A Retrospective Evaluation of the Survival Rates of Splinted and Non-Splinted Short Dental Implants in Posterior Partially Edentulous Jaws

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Background: The aim of the present study is to evaluate the survival rate and bone loss around short implants (≤10 mm) supporting splinted or non-splinted posterior prostheses during a follow-up period of 3 to 16 years.

Methods: A total of 453 implants from 198 patients was divided into splinted or non-splinted groups. Implant survival rate was calculated for each group, and potential risk was represented as odds ratio (OR). The final linear distance from implant platform level to the first bone-to-implant contact was compared to this same reference just after loading by digital periapical radiographs to determine the marginal bone loss (BL).

Results: The splinted group comprised 219 implants in 86 patients, whereas the non-splinted group included 234 implants from 112 patients. The mean follow-up period was 9.7 ± 3.7 years. Although different success rates were found for splinted (97.7%) and non-splinted (93.2%) groups, they exhibited similar BL (1.22 ± 0.95 mm and 1.27 ± 1.15 mm, respectively). The success of splinted implants was associated with no other variable, whereas non-splinted implants exhibited higher risk of failure when placed in men (OR = 3.2) and when implants shorter than 10 mm were used (OR = 3.6 and 4.1 for 8.5 mm and 7 mm, respectively). Regardless of group, 71.4% of the unsuccessful implants failed before the end of the first year after loading.

Conclusion: Non-splinted posterior short implants had a somewhat lower success rate than splinted short implants, and the failure rate in non-splinted short implants appeared to be greater in males as well as in implants ≤10 mm. *J Periodontol 2014;85:787-794.*

KEY WORDS

Alveolar bone loss; dental implants; dental implants, single-tooth; dental prostheses, implant supported; prostheses failure; prosthodontics.

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Osseointegrated implants have been successfully used to replace missing teeth in partially edentulous patients.[1,2] However, atrophy of the posterior alveolar ridges is quite common after tooth loss, which limits the use of dental implants attributable to insufficient bone height.[3] Thus, to eliminate the need for augmentative procedures and to reduce the morbidity and treatment time, the use of short dental implants has been advocated to simplify treatment.[4,5]

Short dental implants are devices with a length <10 mm.[6-8] There are some controversies regarding their success and reliability. Although favorable success rates comparable with longer implants have been reported,[4,9-12] other studies reported a higher number of failures when using short implants,[13-16] occurring mainly within the first year of function.[7,17] One possible reason for this higher failure rate is an unfavorable biomechanical scenario in the posterior region of the jaws, in which short implants are associated with higher loading forces, poor quality bone, and a poor crown-to-implant ratio.[16]

Therefore, splinting implants may provide even more stress and strain distribution to the bone to avoid overloading,[18,19] especially for those placed in poor-quality bone, such as the posterior

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region of the jaws.[20] However, when compared to non-splinted single crowns, there are some disadvantages of splinting, including difficulties to fit the framework and to provide adequate emergency profile and interproximal hygiene issues to the patient. Therefore, splint or not-short implants in the posterior region still creates a dilemma for clinicians.

Although a similar survival rate and similar marginal bone loss were reported for long implants supporting splinted and non-splinted prostheses,[21,22] the benefits of applying this approach to short implants is still not clear. Therefore, the aim of the present retrospective study is to evaluate the survival rate and bone loss around short implants (≤10 mm) supporting splinted or non-splinted posterior prostheses during a follow-up period of 3 to 16 years.

MATERIALS AND METHODS

Patients and Implants

This retrospective study, with a follow-up of 3 to 16 years, was conducted in accordance with the Declaration of Helsinki, as revised in 2008, and reported following the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[23] The study was approved by the Ethics Committee of the São Leopoldo Mandic Institute and Research Center, Campinas, São Paulo, Brazil. The present study includes a total of 453 short dental implants (≤10 mm) from 198 patients (86 males and 112 females, aged 45 to 81 years; mean ages: 62.1 ± 11.0 and 58.8 ± 12.6 years, respectively) under treatment from April 1996 to November 2009 in a private dental office in the city of Belo Horizonte, Minas Gerais, Brazil.

The inclusion criteria were as follows: 1) patients with posterior partially edentulous jaws (Kennedy Class I or II);[24] 2) limited bone height to place standard longer implants; 3) at least two adjacent short implants were present; 4) no immediate implant placement (at least 6 weeks of healing after tooth extraction); 5) good general health at the time of surgery; and 6) the patients provided written informed consent. All included implants have opposing contacts to natural teeth or fixed partial dentures.

The exclusion criteria included the presence of the following: 1) bone grafting at the surgical site; 2) short implants with prosthesis splinted to long implants or teeth; 3) partial or complete removable denture at the opposing arch; and 4) pain in the temporomandibular joint or mastication muscles. Patients reporting bruxism or with signs of occlusal wear facets were also excluded. Smokers were not excluded, but they were informed that smoking is a risk factor for implant failure.

The implants were divided into two groups according to the presence or absence of splinting. Thus, the survival rate and bone loss of 219 short implants supporting splinted prostheses placed in 86 patients were compared to 234 short implants with non-splinted prostheses placed in 112 patients. Smoking habits were recorded from anamnesis files. Implant information regarding diameter platform (regular: 4.1 mm; or wide: 5.0 mm), length (10, 8.5, or 7 mm), implant–abutment connection (internal or external), design (cylindrical or tapered), and surface (rough or smooth) was also collected.

Surgical and Restorative Procedures

All patients were instructed to initiate antibiotic and anti-inflammatory therapy before the intervention and thereafter. Antibiotics were taken twice daily for 7 days, and anti-inflammatory therapy was taken for 5 days. Patients used 0.12% chlorhexidine mouthwash for 1 minute immediately before starting the intervention and thereafter twice daily for 7 days. All surgeries were performed under local anesthesia with a full-thickness flap to expose the alveolar ridge by the same surgeon (JAM), following the recommendations of the manufacturer. Finally, the flaps were closed using mono-nylon suture.

After 12 weeks of healing for implants placed in the mandible and after 18 weeks for those placed in the maxilla, the patients were recalled to load the implants. All clinical prosthetic procedures were performed by the same professional (JAM). Abutments were tightened with the recommended torque, and the patients received single or splinted metal–ceramic prostheses. All patients were recalled for routine follow-up, including radiographic and clinical examination.

Outcome Criteria

Implant success was defined as the absence of mobility, painful symptoms, and radiolucency during radiographic evaluation and a progressive marginal bone loss <1 mm during the first year after implant placement and <0.2 mm per year in subsequent years. Implant removal was mandatory in patients with clinical mobility attributable to implant overloading, implant fracture, or peri-implantitis that was not successfully treated.[25]

Marginal bone levels were assessed by taking digital periapical radiographs of each implant just after prosthetic loading (baseline) and at the last follow-up examination.[26] All radiographs were taken using the long-cone parallel technique, and marginal bone loss (BL) was measured by a masked investigator (JAM) using an image processing software.§ Bone loss was assessed by measuring the

§ Image Tool for Windows, University of Texas Health Science Center, San Antonio, TX.

linear distance from the platform level to the first bone-to-implant contact on mesial and distal sides, and the mean was recorded for each implant. Implant length was used as vertical reference on each image.

Statistical Analyses

Descriptive statistics (means and SDs), odds ratio (OR), and confidence interval of each variable were computed separately for each group using a statistical software program.‖ The failure rates within each effect were compared using the χ^2 test, and risk was expressed as OR. After checking bone loss data distribution for normality with Kolmogorov-Smirnov test, the Mann-Whitney *U* test was selected to disclose differences between the splinted and non-splinted groups. Statistical significance was set at the α level of 0.05.

RESULTS

A total of 198 posterior partially edentulous patients was followed up during a 3- to 16-year period (splinted group [36 males and 50 females] and non-splinted group [44 males and 68 females]).

Of the 453 short implants, 219 implants from 86 patients were included in the splinted group, and 234 implants from 112 patients were included the non-splinted group. The mean follow-up period was 9.7 ± 3.7 years, and the distribution of implants during the follow-ups can be seen in Figure 1. Although the non-splinted group received only single metal–ceramic crowns, the splinted group included 84 two-unit and 17 three-unit fixed prostheses. In both groups, there was a higher prevalence of implants placed in the mandible than in the maxilla, and there was a similar distribution of implants among the tooth sites (Fig. 2).

After loading, five implants failed in the splinted group (four implants supporting two-unit prostheses and one implant supporting a three-unit prosthesis) and 16 implants failed in the non-splinted group, representing overall success rates of 97.7% and 93.2%, respectively. The relative influence of other variables on survival rate of short implants is shown in Table 1. Because of the lower number of failures in splinted implants, no relevant effect was identified to affect the success of this group. However, a higher risk of failure was observed among men (OR = 1.0) and for implants shorter than 10 mm (OR = 4.1 and 3.6 for 8.5- and 7-mm-long implants, respectively) when supporting non-splinted prostheses.

The critical period to determine implant success was the first year after loading, in which five failures (100%) were identified in the splinted group and 11 implants (68.7%) failed in the non-splinted group.

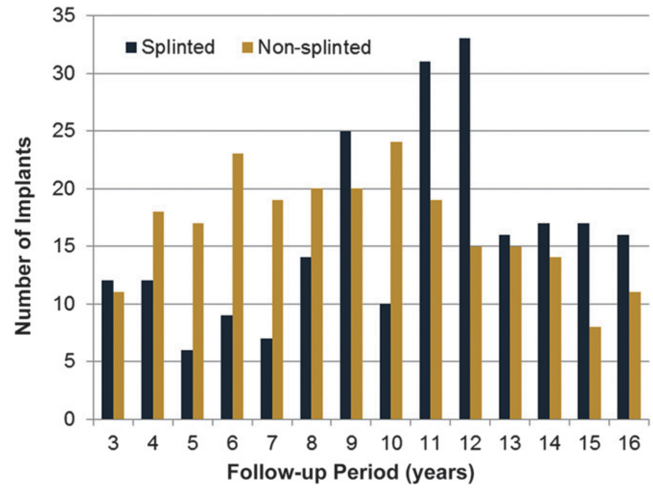

Figure 1.
Implant distribution during the follow-up period in the splinted and non-splinted groups.

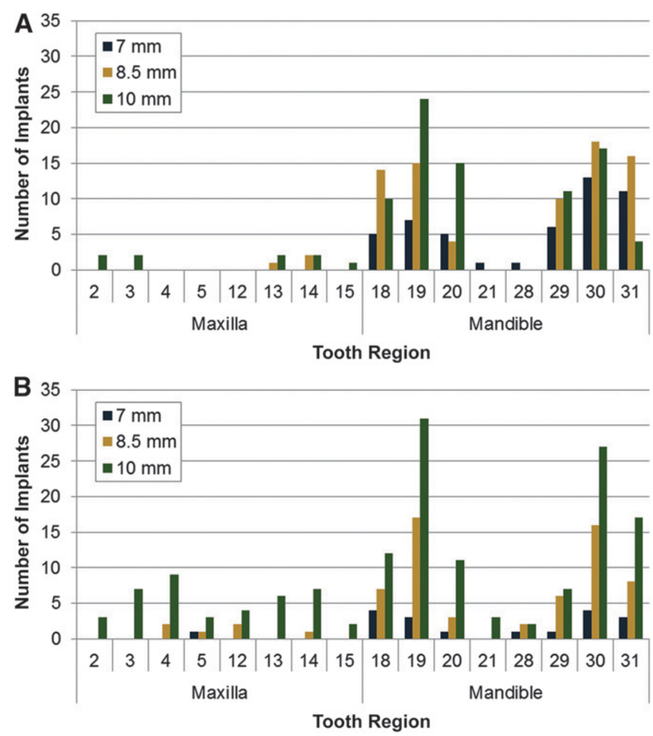

Figure 2.
Implant distribution among tooth positions in the splinted ***(A)*** *and non-splinted* ***(B)*** *groups.*

Other implants failed before 24 (two implants, 12.5%) and 48 (three implants, 18.7%) months.

The distribution of implants and the success rate according to implant length are presented in Table 2. Despite no significant difference between splinted and non-splinted groups when considering all the

‖ SPSS v.17.0, IBM, Armonk, NY.

Table 1.

Survival Rates of Short Implants According to the Supporting Prostheses

	Splinted Prosthesis						Non-Splinted Prosthesis					
Patients Demographics	n	Failures	Survival Rate	OR	95% CI	*P* Value	n	Failures	Survival Rate	OR	95% CI	*P* Value
Sex												
Males	84	1	98.8%	1.0			88	11	87.5%	1.0		
Females	135	4	97.0%	2.5	0.27 – 23.06	0.364	146	5	96.3%	0.2	0.08 – 0.74	0.009
Region												
Maxilla	12	0	100.0%	1.0			48	2	95.8%	1.0		
Mandible	207	5	97.6%	1.0	1.02 – 1.09	0.752	186	14	92.5%	0.5	0.11 – 2.43	0.325
Smoking Status												
Non-smoker	189	5	97.4%	1.0			212	13	93.9%	1.0		
Smoker	30	0	100.0%	0.8	0.90 – 0.99	0.475	22	3	86.4%	2.4	0.63 – 9.23	0.180
Prosthesis												
Two-unit	168	4	97.6%	1.0			234	16	93.1%	1.0		
Three-unit	51	1	98.0%	0.8	0.09 – 7.50	0.669	0	0	—	—	—	—
Implant diameter												
Regular	144	2	98.6%	1.0			120	9	92.5%	1.0		
Wide	75	3	96.0%	1.7	0.85 – 3.73	0.221	114	7	93.9%	0.8	0.29 – 2.24	0.440
Implant length (mm)												
10	90	2	97.8%	1.0			151	5	96.7%	1.0		
8.5	80	1	98.8%	0.6	0.05 – 6.26	0.544	65	9	86.1%	4.1	1.50 – 14.61	0.007
7	49	2	95.9%	1.8	0.25 – 13.72	0.442	18	2	88.9%	3.6	0.65 – 20.36	0.033
Implant–abutment connection												
Internal	21	0	100.0%	1.0			70	2	97.1%	1.0		
External	198	5	97.5%	1.1	1.06 – 1.15	0.601	164	14	91.5%	3.1	0.70 – 14.35	0.093
Implant design												
Tapered	18	0	100.0%	1.0			62	2	96.8%	1.0		
Cylindrical	201	5	97.5%	1.0	1.04 – 1.13	0.649	172	14	91.9%	2.6	0.58 – 12.04	0.153
Implant surface												
Rough	51	0	100.0%	1.0			106	6	94.3%	1.0		
Smooth	168	5	97.0%	1.3	1.21 – 1.41	0.262	128	10	92.2%	1.4	0.49 – 4.02	0.352

P values refer to vertical comparison within each effect (χ^2 test).
95% CI = 95% confidence interval.

Table 2.

Distribution of Implants (n); Success Rate (%) According to Implant Length, Treated Site, and Supported Prosthesis

	Maxilla			Mandible		
Implant	Splinted	Non-Splinted	*P* Value	Splinted	Non-Splinted	*P* Value
10 mm	9; 100%	41; 97.5%	0.636	81; 97.5%	110; 95.4%	0.450
Regular diameter	0; —	20; 100%	*	60; 98.3%	55; 96.3%	0.508
Wide diameter	9; 100%;	21; 95.2%	*	21; 95.2%	55; 94.5%	0.904
Internal connection	6; 100%	30; 100%	*	9; 100%	31; 96.7%	0.585
External connection	3; 100%	11; 90.9%	*	72; 97.2%	79; 94.9%	0.473
Tapered design	6; 100%	30; 100%	*	7; 100%	23; 95.6%;	0.575
Cylindrical design	3; 100%	11; 90.9%	*	74; 97.2%	87; 95.4%;	0.527
Rough surface	6; 100%	30; 100%	*	19; 100%	49; 93.8%	0.270
Smooth surface	3; 100%	11; 90.9%	*	62; 96.7%	61; 96.7%	0.987
8.5 mm	3; 100%	6; 83.3%	0.453	77; 98.7%	59; 86.4%	0.004
Regular diameter	2; 100%	3; 66.6%	*	53; 98.1%	32; 84.3%	0.017
Wide diameter	1; 100%	3; 100%	*	24; 100%	27; 88.8%	0.092
Internal connection	0; —	1; 100%	*	6; 100%	8; 87.5%	0.369
External connection	3; 100%	5; 80.0%	*	71; 98.5%	51; 86.2%	0.007
Tapered design	0; —	1; 100%	*	5; 100%	8; 87.5%	0.411
Cylindrical design	3; 100%	5; 80.0%	*	72; 98.6%	51; 86.2%	0.006
Rough surface	0; —	1; 100%	*	22; 100%	24; 87.5%	0.086
Smooth surface	3; 100%	5; 80.0%	*	55; 98.1%	35; 85.7%	0.021
7 mm	0; —	0; —	*	49; 95.9%	17; 94.1%	0.759
Regular diameter	0; —	0; —	*	29; 100%	10; 90.0%	0.084
Wide diameter	0; —	0; —	*	20; 90.0%	8; 87.5%	0.385
Internal connection	0; —	0; —	*	0; —	0; —	*
External connection	0; —	0; —	*	49; 95.9%	18; 88.8%	0.759
Tapered design	0; —	0; —	*	0; —	0; —	*
Cylindrical design	0; —	0; —	*	49; 95.9%	18; 88.8%	0.759
Rough surface	0; —	0; —	*	4; 100%	2; 100%	*
Smooth surface	0; —	0; —	*	45; 95.5%	16; 87.5%	0.732

P value refers to horizontal comparison of success rate between splinted and non-splinted groups (χ^2 test).
* Indicates that no statistics were computed because not enough valid cases are present in one or both groups.

implants together ($P = 0.086$), 8.5- and 7-mm-long implants showed lower success rates when supporting non-splinted prosthesis.

The mean marginal BL around the implants supporting splinted (1.22 ± 0.95 mm) and non-splinted (1.27 ± 1.15 mm) posterior prostheses were similar and it was not influenced by the implant length (Table 3).

DISCUSSION

Short implants in the posterior maxilla or mandible may be associated with lower prosthesis survival rates because of the unfavorable biomechanical scenario, which may indicate splinting of the prosthesis. However, clinical data supporting this approach to short implants was missing in the literature. In the present study, no significant difference is found between the success and marginal bone loss around the implants supporting splinted or non-splinted prostheses after a mean follow-up of 10 years.

Splinting short implants in the posterior region mainly enhances their stability to eccentric forces.[27] Eccentric bucco-lingual forces can be reduced by using lower sloped cuspids and by making proper selective occlusal adjustments on the prosthesis for a good clearance.[28] In the present study, all prostheses from both groups are manufactured by the same professional/technician, and the occlusal setup was carefully managed to minimize undesirable horizontal forces. These steps helped to avoid overloading on the implants and may be reflected in the similar marginal BL for both groups.

The presence of a reduced number of occlusal centric stops on natural teeth, as in Kennedy Class I patients, could also indicate the use of splinted restorations to prevent overloading.[28] In contrast, the remaining contralateral teeth of Kennedy Class II

Table 3.

Mean Bone Loss (mm) According to Implant Length, Treated Site and Supported Prosthesis (mean ± SD)

	Maxilla			Mandible		
Implant	Splinted	Non-Splinted	*P* Value	Splinted	Non-Splinted	*P* Value
10 mm	1.27 ± 1.00	0.82 ± 1.21	0.806	1.32 ± 1.00	1.43 ± 1.09	0.671
Regular diameter	—	0.58 ± 0.53	*	1.40 ± 1.01	1.66 ± 1.15	0.260
Wide diameter	1.27 ± 1.00	1.08 ± 1.61	*	1.11 ± 0.95	1.15 ± 0.96	0.876
Internal connection	0.37 ± 0.17	1.36 ± 0.84	*	1.06 ± 0.86	1.47 ± 1.05	0.382
External connection	2.67 ± 0.62	0.77 ± 0.65	*	1.36 ± 1.02	1.41 ± 1.11	0.900
Tapered design	0.37 ± 0.17	1.36 ± 0.84	*	0.93 ± 0.64	1.62 ± 1.07	0.139
Cylindrical design	2.67 ± 0.62	0.77 ± 0.65	*	1.37 ± 1.00	1.37 ± 1.09	0.875
Rough surface	0.37 ± 0.17	1.36 ± 0.84	*	1.26 ± 0.82	1.40 ± 1.13	0.604
Smooth surface	2.67 ± 0.62	0.77 ± 0.65	*	1.34 ± 1.05	1.45 ± 1.06	0.546
8.5 mm	0.50 ± 0.41	1.40 ± 1.20	0.288	1.07 ± 0.80	1.37 ± 1.21	0.378
Regular diameter	0.45 ± 0.25	0.25 ± 0.25	*	1.12 ± 0.72	1.34 ± 0.88	0.312
Wide diameter	1.00 ± 0.00	2.17 ± 0.94	*	0.98 ± 0.94	1.40 ± 1.51	0.479
Internal connection	—	1.50 ± 0.00	*	0.83 ± 0.62	1.42 ± 0.67	0.162
External connection	0.50 ± 0.41	1.38 ± 1.34	*	1.09 ± 0.81	1.36 ± 1.27	0.624
Tapered design	—	1.50 ± 0.00	*	0.80 ± 0.68	1.42 ± 0.67	0.162
Cylindrical design	0.50 ± 0.41	1.38 ± 1.34	*	1.09 ± 0.81	1.36 ± 1.27	0.624
Rough surface	—	1.50 ± 0.00	*	1.10 ± 0.68	1.58 ± 1.34	0.394
Smooth surface	0.50 ± 0.41	1.38 ± 1.34	*	1.06 ± 0.85	1.23 ± 1.10	0.710
7 mm	—	—	*	1.35 ± 0.98	1.03 ± 0.69	0.367
Regular diameter	—	—	*	1.52 ± 1.06	0.88 ± 0.65	0.140
Wide diameter	—	—	*	1.06 ± 0.73	1.21 ± 0.70	0.449
Internal connection	—	—	*	—	—	*
External connection	—	—	*	1.35 ± 0.98	1.03 ± 0.69	0.367
Tapered design	—	—	*	—	—	*
Cylindrical design	—	—	*	1.35 ± 0.98	1.03 ± 0.69	0.367
Rough surface	—	—	*	1.38 ± 0.74	0.75 ± 0.25	*
Smooth surface	—	—	*	1.35 ± 1.00	1.08 ± 0.73	0.475

P value refers to horizontal comparison of bone loss between splinted and non-splinted groups (Mann-Whitney *U* test).
* Indicates that no statistics were computed because not enough valid cases are present in one or both groups.

patients would provide more stable occlusion, allowing the use of single restorations. However, in the present study, those patients receive randomly splinted or non-splinted implants, which can be attributed to the presence of healthy anterior guidance and mutually protected or canine guidance occlusion, which is known to decrease stress on posterior implants.[29] Thus, anterior guidance can determine the success of short dental implants regardless of the presence of the remaining posterior teeth or splinting prostheses.

Short implants with single restorations in the posterior region are more susceptible to high masticatory forces, which increases the risk of micromotion above physiologic limits.[30,31] Micromotion may have influenced the higher failure rate among males compared with females in the present study because of the higher occlusal force among male patients,[32] which may produce higher micromotion in short implants with non-splinted restorations. Moreover, the lower bone-to-implant contact area in 7- and 8.5-mm-long implants offers lower resistance to these movements, which may have led to a higher failure rate when compared to 10-mm-long implants supporting non-splinted prosthesis. However, this potential risk seems to be relevant only in the first year of loading, indicating that bone remodeling around the implant creates a dense interface, which may improve the biomechanics of the implants.[33,34]

Finite element analysis showed that a higher crown-to-implant ratio increases peri-implant bone stress;[35] thus, it could be an important biomechanical factor to consider when using single short implants. Therefore, two adjacent crowns with an unfavorable crown-to-implant ratio would present a better biomechanical performance when splinted, especially under non-axial loading.[18,19] Despite a previous study showing that non-splinted short implants have lower crestal BL than splinted longer implants,[36] the present data do not show different bone loss around short implants supporting splinted and non-splinted prostheses. However, the higher failure rate of the non-splinted group may indicate that this aspect can be a potential risk factor for short implants and should be carefully investigated.

In general, non-smoking patients have better implant success, and the effect of smoking should be closely observed in areas of loose trabecular bone.[37] Although smoking level is not checked in the present study, no association is found between this risk factor and the failure of short implants.

Lower survival rates for short implants were reported by studies that used machined surfaces.[38-40] Despite these data highlighting the importance of using rough surfaces in the success of short dental implants, in the present study, the surface does not significantly affect the clinical success or bone loss around short implants. However, this effect could not be isolated, and it was often associated with changes of implant design and implant–abutment connection, making more difficult a specific evaluation of the influence of surface topography on BL.

Some limitations of the current study should be mentioned besides its retrospective nature, such as: 1) the lack of clinical data: 2) the fact that the radiographic assessment is limited to the mesial and distal bone levels; and 3) the low number of failures to evaluate the risk factors. Future studies should consider evaluating the crown-to-implant ratio and use computed tomography to determine the bone response to short implants supporting splinted and non-splinted prosthesis.

CONCLUSION

Despite posterior, single short implants (≤10 mm) being associated with higher risk when placed in male patients, the biomechanical advantage of splinting may be minor when patients present healthy anterior guidance and controlled occlusal clearance.

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