with marginal bone resorption problems at follow-up times up to 16 years (*A*). This surface was the first moderately rough one in routine clinical usage (*B*).

followed up for 9 to 10 years. The Cumulative Survival Rate (CSR) was 97.3% at this time of follow-up. Crestal bone loss was on the order of 1.95 mm (SD 0.4). The authors reported that 13 implants (8.2%) were diagnosed with "peri-implantitis."

Ostman and colleagues[38] placed a total of one hundred twenty-one implants of which one failed for a survival rate of 99.2% at 10 years (Figure 4, A and B). Mean marginal bone loss was 0.7 mm + −1.35 mm at 10 years; five implants (all in smokers) displayed >3-mm bone loss. Two implants (1.9%) showed infection with suppuration at the 10-year annual checkup.

Glauser[39] placed one hundred two slightly tapered TiUnite implants in predominantly soft bone with fixed restorations at the day of implant placement. A total of 66 of these implants have now been followed up for 11 years. The CSR at 11 years was 97.1%. The mean marginal bone resorption from the day of placement until the 11-year examination was 1.66 mm (SD 0.98). The author pointed out that average bone resorption from year 1 to 11 was 0.47 mm (SD 1.09). One implant was found to be affected by a purulent infection and significant crestal bone loss.

As indicated in, particularly, the latter study,[39] TiUnite implants do result in somewhat greater first year crestal bone loss than the other modern implants summarized here, but as observed in a recent paper,[9] TiUnite develops a steady-state situation with respect to further bone loss and, therefore, here published figures in the referred papers point to very good

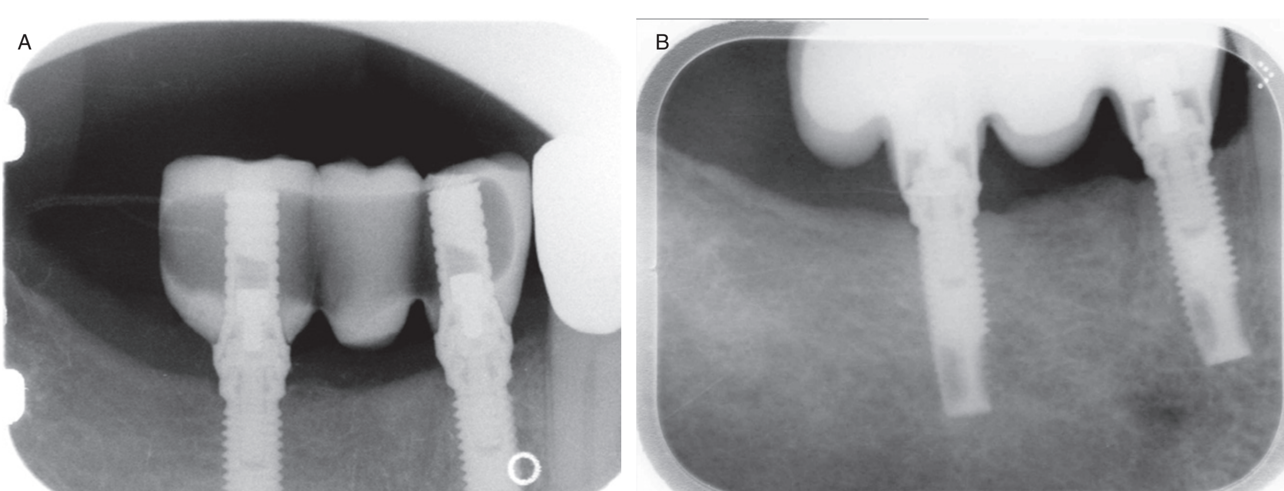

Figure 4 TiUnite implants immediately after placement (*A*) and at the 10-year follow-up (*B*), without any problems of peri-implantitis. These radiograms are from one study of one hundred twenty-one implants where only two implants (1.9%) were diagnosed with peri-implantitis at 10 years of follow-up.

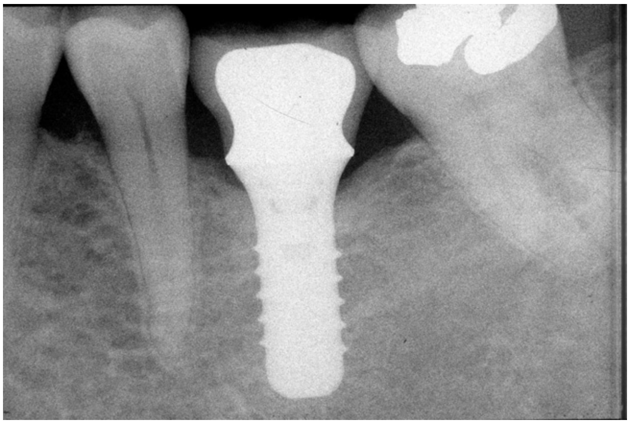

Figure 5 A typical example of an SLA implant, in this case displaying bone gain at 10 years of follow-up.

clinical long-term results with maintained bone levels.

10-Year or More Reports of SLA Implants

Fischer and Stenberg[40] placed one hundred forty-two implants in a randomized controlled trial with a 10-year survival rate of 95.1%. Mean crestal bone loss was 1.07 mm (SD 0.98). One implant displayed more than 4 mm of bone loss as 10 years. Three implants (2.1%) in one patient had been removed because of peri-implant infection and marginal bone loss at the fifth annual checkup.

Buser and colleagues[31] placed five hundred eleven SLA implants of which six failed for a survival rate of 98.8%. Two implants (one in a heavy smoker) showed signs of an acute peri-implant infection with suppuration in the peri-implant sulcus. In fact, seven other implants had previously excessive marginal bone loss with suppuration due to excess cement but showed normal findings after surgical removal of the cement, if then with a higher than normal marginal bone loss. Thus, 1.8% of the implants had a history of or showed peri-implant infections at the 10-year annual checkup; however, it was observed that only two implants or 0.4% had an ongoing peri-implant infection at 10 years of follow-up. This indicates a summed implant success of between 97 and 98.4% at 10 years (Figure 5), dependent on how implants with previous problems of bone resorption related to since removed excess cement particles are characterized.

DISCUSSION

In essence, the collection of data at the Estepona consensus meeting disputes the necessity of very high levels or peri-implantitis around oral implants (Table 1). Inflammation/infection coupled to marginal bone loss may certainly exist; however, 10-year figures of modern implants point to that only 1 to 2% of placed implants will be affected. At this time, we cannot present a proper percentage at the patient level, but we have observed that studies point to a cluster effect, that is, one and the same patient with marginal bone loss around one implant is likely to have problems also around other implants.[41] Some of the long-term studies quoted had rather few implants analyzed, but in toto there were seven hundred twenty TioBlast, four hundred thirty-three TiUnite, and six hundred fifty-three SLA implants included in the various studies, indicative of a substantial number of implants followed up and analyzed.

CONCLUSIONS

1. Estimations of bleeding on probing and probing depth have no known correlation to marginal bone loss around oral implants.
2. Poor, undocumented implant systems, poorly trained clinicians, and patients with drug abuse or subjected to irradiation or grafting were combine to give rise to marginal bone resorption/implant failure, whereas peri-implantitis is mainly a secondary phenomenon to such vicious combinations.
3. Modern oral implants have displayed better clinical results than previously used devices, at least in maxillary cases or when challenging factors apply such as patient smoking, direct or rapid loading, the use of short implants, irradiation to tissues, or bone grafting.
4. If controlled implants are used by properly trained clinicians who work with ordinary patients, then the summed failure rate and frequency of peri-implantitis are within 5% of all placed implants at 10 years of follow-up.

ACKNOWLEDGMENT

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TABLE 1 Frequency of Implants with Reported Peri-Implant Infection and Significant Bone Loss Leading to Implant Removal or Other Surgical Intervention. Interpreted Data from Ten Long-Term Follow-Up Studies on Three Different Implant Surfaces

Study	Surface	Patients	Implants	Follow-Up (Years)	CSR	Mean Bone Loss (mm)	Peri-Implant Infection	
							n	%
Al-Nawas et al. 2010[35]	TioBlast	108	516	7–15	89.7%	2.6	18*	3.4
Gotfredsen 2010[32]	TioBlast	20	40	10	100%	0.6–0.9	1	2.5
Mertens et al. 2012[33]	TioBlast	15	94	11	96.8%	0.9	2	2.1
Jacobs et al. 2010[36]	TioBlast	18	50	16	100%	0.02	0	0
Vroom et al. 2009[34]	TioBlast	20	40	12	100%	0.01	0	0
Fischer and Stenberg 2011[40]	SLA	24	142	10	95.1%	1.1	3†	2.1
Buser et al. 2012[31]	SLA	303	511	10	98.8	–	9‡	1.8
Degidi et al. 2012[37]	TiUnite	59	210	10	97.6%	1.9	13§	8.2
Ostman et al. 2012[38]	TiUnite	46	121	10	99.2%	0.7	2	1.9
Glauser 2012[39]	TiUnite	?	66	11	97.1%	1.7	1	1.5
						Total	**49**	**2.7**

*All implants removed due to “peri-implantitis”. No ongoing infections reported. Includes implants in grafted and irradiated bone.
†All implants removed at the fifth annual checkup. No ongoing infections reported at the 10th annual checkup.
‡Two implants showed peri-implant infection at the 10-year checkup (0.4%). Seven implants had a history of peri-implant infection (1.4%).
§Five of the 13 implants had been removed during the course of the study.

D. Buser, S. Chen, D. Cochran, H. De Bruyn, T. Jemt, S. Koka, M. Nevins, L. Sennerby, M. Simion, T. Taylor, and A. Wennerberg.

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