The Effects of Smoking on the Survival of Smooth- and Rough-Surface Dental Implants

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Purpose: *To compare the long-term survival rates of smooth- and rough-surface dental implants among smokers and nonsmokers.* ***Materials and Methods:*** *A retrospective chart review was conducted for 2 time periods: January 1, 1991, through December 31, 1996, during which smooth-surface implants were utilized, and January 1, 2001, through December 31, 2005, during which rough-surface implants were utilized. This review included all implants placed and restored in 1 institution during the 2 timeframes. Data were specifically collected relative to patient age, gender, smoking status, implant diameter, implant length, and anatomic location of implants. Implants from the first and second time periods were followed through mid-1998 and mid-2007, respectively. Associations of patient/implant characteristics with implant survival were evaluated using marginal Cox proportional hazards models (adjusted for age and gender) and summarized with hazard ratios (HR) and corresponding 95% confidence intervals (CI).* ***Results:*** *A total of 593 patients (322 [54.3%] female; mean [SD] age, 51.3 [18.5] years) received 2,182 smooth-surface implants between 1991 and 1996, while 905 patients (539 [59.6%)] female; mean [SD] age, 48.2 [17.8] years) received 2,425 rough-surface implants between 2001 and 2005. Among the rough-surface implants, smoking was not identified as significantly associated with implant failure (HR = 0.8; 95% CI = 0.3 to 2.1;* P = .68*). In contrast, smoking was associated with implant failure among the group with smooth-surface implants (HR = 3.1; 95% CI = 1.6 to 5.9;* P < .001*). Implant anatomic location was not associated with implant survival among patients with rough-surface implants (*P = .45*) and among nonsmokers with smooth-surface implants (*P = .17*). However, anatomic location affected the implant survival among smokers with smooth-surface implants (*P = .004*). In particular, implant survival was the poorest for implants placed in the maxillary posterior areas of smokers.* ***Conclusions:*** *Based on this retrospective study, the following observations were made: Smoking was identified as a risk factor for implant failure of smooth-surface implants only; among the smokers who received smooth-surface implants, an association was identified between implant failure and location of the implant placement; no association was identified between implant failure and location among the smokers who received rough-surface implants.* Int J Oral Maxillofac Implants 2008;23:1117–1122

Key words: *dental implants, rough surface implants, smooth surface implants, survival rates*

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Smoking has long been identified as a risk factor for general systemic health. In addition to its deleterious cardiovascular and pulmonary effects, smoking has been linked to compromised wound healing.[1–6] Mosely et al suggested nicotine inhibition of wound healing in a rabbit ear model.[1] The authors confirmed findings from a previous study in which impaired healing of hand wounds was observed in patients who smoked.[2] The authors hypothesized that nicotine produced cutaneous vasoconstriction and was associated with decreased microperfusion. It is also suggested that toxins commonly found in cigarettes (nicotine, carbon monoxide, and cyanide)

could contribute to delayed wound healing.[3] Jones and Triplett described a relationship between smoking and impaired intraoral wound healing with the failure of dental implants.[4] Eighty percent of the patients in their study who experienced impaired wound healing were active smokers at the time of implant placement.

Compromised polymorphonuclear neutrophil function has been associated with smoking.[7,8] The polymorphonuclear neutrophil counts in smokers were found to be fewer and with compromised ability to phagocytize particles. Arteriolar vasoconstriction and decreased blood flow are seen in response to smoking.[9] Sarin et al demonstrated that smoking a single cigarette reduced mean blood-flow velocity by 42%.[10]

Smoking was also described to be a risk factor that may influence the survival of dental implants.[11–20] Bain and Moy[11] assessed various predisposing factors toward implant failures in a group of 540 patients. These patients received 2,194 Brånemark implants between 1984 and 1990. Overall failure rates were 4.76% in nonsmokers and 11.28% in smokers. De Bruyn and Collaert compared implant failure rates in smokers and nonsmokers before loading.[12] There was a significant difference in maxillary implants only, with a failure rate of 9% in smokers and 1% in nonsmokers. These findings were corroborated with a number of other clinical studies that generally demonstrated 2 or more times the failure rate in smokers when compared with nonsmokers.[13–15]

Previous studies related to the risk of smoking and dental implants have generally used smooth-surface implants. Contemporary implants, however, utilize rough surfaces.[21] A rough surface topography can be created in a number of ways by anodizing, blasting, acid etching, and plasma spraying to achieve the desired roughness. Studies have demonstrated earlier healing with rough-surface implants.[22–27] Some authors have assessed the effects of smoking on the survival of rough-surface implants.[28,29] The results of these studies did not demonstrate an implant survival risk associated with smoking. In general, these studies were of short duration with relatively small numbers of patients or implants.

The purpose of this study was to compare the long-term survival rates of smooth- and rough-surface dental implants placed in smokers and nonsmokers.

MATERIALS AND METHODS

A retrospective chart review was conducted for all patients who had not denied access to their medical records for research purposes and who received endosseous dental implants at the Mayo Clinic, Rochester, MN, USA, between January 1, 1991, through December 31, 1996, and January 1, 2001, through December 31, 2005. The first time period was chosen to reflect clinical performance of smooth-surface implants (Brånemark System, Nobel Biocare, Yorba Linda, CA, USA) while the second time period was chosen to demonstrate clinical performance of rough-surface implants (TiUnite, Nobel Biocare). Data were extracted from the combined medical and dental records relative to patient age, gender, smoking status, implant diameter, implant length, and location of implant placement within its respective dental arch. Patients were classified as either smokers or nonsmokers based on self-reported questionnaires at the time of implant placement. Information on pack/year history and/or past history of cigarette smoking was unavailable. The survival of each implant was documented by its presence or absence in the oral cavity. Implant failure was defined as its loss or explantation. To facilitate the comparison between the 2 groups, implants for the first and second time periods were followed through mid-1998 and mid-2007, respectively. For each implant, the duration of follow-up was calculated from the time of placement to the date of failure or date of last follow-up in the specified time period. Implant survival was estimated using the Kaplan-Meier method. The associations between implant survival and the recorded variables were estimated by fitting marginal Cox proportional hazards models, adjusting for age and gender. The robust standard error method of Lin and Wei[30] was used to account for the correlation between the variables. Associations were summarized by calculating hazard ratios (HR) and corresponding 95% confidence intervals (95% CI) using the robust standard errors.

RESULTS

A total of 593 patients were included for the time period from 1991 through 1996. Of this group, 322 were females and 271 were males. The mean age was 51.3 years (range 14.3 to 92.4 years). One hundred four patients (17.5%) were smokers. For the time period from 2001 through 2005, 905 patients were included. Of this group, 539 were females and 366 were males. The mean age was 48.2 years (range 14.1 to 88.7 years). Ninety-five patients (10.5%) were smokers. Table 1 summarizes patient-level characteristics for both groups. For the time period between 1991 and 1996, a total of 2,182 smooth-surface implants (Brånemark System) were placed and followed, while 2,425 rough-surface implants were placed and followed between 2001 and 2005 (TiU-

Table 1 Summary of Patient-Level Characteristics of Smooth- and Rough-Surface Implants

Characteristics	Smooth-surface implant patients (n = 593)	Rough-surface implant patients (n = 905)
Patient age at placement (y)		
Mean (SD)	51.3 (18.5)	48.2 (17.8)
Median	55.4	49.1
Range	14.3–92.4	14.1–88.7
Gender, N (%)		
Female	322 (54.3)	539 (59.6)
Male	271 (45.7)	366 (40.4)
Smoking status, N (%)		
Smokers	104 (17.5)	95 (10.5)
Nonsmokers	489 (82.5)	810 (89.5)

Table 2 Summary of Implant-Level Characteristics for Both Groups

Characteristics	Smooth implants (N = 2,182)	Rough implants (N = 2,425)
Location, N (%)		
Mandibular anterior	574 (26.3)	517 (21.3)
Mandibular posterior	727 (33.3)	815 (33.6)
Maxillary anterior	481 (22.0)	585 (24.1)
Maxillary posterior	400 (18.3)	508 (20.9)
Diameter (mm), N (%)		
3.3	2 (0.1)	85 (3.5)
3.75	1766 (80.9)	1159 (47.8)
4	329 (15.1)	971 (40.0)
5	85 (3.9)	210 (8.7)
Length (mm), N (%)		
7	26 (1.2)	10 (0.4)
8.5	22 (1.0)	27 (1.1)
10	196 (9.0)	233 (9.6)
11.5	41 (1.9)	253 (10.4)
13	391 (17.9)	647 (26.7)
15	621 (28.5)	792 (32.7)
18	724 (33.2)	448 (18.5)
20	161 (7.4)	15 (0.6)

nite). Implant-level characteristics for both groups are summarized in Table 2.

Among the 2,182 smooth-surface implants, 111 implant failures were recorded in 65 patients in the specified time period. The median time to implant failure was 196 days. The median follow-up of the remaining smooth-surface implants that had not yet failed in the specified time period was 3.6 years (interquartile range, 1.9 to 5.5 years). For smooth implants, the survival free of implant failure was 95.9%, 95.1%, and 94.0% at 1, 3, and 5 years following placement.

Among the 2,425 rough-surface implants, 85 implant failures were recorded in 64 patients in the specified time period. The median time to implant failure was 174 days. The median follow-up of the remaining rough-surface implants that had not yet failed in the specified time period was 1.2 years (interquartile range, 0.6 to 2.6 years). For rough implants, the survival-free of implant failure was 96.6%, 95.4%, and 94.5% at 1, 3, and 5 years following placement.

As shown in Table 3 and Fig 1, among the rough implants, smoking was not identified as significantly associated with implant failure (HR = 0.8; 95% CI = 0.3 to 2.1; P = .68; adjusted for age and gender). In contrast, smoking was associated with implant failure among the group with smooth implants (HR = 3.1; 95% CI = 1.6 to 5.9; P < .001). Furthermore, among the smokers, smooth implants were 3.1 times (95% CI = 1.1 to 9.0; P = .039) more likely to fail than rough implants. In particular, the smooth-surface implants placed in smokers had a failure rate of 8.7% within 1 year following placement. However, among the nonsmokers, there was not a significant difference in implant failure between the 2 groups of implants (HR = 0.8; 95% CI = 0.5 to 1.2; P = .28).

Implant anatomic location was not significantly associated with implant survival among patients with rough-surface implants (P = .45). This was observed among smokers and nonsmokers with rough-surface implants (Table 4). However, anatomic location did significantly affect survival rates among smokers with smooth-surface implants (P = .004), but this association was not identified among nonsmokers with smooth-surface implants (P = .17; Table 5). As shown in Table 5, smooth implants placed in the anterior mandible had the highest survival rates compared to the other anatomic areas (HR = 2.9 to 8.4). At 1 and 3 years after placement, the survival for the 84 smooth-surface implants placed in the posterior maxilla was 86.5% and 81.9%, respectively. By 5 years, the implant survival rate dropped to 65.3% (with 23 implants still being followed).

Table 3 Kaplan-Meier Estimates of Survival Free of Implant Failure, by Type of Implant and Smoking Status

Years following placement	Survival rates (%)			
	Smooth-surface implants		Rough-surface implants	
	Nonsmokers	Smokers	Nonsmokers	Smokers
0	100 (n = 1715)*	100 (n = 467)	100 (n = 2126)	100 (n = 299)
1	97.2 (n = 1424)	91.3 (n = 368)	96.6 (n = 1259)	96.4 (n = 136)
2	96.4 (n = 1224)	90.8 (n = 323)	95.7 (n = 746)	96.4 (n = 66)
3	96.4 (n = 959)	90.4 (n = 241)	95.3 (n = 471)	96.4 (n = 50)
4	96.1 (n = 764)	86.5 (n = 182)	94.6 (n = 333)	96.4 (n = 28)
5	96.1 (n = 545)	86.0 (n = 129)	94.3 (n = 160)	96.4 (n = 21)

*The number in parentheses indicates the number of implants still at risk for failure at time t year.

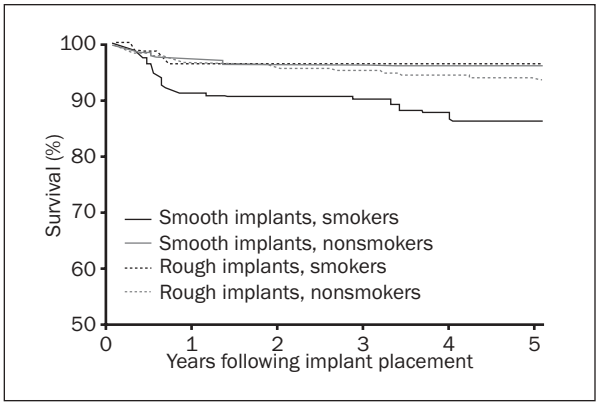

Fig 1 Kaplan-Meier curves for implant survival, by type of implant and smoking status.

Table 4 Kaplan-Meier Estimates of Survival Free of Implant Failure, by Anatomic Location and Smoking Status, for Rough-Surface Implants

Location	Smoking status	No. of implants	Survival rate (%)			HR (95% CI)
			1 year	3 years	5 years	
Mn anterior	Nonsmoker	445	96.2	95.8	95.8	Referent
Mn posterior	Nonsmoker	725	95.9	94.5	91.9	1.1 (0.6–2.2)
Mx anterior	Nonsmoker	511	97.3	95.8	95.8	0.7 (0.3–1.7)
Mx posterior	Nonsmoker	445	97.5	95.4	95.4	0.8 (0.3–1.8)
Mn anterior	Smoker	72	94.7	94.7	94.7	Referent
Mn posterior	Smoker	90	94.0	94.0	94.0	1.1 (0.3–3.9)
Mx anterior	Smoker	74	100.0	100.0	100.0	—
Mx posterior	Smoker	63	97.6	97.6	97.6	0.4 (0.04–5.0)

Mn, mandibular; Mx, maxillary.

Table 5 Kaplan-Meier Estimates of Survival Free of Implant Failure, by Anatomic Location and Smoking Status, for Smooth-Surface Implants

Location	Smoking status	No. of implants	Survival rate (%)			HR (95% CI)
			1 year	3 years	5 years	
Mn anterior	Nonsmoker	431	99.0	98.4	98.0	Referent
Mn posterior	Nonsmoker	586	95.9	95.7	95.1	2.8 (1.1–7.1)
Mx anterior	Nonsmoker	382	96.9	95.0	95.0	2.5 (0.9–8.5)
Mx posterior	Nonsmoker	316	97.4	96.6	96.6	1.8 (0.5–7.1)
Mn anterior	Smoker	143	97.5	97.5	96.2	Referent
Mn posterior	Smoker	141	92.1	92.1	90.7	2.9 (0.8–8.2)
Mx anterior	Smoker	99	86.4	86.4	86.4	4.9 (0.9–26.4)
Mx posterior	Smoker	84	86.5	81.9	65.3	8.4 (2.2–31.7)

Mn, mandibular; Mx, maxillary.

DISCUSSION

The results of this article identify smoking as a risk factor for failure of smooth-surface implants only. These results are consistent with previous studies using smooth-surface implants.[11–15] Bain and Moy[11] originally described an association between smoking and implant survival. The authors provided the hypothesis that high failure rates of dental implants in smokers may be related to the compromised polymorphonuclear neutrophil function and vasoconstriction in the oral mucosa produced by nicotine in cigarettes. These effects negatively influenced the osseointegration of implants. Subsequent studies concurred with the hypothesis of physiologic disadvantages of bone healing after implant placement in smokers; however, these studies used smooth-surface implants. The majority of dental implants placed today, however, have rough surface characteristics.

Kumar et al[28] evaluated the effects of smoking on osseointegration of rough-surface implants (ITI SLA, Straumann USA, Waltham, MA). In their study of 1,183 implants placed in 461 patients, the overall success rates for smokers and nonsmokers were 98.4% and 98.1%, respectively. Smoking was not identified as a risk factor for failure of implants. The authors concluded that the surface of an implant may be a critical determinant for achieving osseiointegration in smokers. In a different short-term study, Rocci et al[29] compared the success rates of 66 rough TiUnite implants placed in 22 patients with those of 55 smooth Brånemark implants placed in another group of 22 patients. After 1 year of prosthetic loading in the posterior mandible, the number of failed implants was significantly higher for smokers in the smooth-implant group only. The authors proposed that the surface of TiUnite implants improved early osseointegration, which in turn improved the chances of success of implants placed in smokers.

In contrast to the association of smoking and failure of smooth-surface implants, the current results demonstrated no association between smoking and the failure of rough-surface implants over a 5-year period after placement. The results confirmed that the short-term findings described previously are consistent with long-term analysis. These findings support the improved performances of newer-generation rough-surface implants in smokers and in any anatomic area. Early-generation Brånemark implants used in this study were machined to receive a smooth surface by a turning process. Later-generation TiUnite implants utilize roughened surfaces characterized by a micro-porous thickened oxide layer (1 to 10 μm thick) created through an electrochemical process. The open porous structure with various pits of variable dimensions (1 to 5 μm in diameter) creates a surface designed to allow greater bone-to-implant contact. Zechner et al[31] demonstrated a difference in bone healing between TiUnite and the earlier Brånemark implants. Histologic evaluation from this study demonstrated new bone formation directly on the surface of TiUnite implants, whereas it formed appositionally over osteotomy bone around the smooth-surface implants. These findings suggested the osseoconduction process of bone healing around the rough-surface TiUnite implants.

Early bone formation depends on platelet activation and fibrin retention by the implant surface. This precedes osteogenic cell migration through the fibrin network.[32] The osteogenic cells populate the implant surface and differentiate into osteoblasts. By this, the osteoblasts would produce mature lamellar bone tissue around the implant leading to anchorage.[33] This physiologic process of early bone healing around the rough-surface dental implants may outweigh the healing disadvantages in smokers.

The current results demonstrated that when smooth-surface implants were placed in the maxillary posterior areas of smokers, a steady state of implant survival was not achieved. Instead, data revealed an ongoing deterioration in survival rates over time. The survival rate of these implants after the first year was 86.5%, whereas it was reduced after the third year (81.9%), and significantly reduced after the fifth year (65.3%). This trend of an ongoing failure pattern was not seen in other areas where smooth implants were placed in smokers (see Table 5). Many authors have concluded that most failures occur within the first year of implant placement. These failures are classified as early or primary biologic failures (failure to establish osseointegration). The ongoing failure pattern observed with smooth-surface implants placed in the maxillary posterior areas of smokers in this study appears to be both primary and secondary (failure to achieve or to maintain osseointegration).[34]

The results of this study were based on a retrospective chart review of the patients and implants included. Disadvantages may involve certain degrees of variability, such as whether implants received grafting or membranes, the systemic medical conditions of the patients, and the reasons for tooth loss, all of which were not included in this study. Further prospective long-term controlled studies that could be utilized to account for such confounding variables are necessary to support the conclusions of this article.

CONCLUSIONS

Based on this comparative study of more than 4,600 implants placed in 2 different time periods that reflect the use of different implant surfaces, smoking and anatomic location of implants were not found to be risk factors for failures of rough-surface implants. Smoking and anatomic location were identified as risk factors for failures of smooth-surface implants. In particular, smooth-surface implants placed in the posterior maxilla of smokers had the highest failure rate.

REFERENCES

1. Mosely LH, Finseth F, Goody M. Nicotine and its effect on wound healing. Plast Reconstr Surg 1978;61:570–575.
2. Mosely LH, Finseth F. Cigarette smoking: Impairment of digital blood flow and wound healing in the hand. Hand 1977;9: 97–101.
3. Silverstein P. Smoking and wound healing. Am J Med 1992; 93:22–24.
4. Jones JK, Triplett RG. The relationship of cigarette smoking to impaired intraoral wound healing: A review of evidence and implications for patient care. J Oral Maxillofac Surg 1992;50: 237–240.
5. Sherwin MA, Gastwirth CM. Detrimental effects of cigarette smoking on lower extremity wound healing. J Foot Surg 1990; 29:84–87.
6. Riefkohl R, Wolfe JA, Cox EB, McCarty KS Jr. Association between cutaneous occlusive vascular disease, cigarette smoking, and skin slough after rhytidectomy. Plast Reconstr Surg 1986;77:592–595.
7. Noble RC, Penny BB. Comparison of leukocyte count and function in smoking and nonsmoking young men. Infect Immun 1975;12:550–555.
8. Kenney EB, Kraal JH, Saxe SR, Jones J. The effect of cigarette smoke on human oral polymorphonuclear leukocytes. J Periodontal Res 1977;12:227–234.
9. Reus WF, Robson MC, Zachary L, Heggers JP. Acute effects of tobacco smoking on blood flow in the cutaneous micro-circulation. Br J Plast Surg 1984;37:213–215.
10. Sarin CL, Austin JC, Nickel WO. Effects of smoking on digital blood-flow velocity. JAMA 1974;229:1327–1328.
11. Bain CA, Moy PK. The association between the failure of dental implants and cigarette smoking. Int J Oral Maxillofac Implants 1993;8:609–615.
12. De Bruyn H, Collaert B. The effect of smoking on early implant failure. Clin Oral Implants Res 1994;5:260–264.
13. Gorman LM, Lambert PM, Morris HF, Ochi S, Winkler S. The effect of smoking on implant survival at second-stage surgery: DICRG Interim Report No. 5. Dental Implant Clinical Research Group. Implant Dent 1994;3:165–168.
14. Schwartz-Arad D, Samet N, Mamlider A. Smoking and complications of endosseous dental implants. J Periodontol 2002; 73:153–157.
15. DeLuca S, Habsha E, Zarb GA. The effect of smoking on osseointegrated dental implants. Part I: Implant survival. Int J Prosthodont 2006;19:491–498.
16. Lambert PM, Morris HF, Ochi S. The influence of smoking on 3-year clinical success of osseointegrated dental implants. Ann Periodontol 2000;5:79–89.
17. Wallace RH. The relationship between cigarette smoking and dental implant failure. Eur J Prosthodont Restor Dent 2000; 8:103–106.
18. Moy PK, Medina D, Shetty V, Aghaloo TL. Dental implant failure rates and associated risk factors. Int J Oral Maxillofac Implants 2005;20:569–577.
19. McDermott NE, Chuang SK, Woo VV, Dodson TB. Complications of dental implants: Identification, frequency, and associated risk factors. Int J Oral Maxillofac Implants 2003;18:848–855.
20. Chuang SK, Wei LJ, Douglass CW, Dodson TB. Risk factors for dental implant failure. A strategy for the analysis of clustered failure-time observations. J Dent Res 2002;8:572–577.
21. Jokstad A, Braegger U, Brunski JB, Carr AB, Naert I, Wennerberg A. Quality of dental implants. Int Dent J 2003;53(suppl 2): 409–443.
22. Hallgren C, Sawase T, Ortengren U, Wennerberg A. Histomorphometric and mechanical evaluation of the bone-tissue response to implants prepared with different orientation of surface topography. Clin Implant Dent Relat Res 2001;3: 194–203.
23. Wennerberg A, Hallgren C, Johansson C, Danelli S. A histomorphometric evaluation of screw-shaped implants each prepared with two surface roughnesses. Clin Oral Implants Res 1998;9:11–19.
24. Buser D, Schenk RK, Steinemann S, Fiorellini JP, Fox CH, Stich H. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. J Biomed Mater Res 1991;25:889–902.
25. Larsson C, Thomsen P, Aronsson BO, et al. Bone response to surface-modified titanium implants: Studies on the early tissue response to machined and electropolished implants with different oxide thicknesses. Biomaterials 1996;17:605–616.
26. Ivanoff CJ, Widmark G, Johansson C, Wennerberg A. Histologic evaluation of bone response to oxidized and turned titanium micro-implants in human jawbone. Int J Oral Maxillofac Implants 2003;18:341–348.
27. Wennerberg A, Hallgren C, Johansson C, Danelli S. A histomorphometric evaluation of screw-shaped implants each prepared with two surface roughnesses. Clin Oral Implants Res 1998;9:11–19.
28. Kumar A, Jaffin RA, Berman C. The effect of smoking on achieving osseointegration of surface-modified implants: A clinical report. Int J Oral Maxillofac Implants 2002;17:816–819.
29. Rocci A, Martignoni M, Gottlow J. Immediate loading of Brånemark System TiUnite and machined-surface implants in the posterior mandible: A randomized open-ended clinical trial. Clin Implant Dent Relat Res 2003;5 Suppl 1:57–63.
30. Lin DY, Wei LJ The Robust Inference for the Cox Proportional Hazards Model. J Am Stat Assoc 1989; 84:1074–1078.
31. Zechner W, Tangl S, Fürst G, et al. Osseous healing characteristics of three different implant types. Clin Oral Implants Res 2003;14:150–157.
32. Park JY, Davies JE. Red blood cell and platelet interactions with titanium implant surfaces. Clin Oral Implants Res 2000;11: 530–539.
33. Triplett RG, Frohberg U, Sykaras N, Woody RD. Implant materials, design, and surface topographies: Their influence on osseointegration of dental implants. J Long Term Eff Med Implants 2003;13:485–501.
34. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. Eur J Oral Sci 1998;106: 527–551.