Clin Oral Invest (2009) 13:375–381
DOI 10.1007/s00784-009-0257-5

ORIGINAL ARTICLE

Calibration of radiographs by a reference metal ball affects preoperative selection of implant size

Lars Schropp · Andreas Stavropoulos · Erik Gotfredsen · Ann Wenzel

Received: 3 October 2008 / Accepted: 2 February 2009 / Published online: 17 February 2009

Abstract The aim was to evaluate the impact of a reference ball for calibration of periapical and panoramic radiographs on preoperative selection of implant size for three implant systems. Presurgical digital radiographs (70 panoramic, 43 periapical) from 70 patients scheduled for single-tooth implant treatment, recorded with a metal ball placed in the edentulous area, were evaluated by three observers with the intent to select the appropriate implant size. Four reference marks corresponding to the margins of the metal ball were manually placed on the digital image by means of computer software. Additionally, an implant with proper dimensions for the respective site was outlined by manually placing four reference marks. The diameter of the metal ball and the unadjusted length and width of the implant were calculated. Implant size was adjusted according to a "standard" calibration method (SCM; magnification factor 1.25 in panoramic images and 1.05 in periapical images) and according to a reference ball calibration method (RCM; true magnification). Based on the unadjusted as well as the adjusted implant dimensions, the implant size was selected among those available in a given implant system. For periapical radiographs, when comparing SCM and RCM with unadjusted implant dimensions, implant size changed in 42% and 58%, respectively. When comparing SCM and RCM, implant size changed in 24%. For panoramic radiographs, comparing SCM and RCM changed implant size in 48%. The use of a reference metal ball for calibration of periapical and panoramic radiographs when selecting implant size during treatment planning might be advantageous.

Keywords Radiography · Periapical · Panoramic · Implant planning · Calibration · Magnification · Reference ball

L. Schropp (✉)
Department of Prosthetic Dentistry, School of Dentistry,
Aarhus University,
Vennelyst Boulevard 9,
8000 Aarhus C, Denmark
e-mail: lschropp@odont.au.dk

A. Stavropoulos
Department of Periodontology, School of Dentistry,
Aarhus University,
Vennelyst Boulevard 9,
8000 Aarhus C, Denmark

E. Gotfredsen · A. Wenzel
Department of Oral Radiology, School of Dentistry,
Aarhus University,
Vennelyst Boulevard 9,
8000 Aarhus C, Denmark

Introduction

Radiographic examination is a prerequisite for preoperative planning in implant treatment. Based on the analysis of available radiographs, an implant with proper/adequate dimensions for the intended site may be determined.

Image size distortion (enlargement or reduction) is a well-known phenomenon in radiography. An average magnification factor of 1.25 can be expected in panoramic radiographs [20, 21] and should be taken into account when determining the implant size most suitable for the region. To compensate for this magnification in the radiographic image, a transparent sheet displaying the available implants for a given system, enlarged by 25%, is usually placed on top of the radiographic film when selecting implant size during treatment planning. However, great variation exists in the actual magnification in radiographs. The degree of magnification depends on several factors, such as patient position, mandibular angulation, equipment, and location in the arch [1, 9]. Further, Gomez-Roman and co-workers [9] demonstrated that the magnification of panoramic images varies more in the horizontal than in the vertical plane.

Likewise, image magnification can be seen in periapical radiographs and depends on the relative distances of the focal spot-to-film and object-to-film [23]. An average magnification factor of 1.05 can be expected in periapical radiographs recorded with the paralleling technique [15]. However, it seems that usually the clinician does not compensate for this relatively minor enlargement in connection with presurgical planning of implant placement.

To calculate the “true” size distortion in a certain area of a radiograph, it has been suggested to use a metal marker of known dimensions as a reference, which is included in the radiograph close to the area of interest [12]. However, no previous study has evaluated the significance of using such a reference marker in implant size selection during treatment planning.

The purpose of the present study was to evaluate the impact of a reference metal ball for calibration of periapical and panoramic radiographs on the preoperative selection of implant size for three implant systems.

Materials and methods

Seventy patients (45 female, 25 male) treated with single-tooth implants in the School of Dentistry, Aarhus University, Denmark, were included in this study. Presurgical radiographs (70 panoramic and 43 periapical) of 70 single implant sites were evaluated by three observers (one radiologist, one surgeon, and one prosthodontist) with the intent to select the appropriate implant size. Distribution of the implant sites is shown in Table 1.

The panoramic radiographic examination was performed in a Scanora™ X-ray unit (Soredex; Orion Corporation Ltd, Helsinki, Finland), and the periapical radiographs were recorded with a dental unit (GX-1000; Gendex, Chicago, IL, 65 kV, 10 mA, paralleling technique with a 4×5 cm radiation field). The images were either born digital (photostimulable phosphor systems: Digora (Soredex; Tuusula, Finland) and DenOptix® (Kavo/Gendex, Des Plaines, IL, USA)) or scanned films (Ektaspeed Plus paper pack, Eastman Kodak Company, Rochester, NY, USA). Scanning was carried out by a flatbed scanner with a transparency module (Hewlett-Packard, Palo Alto, CA, USA) and the radiographs were digitized with a resolution of 300 dpi.

Before the radiographs were taken, a 5 mm Ø metal ball was fixed by a piece of wax in the region of interest. Using computer software designed for measuring in radiographs [10], the observers manually placed four reference marks on the digital image on the topmost, bottommost, leftmost, and rightmost margins of the metal ball. Furthermore, the observers manually outlined an implant with the subjec-

Table 1 Calculated magnification factor (CMF) in periapical and panoramic images for the average observer

	N	Horizontal			Vertical		
		Mean	SD	Range	Mean	SD	Range
Periapical							
Maxilla							
Anterior	29	1.06	0.02	1.01–1.11	1.08	0.05	1.03–1.26
Premolar	11	1.05	0.03	1.02–1.12	1.06	0.04	1.01–1.14
Molar	0	–	–	–	–	–	–
Mandible							
Anterior	1	1.05	–	1.05–1.05	1.10	–	1.10–1.10
Premolar	2	1.06	0.01	1.05–1.06	1.08	0.04	1.05–1.11
Molar	0	–	–	–	–	–	–
All	43	1.06	0.02	1.01–1.12	1.07	0.04	1.01–1.26
Panoramic							
Maxilla							
Anterior	29	1.18	0.20	0.91–1.93	1.26	0.09	1.17–1.67
Premolar	17	1.22	0.12	1.05–1.49	1.25	0.02	1.20–1.29
Molar	7	1.29	0.19	1.16–1.69	1.27	0.01	1.26–1.29
Mandible							
Anterior	1	1.22	–	1.22–1.22	1.27	–	1.27–1.27
Premolar	9	1.28	0.09	1.17–1.46	1.27	0.03	1.23–1.31
Molar	7	1.22	0.09	1.12–1.38	1.26	0.02	1.23–1.30
All	70	1.22	0.16	0.91–1.93	1.26	0.06	1.17–1.67

tively determined proper dimensions for the future implant site by placing four reference marks corresponding to the platform level as well as the mesial, distal, and apical demarcation of the implant-to-be (Fig. 1a, b). Subsequently, the software calculated the diameter of the metal ball in the horizontal and vertical planes, and the unadjusted length and width of the outlined implant. Since the spatial resolution in the images was known, the above values could be obtained in millimeters.

Data were exported to a statistical program (SPSS version 13.0; SPSS Inc., Chicago, IL, USA) that calculated the magnification factor (CMF). Implant size was adjusted both according to the "standard" calibration method (SCM) using an image magnification factor of 1.25 in panoramic images and 1.05 in periapical images, and according to the reference ball calibration method (RCM), where the implant size was adjusted for the true magnification factor in the region of interest. Based on the unadjusted as well as the adjusted implant dimensions, the software selected the corresponding implant size among the implants available in a given implant system. Unadjusted and adjusted implant dimensions (selected from each implant system) were then compared to estimate the change (in % of cases) in implant size (length, width, or both) after a given adjustment method (SCM and RCM). Since adjusting for size distortion is considered an indispensable step in treatment planning when using panoramic radiographs, comparisons only between SCM and RCM were made for this type of images. Separate analyses were made for each of the following three implant systems: Brånemark System® MkIII, Straumann® Standard implants, and 3i Hybrid Osseotite®.

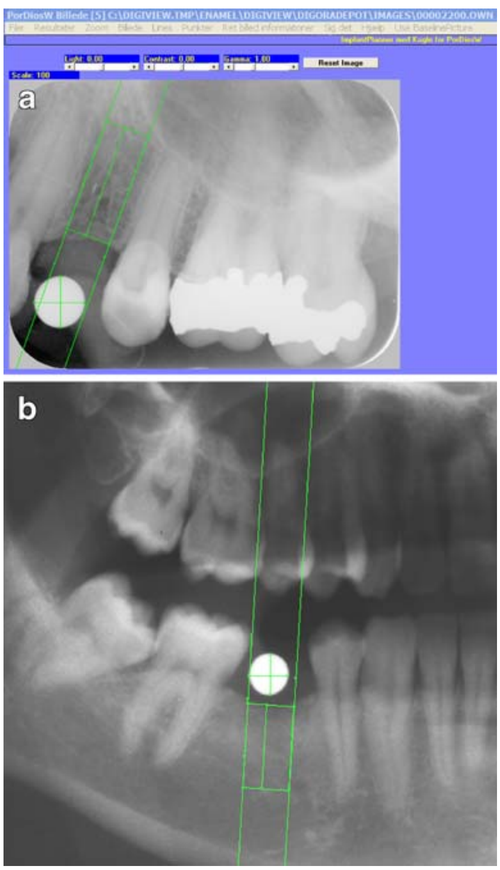

Fig. 1 **a** Eight reference marks corresponding to the topmost, bottommost, leftmost, and rightmost margins of the reference metal ball, and the platform level as well as the mesial, distal, and apical demarcation of the implant-to-be set in a periapical radiograph (digitized with a resolution of 300 dpi). In this case, selection of the "appropriate" implant size was mainly dictated by the neighboring vital anatomical structures. **b** An example of implant planning in a panoramic radiograph (digitized with a resolution of 300 dpi), where selection of the "appropriate" implant size was mainly dictated by the size of the missing tooth rather than the neighboring anatomical structures

The Brånemark implants (NobelBiocare, Göteborg, Sweden) were available in 25 sizes within four widths (3.3; 3.75; 4.0; 5.0 mm) and seven lengths (7.0; 8.5; 10.0; 11.5; 13.0; 15.0; 18.0 mm). The Straumann implants (Straumann AG, Basel, Switzerland) were available in 16 sizes within three widths (3.3; 4.1; 4.8 mm) and six lengths (6.0; 8.0; 10.0; 12.0; 14.0; 16.0 mm). The 3i implants (BIOMET 3i, Palm Beach, Fl, USA) were available in 34 sizes within five widths (3.25; 3.75; 4.0; 5.0; 6.0 mm) and eight lengths (7.0; 8.5; 10.0; 11.5; 13.0; 15.0; 18.0; 20.0 mm).

Results

The average calculated magnification factor (CMF) in the panoramic radiographs was in the horizontal plane 1.22 (range 0.91 to 1.93) and in the vertical plane 1.26 (range 1.17 to 1.67) The CMF in the periapical radiographs was in the horizontal plane 1.06 (range 1.01 to 1.12) and in the vertical plane 1.07 (range 1.01 to 1.26). Table 1 shows mean value, standard deviation, and range for CMF distributed by region.

Table 2 shows the change (in % of cases) in implant size (irrespective of change in length, width, or both) after comparing the values obtained with the standard calibration method (SCM) to those obtained with the reference ball calibration method (RCM) and/or with those of the unadjusted implant dimensions, averaged for the three observers. For the periapical radiographs, a different implant size was selected in at least 40% of the cases when comparing the values obtained with SCM to the unadjusted ones and in at least 56% of the cases when comparing the values from RCM with the unadjusted ones. When comparing SCM with RCM, there was a change in implant size in 24% of the cases, on average. The Straumann system differed from the two other systems since only half

Table 2 Changes in implant size (in % of cases) between standard calibration method (SCM), reference ball calibration method (RCM), and unadjusted images (average values of all observers)

	Brånemark (%)	Straumann (%)	3i (%)	Mean (%)
Periapical				
SCM vs. unadjusted	40	47	40	42
RCM vs. unadjusted	61	56	58	58
SCM vs. RCM	30	14	28	24
Panoramic				
SCM vs. RCM	46	47	51	48

as many implants changed between SCM and RCM when using this system. For the panoramic radiographs, when comparing the values obtained with SCM with those from RCM, a different implant size was selected in at least 46% of the cases, on average.

Table 3 shows the results of the comparisons with regard to the specific change obtained (longer, shorter, wider, and narrower). Generally in periapical radiographs, the RCM mainly indicated the need for shorter (18%) and/or narrower (9%) implants compared with the SCM, whereas in only few cases longer or wider implants were selected. Looking at the various systems, comparison of SCM and RCM values showed that implant length was adjusted three times more often when using Brånemark or 3i implants compared to Straumann implants. In panoramic radiographs, the RCM method indicated, on average, more changes in width (46%) than in length (19%). A comparison between the implant systems revealed that adjustment in width was more frequent for 3i implants while adjustment in length was more frequent for Straumann implants.

Implant size changes between SCM and RCM in panoramic radiographs (Table 2) were more pronounced

Table 3 Changes in implant length and width (in % of cases)

	Longer (%)	Shorter (%)	Wider (%)	Narrower (%)
Brånemark				
Periapical				
SCM vs. unadjusted	0	35	0	28
RCM vs. unadjusted	0	54	0	40
RCM vs. SCM	5	23	0	12
Panoramic				
RCM vs. SCM	10	6	30	14
Straumann				
Periapical				
SCM vs. unadjusted	0	40	0	21
RCM vs. unadjusted	0	49	0	23
RCM vs. SCM	0	9	2	5
Panoramic				
RCM vs. SCM	13	9	29	14
3i				
Periapical				
SCM vs. unadjusted	0	35	0	26
RCM vs. unadjusted	0	51	0	35
RCM vs. SCM	5	21	0	9
Panoramic				
RCM vs. SCM	7	11	30	20
Average for 3 systems				
Periapical				
SCM vs. unadjusted	0	37	0	25
RCM vs. unadjusted	0	51	0	33
RCM vs. SCM	3	18	1	9
Panoramic				
RCM vs. SCM	10	9	30	16

in the maxillary anterior region (62%) than in the premolar (41%) and molar (38%) regions and more in the mandibular premolar region (41%) than in the molar region (24%).

Discussion

Replacement of missing teeth by implants is a standard procedure in oral rehabilitation. However, many factors should be considered to ensure a high success of implant treatment. A careful treatment planning includes radiographic examination of the implant recipient site and selection of an appropriate implant size. Theoretically, larger implants should be preferable in order to withstand loading forces on the prosthetic reconstruction, and previous studies have supported this viewpoint by indicating increased failure rates with short and/or narrow implants [6, 24]. Also, although fractures of dental implants are rare, it should be emphasized that the fracture risk of narrow diameter implants seems increased, probably due to lower mechanical endurance [5, 14]. On the other hand, recent publications involving new implant designs and surfaces have reported comparable survival rates for short and longer implants, and no relationship between implant diameter and survival rate [16]. Nevertheless, short or narrow implants may be disadvantageous in some clinical situations, and therefore longer and/or wider implants may be preferred. For example, implant placement in fresh extraction sockets may require wider and/or longer implants to ensure primary implant stability and to reduce the distance between implant and bone socket walls while in a recent study [3], a higher survival rate of longer implants compared with standard implants used for immediate loading was observed. Proper implant placement requires that the implant body is completely surrounded by bone of sufficient volume; however, the maximum possible implant dimensions in a given case are strictly determined by the various neighboring vital anatomical structures of the site, which must not be compromised during surgery. Then, in cases of inadequate bone volume, additional treatment (e.g., bone augmentation procedures) might be indicated or a treatment not involving implants might be necessary/preferable. Thus, defining the largest possible implant size for a given site seems to be an important step in treatment planning. In practice, one must realize that the selection of implant sizes is not unlimited. Implant companies offer implant systems with a varying number of implant sizes. A minimum implant width of 3 mm and a minimum length of 7 mm are common for most standard systems.

The results of the present study demonstrated that the use of a reference metal ball for calculation of the actual image magnification had a high impact on the selection of implant size for three implant systems. This was especially true when implant size selection was based on panoramic radiographs, where in approximately 50% of the cases in the present material, a change in implant length, width, or both was observed when the reference ball calibration method (RCM) instead of the standard calibration method (SCM) was used (Table 2). The RCM had more impact on implant width than on implant length, while more changes were seen in the maxillary anterior region and fewer in the mandibular molar region. This is an important finding when one considers that this is the most esthetically demanding region in the mouth, and precise treatment planning regarding implant position and dimensions is often required in order to achieve optimal results. As already mentioned, the two calibration methods were not compared with the unadjusted implant sizes since it was assumed that clinicians calibrate their measurements in panoramic radiographs at least by the standard magnification factor (1.25).

Even in periapical radiographs, where a relatively small magnification of 1.05 can be expected, the results suggested that some kind of calibration should be performed. In approximately 40–60% (Table 2) of the cases, implant size was adjusted either using SCM or RCM when compared with unadjusted values. More interestingly, implant size was adjusted in approximately 25% of the cases when using RCM instead of SCM. Additionally, RCM predicted the implants to be mostly shorter and/or narrower than did the SCM. This finding indicates that calibration by the use of a reference ball (i.e., RCM) may predict the need for additional treatment (augmentation procedures), but most importantly may reduce the risk of injuring vital anatomic structures and/or the associated complication rates. Precise implant size selection may also increase the chance of success in esthetically demanding cases. In fact, guidelines regarding the minimum implant-to-tooth and implant-to-implant distance, as well as regarding the distance of the implant platform to the CEJ (in an occlusal plane) [8, 18, 19] for optimizing the esthetic outcome have been provided for the various implant systems.

In this context, however, it should be pointed out that the present evaluation is a concordance study rather than an accuracy study, and therefore no conclusions can be drawn regarding the outcome of treatment after using the RCM compared with that after using the SCM. It is thus not possible to estimate from the current study whether choosing the implant size based on the RCM would be more appropriate (i.e., would yield a better treatment outcome) than if implant size selection was based on the SCM. Nevertheless, it seems reasonable to assume that the RCM—being based on the true magnification factor—allows for a more precise selection of the implant size compared with the SCM. This assumption is in agreement with previously published recommendations on imaging procedures for pre-operative assessment for implant treatment [13].

In the present analysis, a magnification factor of 1.05 in the periapical radiographs and 1.25 in the panoramic radiographs was chosen for SCM. As already mentioned, these values are previously reported in the literature [15, 20, 21] for the respective radiographic techniques and have been suggested for calibration purposes. The Scanora X-ray unit (jaw panorama—Program 001), however, works with a magnification factor of 1.30, according to the manufacturer. Nevertheless, the standard magnification of 1.25 was deliberately employed. The rationale for this was: (1) the transparent implant templates provided by most of the manufacturers and suggested for implant planning employ a magnification factor of 1.25 for all panoramic radiographs, (2) it was assumed that most referring dentists are often unaware of the average magnification factor of the specific panoramic equipment used and, thus, customarily use the above-mentioned templates or the average magnification of 1.25 without a template, and (3) the mean magnification factor for panoramic radiographs in the present study was 1.22 in the horizontal plane and 1.26 in the vertical plane, i.e., in fact, closer to a magnification of 1.25 rather than 1.30. In this context, it is obvious that the use of a magnification factor of 1.30, instead of 1.25 for image calibration, would have probably resulted in still more changes in implant size between the SCM and RCM.

In panoramic images the largest deviation from the standard magnification factor (1.25) was seen in the horizontal plane and was more pronounced in the maxillary anterior region with a mean magnification of only 1.18 times (Table 1). The dispersion was however large, particularly in panoramic images, which is in agreement with a recent textbook on dental radiography stating that the magnification in panoramic images varies between 1.10 and 1.30 times [11]. It is noteworthy that the present study showed an even greater variation with a mean magnification for all regions ranging from 0.9 to 1.9 (Table 1). Furthermore, it was found that the range was larger in the horizontal plane than in the vertical plane, which supports the findings of a study by Gomez-Roman et al. [9]. In periapical images, calculation of the true magnification factor revealed that the largest deviation from the standard factor was found in the vertical plane, but was on average close to the standard magnification factor of 1.05.

Three widespread implant systems were evaluated since it was reasonable to expect that changes in implant size between the different calibration methods would depend on the number of available implants for a given implant system. In general, only small differences were found between the three implant systems; however, the Straumann system seemed less affected by the calibration methods since the change in implant size was more infrequent with this system compared with the other two systems. Obviously, this finding was due to the fact that the Straumann system has fewer implant sizes to choose among.

In the present study, a reference metal ball was used for calibration of the magnification in the radiographs. Several other methods have been suggested in the literature for calibration purposes [2], e.g., the use of cylindrical metal markers or Gutta Percha markers. Gutta Percha markers, however, seem not convenient because they cannot be easily sterilized. On the other hand, autoclavable cylinder markers could, in addition to calibration purposes, be used as indicators for implant angulation. Although no information on implant angulation can be obtained with a metal ball, this method has the advantage that the radiographic image of a metal ball is not influenced by the geometrical conditions/parameters associated with an exposure (projection geometry) due to the symmetrical shape of the sphere. Nevertheless, the possible influence of the geometrical shape of a given marker on the accuracy of calibration and/or on the change of implant size remains unknown for the moment.

Finally, in the planning of implant treatment other radiographic examinations, such as conventional cross-sectional tomography or CT, have been recommended in addition to periapical and panoramic radiography [22]. However, different viewpoints exist on the need for more advanced radiographic techniques [4, 7, 17], and one must always take into consideration the cost–benefit and/or hazard risks of these methods. Furthermore, it must be realized that the choice of radiographic examination may be influenced by availability of equipment and resources.

Conclusion

The use of a reference metal ball for calibration of periapical and panoramic radiographs during treatment planning seems advantageous since it allows a more precise selection of the implant size.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Batenburg RH, Stellingsma K, Raghoebar GM, Vissink A (1997) Bone height measurements on panoramic radiographs: the effect of shape and position of edentulous mandibles. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 84:430–435
2. Borrow JW, Smith JP (1996) Stent marker materials for computerized tomograph-assisted implant planning. Int J Periodontics Restorative Dent 16:60–67

3. Degidi M, Piattelli A, Iezzi G, Carinci F (2007) Do longer implants improve clinical outcome in immediate loading? Int J Oral Maxillofac Surg 36:1172–1176
4. Diniz AF, Mendonca EF, Leles CR, Guilherme AS, Cavalcante MP, Silva MA (2008) Changes in the pre-surgical treatment planning using conventional spiral tomography. Clin Oral Implants Res 19:249–253
5. Eckert SE, Meraw SJ, Cal E, Ow RK (2000) Analysis of incidence and associated factors with fractured implants: a retrospective study. Int J Oral Maxillofac Implants 15:662–667
6. Ferrigno N, Laureti M, Fanali S, Grippaudo G (2002) A long-term follow-up study of non-submerged ITI implants in the treatment of totally edentulous jaws. Part I: Ten-year life table analysis of a prospective multicenter study with 1286 implants. Clin Oral Implants Res 13:260–273
7. Frei C, Buser D, Dula K (2004) Study on the necessity for cross-section imaging of the posterior mandible for treatment planning of standard cases in implant dentistry. Clin Oral Implants Res 15:490–497
8. Gastaldo JF, Cury PR, Sendyk WR (2004) Effect of the vertical and horizontal distances between adjacent implants and between a tooth and an implant on the incidence of interproximal papilla. J Periodontol 75:1242–1246
9. Gomez-Roman G, Lukas D, Beniashvili R, Schulte W (1999) Area-dependent enlargement ratios of panoramic tomography on orthograde patient positioning and its significance for implant dentistry. Int J Oral Maxillofac Implants 14:248–257
10. Gotfredsen E, Kragskov J, Wenzel A (1999) Development of a system for craniofacial analysis from monitor-displayed digital images. Dentomaxillofac Radiol 28:123–126
11. Horner K, Drage N, Brettle D (2008) Panoramic equipment and imaging. In: Horner K, Drage N, Brettle D (eds) 21st century imaging. Quintessence Publishing Co., London, pp 29–44
12. Jacobs R, van Steenberghe D (1998) Radiographic indications and contra-indications for implant placement. In: Jacobs R, van Steenberghe D (eds) Radiographic planning and assessment of endosseous oral implants. Springer, Berlin, pp 45–58
13. Jacobs R, van Steenberghe D (1998) Radiographic planning and assessment of endosseous oral implants. Springer, Berlin
14. Jung RE, Pjetursson BE, Glauser R, Zembic A, Zwahlen M, Lang NP (2008) A systematic review of the 5-year survival and complication rates of implant-supported single crowns. Clin Oral Implants Res 19:119–130
15. Larheim TA, Eggen S (1979) Determination of tooth length with a standardized paralleling technique and calibrated radiographic measuring film. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 48:374–378
16. Renouard F, Nisand D (2006) Impact of implant length and diameter on survival rates. Clin Oral Implants Res 17(Suppl 2):35–51
17. Schropp L, Wenzel A, Kostopoulos L (2001) Impact of conventional tomography on prediction of the appropriate implant size. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 92:458–463
18. Tarnow D, Elian N, Fletcher P, Froum S, Magner A, Cho SC et al (2003) Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. J Periodontol 74:1785–1788
19. Tarnow DP, Cho SC, Wallace SS (2000) The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 71:546–549
20. Tronje G, Welander U, McDavid WD, Morris CR (1981) Image distortion in rotational panoramic radiography. I. General considerations. Acta Radiol Diagn (Stockh) 22:295–299
21. Tronje G, Welander U, McDavid WD, Morris CR (1982) Image distortion in rotational panoramic radiography. VI. Distortion effects in sliding systems. Acta Radiol Diagn (Stockh) 23:153–160
22. Tyndall AA, Brooks SL (2000) Selection criteria for dental implant site imaging: a position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 89:630–637
23. White SC, Pharoah MJ (2004) Projection geometry. In: White SC, Pharoah MJ (eds) Oral radiology: principles and interpretation. Mosby, St. Louis, MO, pp 83–90
24. Winkler S, Morris HF, Ochi S (2000) Implant survival to 36 months as related to length and diameter. Ann Periodontol 5:22–31