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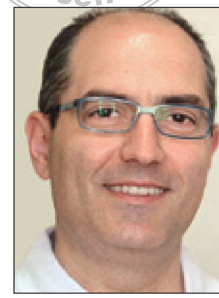
Radiographic interpretation agreement in implant dentistry



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Purpose: The aim of this survey is to assess the different radiographic interpretations of simulated dental implant cases among a group of specialists in oral surgery.

Material and methods: A total of 76 active members of the Italian Society of Oral Surgery and Implantology were recruited for the study. The participants in the study were requested to assign scores to radiographic images of 12 simulated cases of dental implants: a baseline and follow-up image for cases with different bone loss (0, 1 or 5 mm), implant length (8 or 12 mm) and years of follow-up (1 or 5 years).

Results: In total, 63 active members agreed to participate in the survey. The inter-rater agreement was 0.86 (CI 95% 0.74; 0.95). In cases where the bone loss was absent (0 mm) no difference was detected at 1 or 5 years of follow-up. In contrast, when bone loss was present (1 or 5 mm) the longer follow-up (5 years) revealed the highest score. The lowest score was attributed to 5 mm of bone loss and 1 year of follow-up. Moreover, a significant difference between the short (8 mm) and the long (12 mm) implant was observed (score difference 0.45; CI 95% 0.28; 0.63).

Conclusions: This investigation suggests that subjective evaluation of radiographs on simulated implants by skilled clinicians is rather uniform, and bone loss, follow-up and implant length are factors considered in the perception of implant success.

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Introduction

Today dental implant therapy represents an effective treatment option for replacing missing teeth[1,2]. The outcome assessment of current implant systems is based on clinical and radiographic variables suggested in several studies published in the last 30 years. In particular, the most frequently cited success criteria are those presented by Albrektsson and coworkers[3]. These success criteria have been described as follows:

'1. That an individual, unattached implant is immobile when tested clinically.

1. That a radiograph does not demonstrate any evidence of peri-implant radiolucency.
2. That vertical bone loss be less than 0.2 mm annually following the implant's first year of service.
3. That individual implant performance be characterized by an absence of persistent and/or irreversible signs and symptoms such as pain, infections, neuropathies, paresthesia, or violation of the mandibular canal.
4. That, in the context of the above, a success rate of 85% at the end of a five-year observation period and 80% at the end of a ten-year period be a minimum criterion for success.'

Other success criteria have been proposed by other authors[4,5], adding to the previous ones subjective patient evaluation with respect to implant function, absence of discomfort and patient attitude of improved aesthetics, and psychological attitude.

In 1990, Buser et al[6] suggested other criteria be used to establish a successful outcome for dental implants based on the following:

- absence of persistent subjective complaints
- absence of a recurrent peri-implant infection with suppuration
- absence of mobility
- absence of a continuous radiolucency around the implant
- possibility for restoration.

It is important to note that within these variables, the loss of the marginal bone level was not considered.

In 2004, Karoussis et al[7] combined success criteria proposed by other authors[3,6,8,9] in a more comprehensive list that was adopted to evaluate the outcome of their study at 10 years of follow-up:

- absence of mobility
- absence of persistent subjective complaints
- no periodontal probing depth (PPD) > 5 mm
- no PPD = 5 mm and bleeding on probing
- absence of a continuous radiolucency around the implant
- after the first year of service, the annual vertical bone loss should not exceed 0.2 mm.

In the authors' opinion, 'success' was defined only when an implant fulfilled both the clinical and the radiographic criteria. The same list of success criteria was used more recently in a systematic review by Ong et al[10]. In the same manner, other authors[11-13] have adopted their own criteria of success that consisted of a different combination (or selection) of the same variables reported by Albrektsson et al[3] and Buser et al[6] previously.

Based on these data, it is possible to conclude that the success criteria are commonly used in a confusing manner and not in a uniform way. In fact, the lack of standardised and internationally recognised success criteria makes the establishment of a 'successful dental implant' very difficult. For instance, there is little information about whether sulcus depth is related to implant success or failure[14]. Lekholm et al[15] (1986) have demonstrated that the presence of deep pockets is not necessarily correlated with accelerated marginal bone loss. In fact, probing pocket depth alone does not represent an indicator of failure because other factors such as gingival thickness or length of abutment may influence the judgement of a successful or a failed implant[10].

No information is available on whether there is agreement among different clinicians in following the above-mentioned success criteria. In fact, the operators who, in their daily practice, are called to assess the different conditions of implant cases might interpret the considered clinical and radiographic variables suggested by the literature in a different manner.

Therefore, the aim of this survey is to assess the radiographic interpretations of simulated dental implant cases by a group of specialists in oral surgery, where different implant lengths, bone loss and follow-up time are considered.

Material and methods

In 2008, the 76 active members of the Italian Society of Oral Surgery and Implantology (SICOI) were recruited as participants for the study. An investigator (LB) administered a questionnaire personally to each participant. The questions included the following variables: name, gender, age and years of clinical practice. After answering these questions, twelve pairs of simulated cases were shown to the participants. Each case consisted of the baseline and re-examination (follow-up) radiograph (indicated at 1 or 5 years) of one dental implant with two different

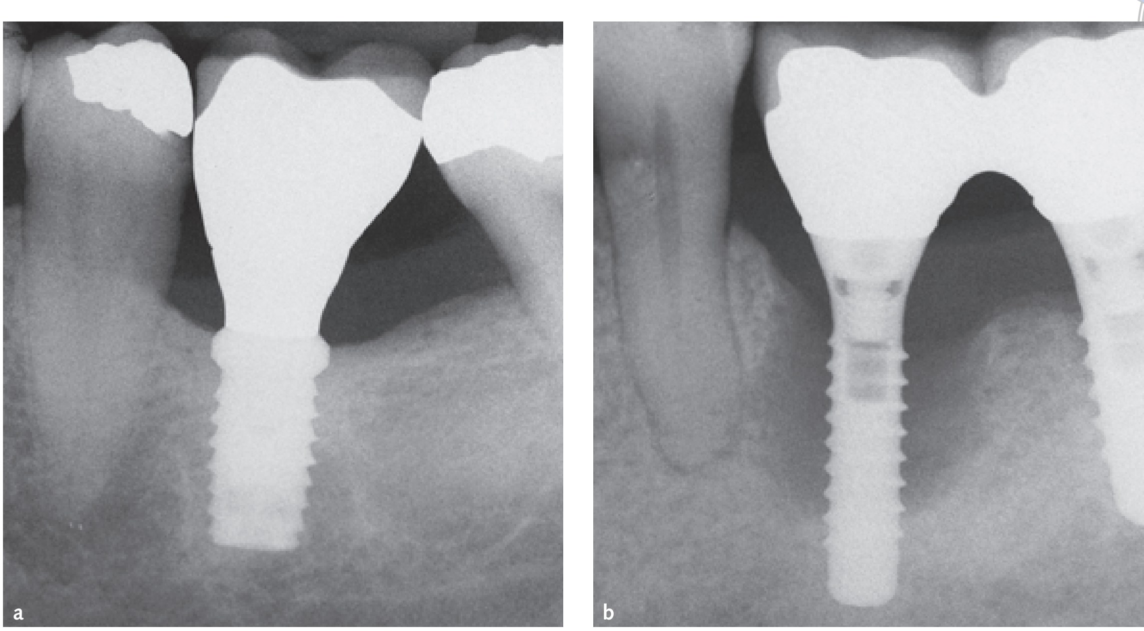

Fig 1 Original radiographs of two implants with different lengths: 8 mm (a) and 12 mm (b).

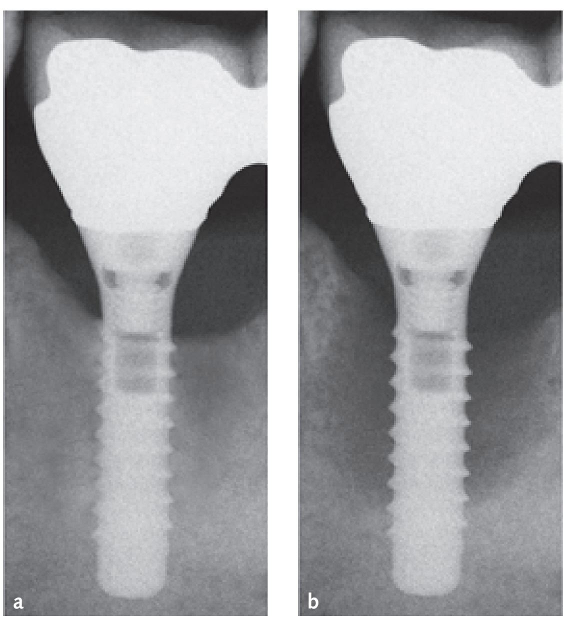

Fig 2 Baseline radiograph of a longer implant (12 mm) with no sign of bone loss (a) paired with a follow-up visit at 1 year with 5 mm of bone loss (b).

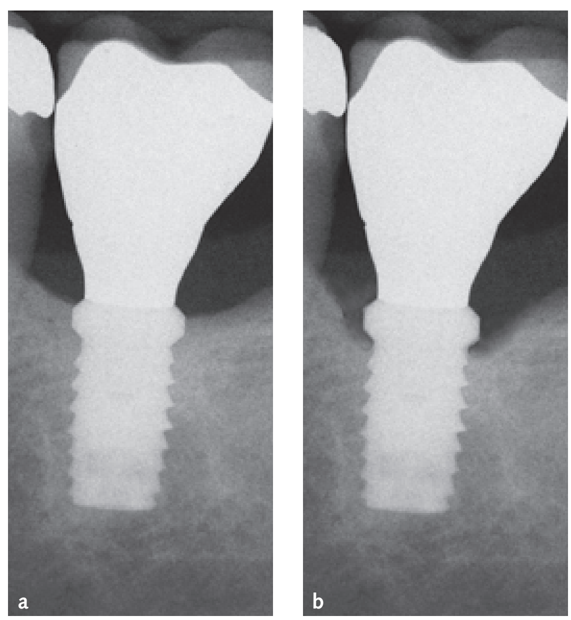

Fig 3 Baseline radiograph of a short implant (8 mm) with no sign of bone loss (a) paired with a follow-up visit at 5 years with 1 mm of bone loss (b).

lengths (8 mm and 12 mm). In order to standardise the light exposure and magnification among the pictures, it was decided to choose one original radiograph per implant length (8 mm and 12 mm) with no sign of bone resorption (Fig 1a and 1b). In order to simulate the bone loss around the implant, a specific software program (Adobe Photoshop CS, version 8.0.1, San Jose, CA, USA) for photograph editing was used. In particular, a circumpherential bone loss of 1 and 5 mm was created. Therefore, considering all of the three factors, implant length at two levels (8 and 12 mm), bone loss at three levels (0, 1, 5 mm), and time of follow-up at two levels (1 and 5 years), the illustrations resulted in 12 combinations:

1. baseline radiograph of a longer implant (12 mm) with no sign of bone loss (Fig 2a) paired with a follow-up visit at 1 year with 5 mm of bone loss (Fig 2b)
2. baseline radiograph of a short implant (8 mm) with no sign of bone loss (Fig 3a) paired with a follow-up visit at 5 years with 1 mm of bone loss (Fig 3b)

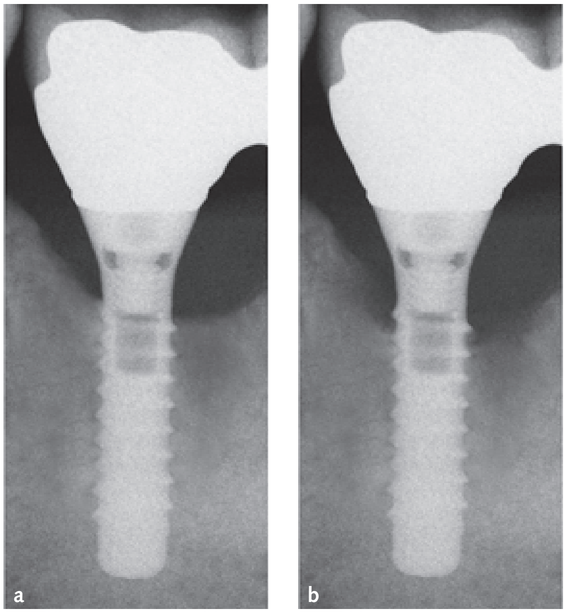

Fig 4 Baseline radiograph of a longer implant (12 mm) with no sign of bone loss (a) paired with a follow-up visit at 1 year with 1 mm of bone loss (b).

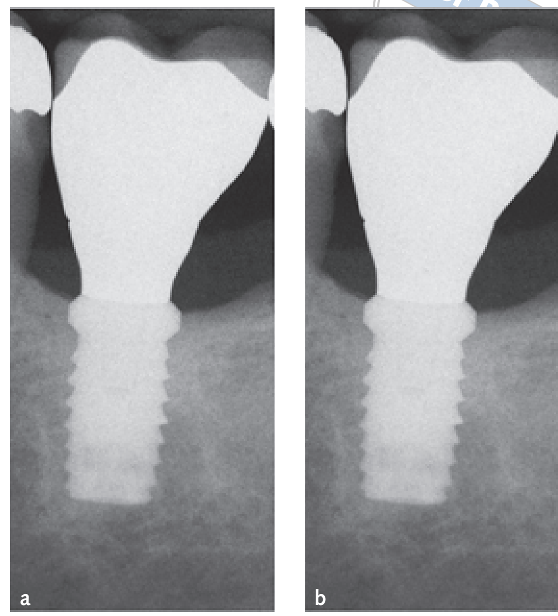

Fig 5 Baseline radiograph of a short implant (8 mm) with no sign of bone loss (a) paired with a follow-up visit at 5 years with no sign of bone loss (b).

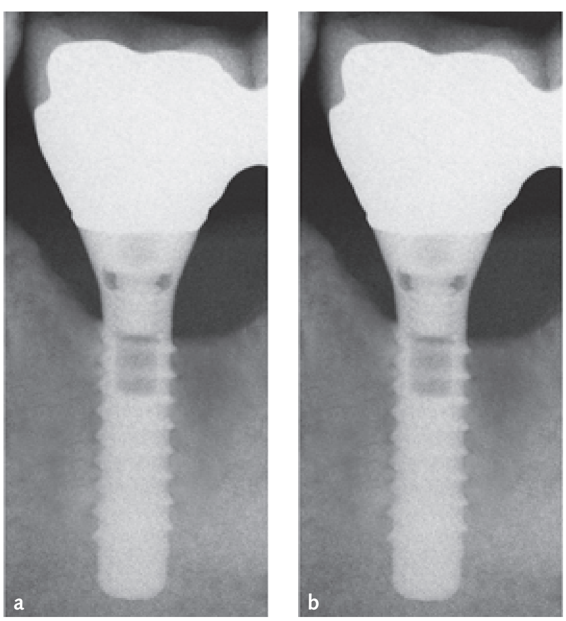

Fig 6 Baseline radiograph of a longer implant (12 mm) with no sign of bone loss (a) paired with a follow-up visit at 1 year with no sign of bone loss (b).

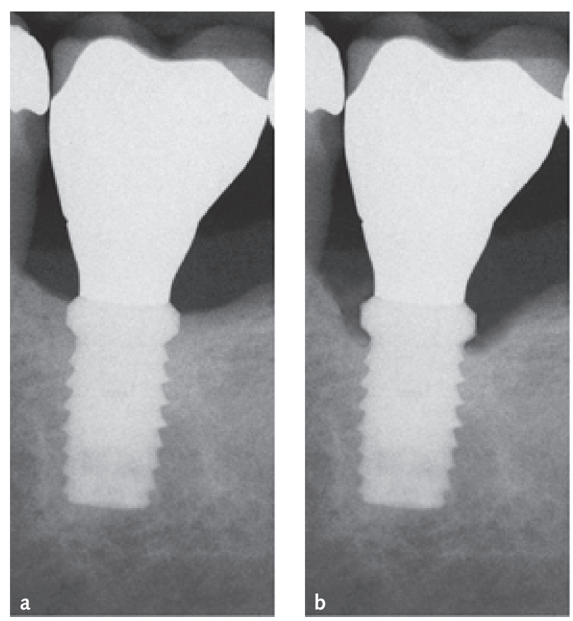

Fig 7 Baseline radiograph of a short implant (8 mm) with no sign of bone loss (a) paired with a follow-up visit at 1 year with 1 mm of bone loss (b).

3. baseline radiograph of a longer implant (12 mm) with no sign of bone loss (Fig 4a) paired with a follow-up visit at 1 year with 1 mm of bone loss (Fig 4b)
4. baseline radiograph of a short implant (8 mm) with no sign of bone loss (Fig 5a) paired with a follow-up visit at 5 years with no sign of bone loss (Fig 5b)
5. baseline radiograph of a longer implant (12 mm) with no sign of bone loss (Fig 6a) paired with a follow-up visit at 1 year with no sign of bone loss (Fig 6b)
6. baseline radiograph of a short implant (8 mm) with no sign of bone loss (Fig 7a) paired with a follow-up visit at 1 year with 1 mm of bone loss (Fig 7b)

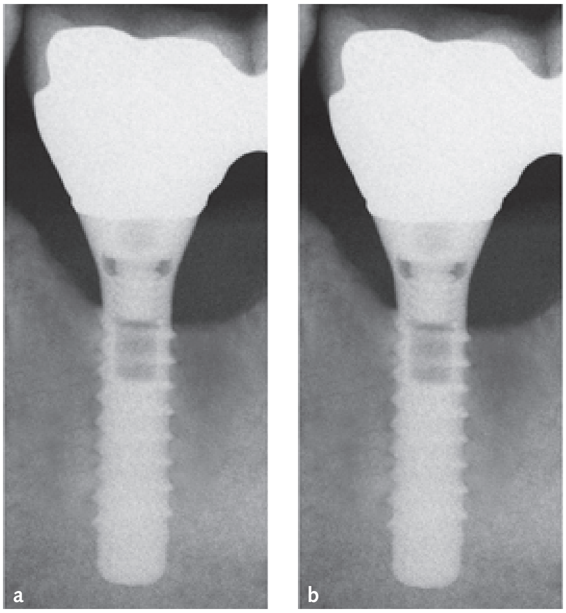

Fig 8 Baseline radiograph of a longer implant (12 mm) with no sign of bone loss (a) paired with a follow-up visit at 5 years with no sign of bone loss (b).

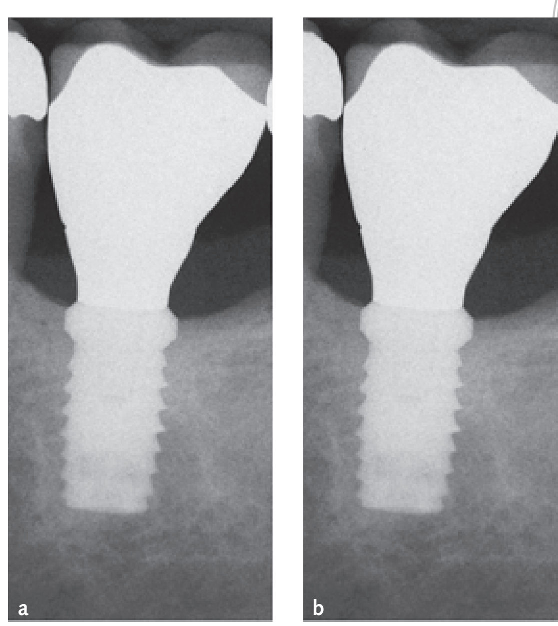

Fig 9 Baseline radiograph of a short implant (8 mm) with no sign of bone loss (a) paired with a follow-up visit at 1 year with no sign of bone loss (b).

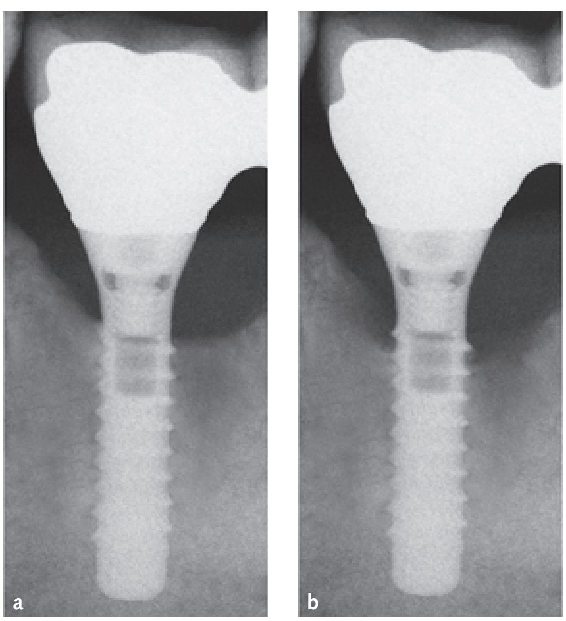

Fig 10 Baseline radiograph of a longer implant (12 mm) with no sign of bone loss (a) paired with a follow-up visit at 5 years with 1 mm of bone loss (b).

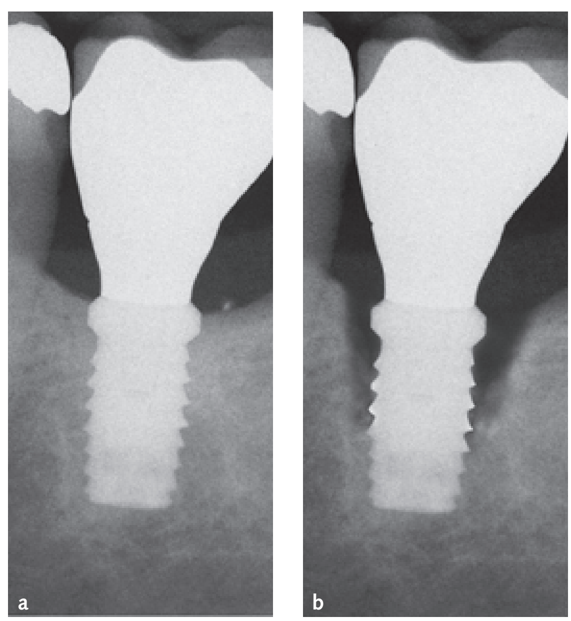

Fig 11 Baseline radiograph of a short implant (8 mm) with no sign of bone loss (a) paired with a follow-up visit at 1 year with 5 mm of bone loss (b).

7. baseline radiograph of a longer implant (12 mm) with no sign of bone loss (Fig 8a) paired with a follow-up visit at 5 years with no sign of bone loss (Fig 8b)
8. baseline radiograph of a short implant (8 mm) with no sign of bone loss (Fig 9a) paired with a follow-up visit at 1 year with no sign of bone loss (Fig 9b)
9. baseline radiograph of a longer implant (12 mm) with no sign of bone loss (Fig 10a) paired with a follow-up visit at 5 years with 1mm of bone loss (Fig 10b)
10. baseline radiograph of a short implant (8 mm) with no sign of bone loss (Fig 11a) paired with a follow-up visit at 1 year with 5 mm of bone loss (Fig 11b)

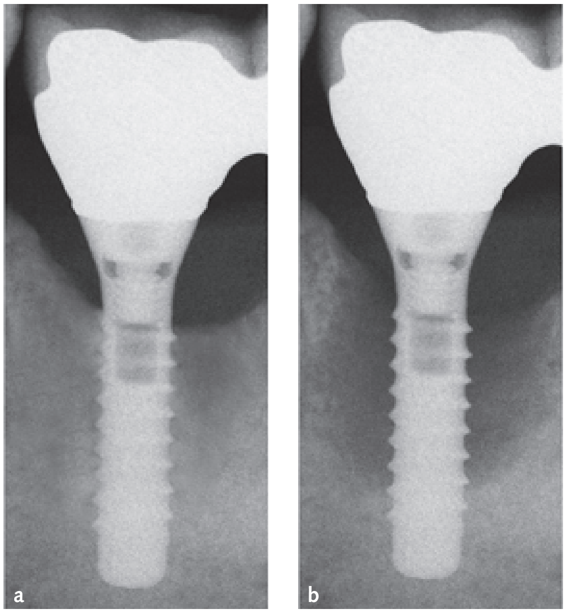

Fig 12 Baseline radiograph of a longer implant (12 mm) with no sign of bone loss (a) paired with a follow-up visit at 5 years with 5 mm of bone loss (b).

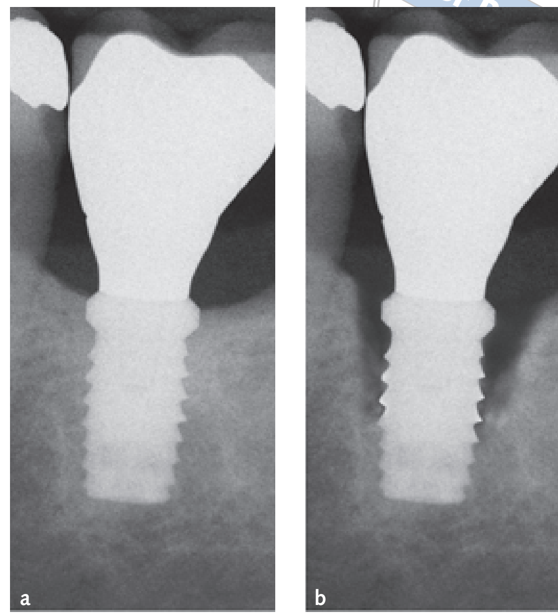

Fig 13 Baseline radiograph of a short implant (8 mm) with no sign of bone loss (a) paired with a follow-up visit at 5 years with 5 mm of bone loss (b).

11. baseline radiograph of a longer implant (12 mm) with no sign of bone loss (Fig 12a) paired with a follow-up visit at 5 years with 5 mm of bone loss (Fig 12b)
12. baseline radiograph of a short implant (8 mm) with no sign of bone loss (Fig 13a) paired with a follow-up visit at 5 years with 5 mm of bone loss (Fig 13b).

For each pair of images (baseline and follow-up visit), the examiner asked the same question of each subject selected for this study: 'What score (from 0 ["failed implant"] to 10 ["successful implant"]) do you assign to the outcome of this implant therapy?' Each pair of images was printed on photography paper, reported on one single page, and shown consecutively as described previously (#1–#12). The score expressed by the interviewed subject was recorded in a paper form.

After the completion of the interviews, all of the data were recorded on an electronic spreadsheet (Microsoft® Office Excel 2007, Redmond, WA, USA).

Statistical analysis

Descriptive statistic analysis was performed using frequency and percentage for the qualitative variables, while mean and standard deviation were computed for the quantitative variables.

An inter-rater agreement among the participants on the 12 questions was calculated using the intra-class correlation coefficient[16].

The two-way random intra-class correlation coefficient (ICC) and 95% confidence interval were used to assess the inter-rater agreement among the participants. This statistical analysis was performed with R software (version 2.9.2, The R Foundation for Statistical Computing, Vienna, Austria).

Inferential statistic analysis was applied using a mixed REstricted Maximum Likelihood (REML) model in which the single score was considered the outcome variable. All of the 12 answers given by each participant were considered and the model was full factorial on three factors: implant length, bone loss and follow-up time. The interactions among the factors were calculated but, if not significant, they were successively dropped out from the model. In cases of significant results, a post hoc comparison using the Tukey–Kramer honestly significant difference test was also carried out.

This statistical analysis was carried out using the software JMP® version 7.0, 2007 (SAS Institute, Cary, NC, USA).

Table 1 Descriptive statistics.

Combination	Implant length (mm)	Bone loss (mm)	Follow-up (years)	Score (mean)	Score (standard deviation)
#1	12	5	1	1.3	1.2
#2	8	1	5	7.5	1.3
#3	12	1	1	5.2	1.4
#4	8	0	5	9.5	1.0
#5	12	0	1	8.7	1.3
#6	8	1	1	6.3	1.5
#7	12	0	5	8.9	1.3
#8	8	0	1	9.3	1.0
#9	12	1	5	6.8	1.1
#10	8	5	1	1.1	1.1
#11	12	5	5	2.0	1.4
#12	8	5	5	2.0	1.4

Table 2 Inferential statistics. Mixed REstricted Maximum Likelihood (REML) model in which the single score was considered the outcome variable (R^2 = 0.88).

Source	DF	F ratio	Prob > F
Implant length	1	25.81	<0.0001
Bone loss	2	2421.97	<0.0001
Follow-up	1	80.03	<0.0001
Bone loss*follow-up	2	14.34	<0.0001

DF: degrees of freedom

Results

Of the 76 active members of the Italian Society of Oral Surgery and Implantology, 63 agreed to participate in the survey. All of the participants were males and the mean age was 48.6 ±10.3 (range from 28 to 79 years). The mean years of practice were 22.2 ± 9.9 years (range from 4 to 53 years). The mean scores attributed to the 12 questions are reported in Table 1.

The inter-rater agreement was 0.86 (CI 95% 0.74; 0.95). The inferential statistic analysis revealed that all of the three independent factors and the interaction bone loss* follow-up were significant with respect to the recorded score (Table 2). The interactions implant length* bone loss, implant length* follow-up, and implant length* bone loss* follow-up were not significant and were dropped from the model.

The analysis reported a significant difference between the short (8 mm) and the long (12 mm) implant (score difference 0.45; CI 95% 0.28; 0.63) among the answers given by the participants, with the highest score given to the short implants. Considering the significant interaction between bone loss and follow-up, these two factors were considered together (Tables 3 and 4). In particular, in cases where the bone loss is absent (0 mm) no differences were detected at 1 or 5 years of follow-up. On the contrary, when bone loss is present (1 or 5 mm) the longer follow-up (5 years) gave the highest score. The lowest score was attributed to 5 mm of bone loss and 1 year of follow-up.

Discussion

Different success criteria have been proposed for implants[3-10]. The need for objective criteria was initially advocated to validate implant systems. Later, modifications were aimed at evaluating single

Table 3 Least square means differences using Tukey–Kramer honestly significant difference test.

Bone loss (mm)	Follow-up (years)						Least square mean
0	5	A					9.21
0	1	A					9.02
1	5		B				7.13
1	1			C			5.77
5	5				D		2.04
5	1					E	1.20

Levels not connected by the same letter are significantly different (e.g. bone loss 0 mm and follow-up 5 years is not significantly different from bone loss 0 mm and follow-up 1 year).

Table 4 Confidence intervals of the interaction levels.

Bone loss, follow-up	Bone loss, follow-up	Difference	Lower CL	Upper CL
0 mm, 5 yrs	5 mm, 1 yr	8.01	7.57	8.45
0 mm, 1 yr	5 mm, 1 yr	7.82	7.38	8.26
0 mm, 5 yrs	5 mm, 5 yrs	7.17	6.73	7.61
0 mm, 1 yr	5 mm, 5 yrs	6.97	6.53	7.42
1 mm, 5 yrs	5 mm, 1 yr	5.93	5.49	6.37
1 mm, 5 yrs	5 mm, 5 yrs	5.09	4.65	5.53
1 mm, 1 yr	5 mm, 1 yr	4.57	4.13	5.02
1 mm, 1 yr	5 mm, 5 yrs	3.73	3.29	4.17
0 mm, 5 yrs	1 mm, 1 yr	3.43	2.99	3.87
0 mm, 1 yr	1 mm, 1 yr	3.24	2.80	3.68
0 mm, 5 yrs	1 mm, 5 yrs	2.07	1.63	2.52
0 mm, 1 yr	1 mm, 5 yrs	1.88	1.44	2.32
1 mm, 5 yrs	1 mm, 1 yr	1.36	0.92	1.80
5 mm, 5 yrs	5 mm, 1 yr	0.84	0.40	1.28
0 mm, 5 yrs	0 mm, 1 yr	0.19	-0.25	0.63

The column 'Difference' reports the adjusted difference between the combinations of bone loss and years of follow-up. The columns 'Lower CL' and 'Upper CL' report the confidence limits at 95% of the difference.

implants, but did not attain universal consensus. Even objective measurements on radiographs do not provide a universal measure of success. Moreover, precise measurements on radiographs are usually carried out in research settings while immediate visual evaluations without any measuring device are typical of clinical settings.

It was deemed important to understand how clinicians evaluate the success of implants on radiographs subjectively. In particular, for this investigation it was decided to use radiographic images with standardised simulated alterations in order to test the perception of identical defects in different albeit standardised situations (e.g. the implant length). In this manner, confounding factors such as light exposition, grey scale or film alterations may be controlled and, therefore, not able to influence the radiographic assessment. On the contrary, this aspect may represent the main limit of the present investigation, since the assessment was not performed on real cases with different levels of bone loss. Further studies may investigate possible differences in the radiographic interpretations of real dental implant cases based on original radiographic images with different levels of bone destruction.

The active members of the Italian Society of Oral Surgery and Implantology were considered a suitable sample of implant experts.

The high inter-rater agreement indicates that the perception of bone loss around implants is rather uniform among skilled clinicians. The different levels of the considered variables (implant length, time elapsed and bone loss) evoked similar responses in the sample of examiners. Moreover, all of the variables had significant effects on the response while the interaction among these variables turned out to be not significant, with the exception of the interaction between bone loss and time. It is not surprising that the same bone loss was judged worse if it occurred in a short time interval than if the same loss occurred over a longer period.

However, the fact that a better prognostic judgement was associated with shorter implants exhibiting the same amount of bone loss at the same time, is surprising. The fact that under these conditions, the healthy portion of implant is shorter if the implant is shorter would suggest the opposite conclusion. Maybe the interviewed clinicians strived to avoid any conditioning by optical effects and over-corrected their evaluation.

In conclusion, the results of this investigation suggest that subjective evaluation of radiographs showing simulated implants performed by skilled clinicians is rather uniform and approximates the judgement that can be based on the measurements.

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