Does Implant Connection Design Affect Interpretation of Radiographic Images?

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Abstract

Aims: Detection of marginal gaps at the implant-impression coping interface before impression-making is a common clinical task in prosthodontic treatment. Dental radiography is the most commonly used method for intraoral detection of gaps. The objective of this study was to assess the effect of implant connection design on the detection of experimentally-created marginal gaps at the implant-impression coping interface at various tube angulations.

Methods: The impression coping with a 0.5 mm space was screwed onto three implant systems (Branemark (B), Nobel Replace (NR) and Nobel Active (NA)). Overall, 54 digital X-rays were taken with vertical and horizontal inclines of -20°, -10°, 0°, 10° and 20°. Ten prosthodontists examined the radiographs without using magnification. Data were analyzed using Chi-square and Fisher's exact tests. A two-way random model and absolute agreement was used to evaluate the intra class correlation coefficient (ICC) (p-value<0.05).

Results: The mean specificity was 0.7 in system B, 0.9 in system NA and 0.5 in system NR. The mean sensitivity was 0.9 in B, 0.3 in NA and 0.7 in NR systems. Youden's statistic value was 0.6 for B, 0.1 for NA and 0.3 for NR.

Conclusions: Radiography is a reliable diagnostic test for system B but not for systems NA or NR. Positive or negative angulation direction had no effect on the resolution of radiographs in the three connection types. Moreover, vertical radiation angulation in the absence of a gap and horizontal angulation in the presence of a gap affects radiograph resolution and the clinicians' diagnosis.

Key Words: Radiographic Image Interpretation, Gap, Dental Implant-Abutment Connection.

Introduction

Implants only have minimal mobility attributed to bone elasticity, and assessment of the three-dimensional (3D) implant position is necessary for implant-supported prostheses [1]. Impression making is considered to be a distinct clinical procedure stage and prosthesis misfit and subsequent mechanical and biological complications may occur because of an inaccurate impression. Mechanical complications attributed to prosthesis misfit include screw loosening, screw fracture, implant fracture and occlusal inaccuracy. Increased plaque accumulation and subsequent soft and hard tissue reactions and degradations are among the biological complications resulting from marginal discrepancy that result from prosthesis misfit. Achieving an ideal passive fit is not clinically feasible; however, the misfit can be minimized to prevent possible complications. This is now considered a major goal in implant dentistry [2].

Absence of a gap at the impression coping-implant interface is the first point that should be considered when making an impression. Various techniques have been recommended for fit control including probing with dental explorers, visual examination and use of Periotest. Intraoral radiography is the most commonly used technique for gap verification at the implant-abutment interface. In some cases, the implant needs to be placed more subgingivally because of bone availability or esthetic considerations. In such cases, a greater portion of the impression coping is placed below the gingival margin, causing the supragingivally-exposed part of the coping to decrease [3]. Intraoral radiography is the most suitable technique for detection of gaps in such cases. Use of a paralleling device is also recommended to ensure the proper position and angulation of X-ray film and the radiographic tube; however, paralleling devices are not commonly used in daily practice [4].

The implant abutment interface generally divides into external and internal connections. Companies present different geometries to improve the stability and anti-rotational property. Hexagonal features are used as an anti-rotational support in external connections. In internal connections, anti-rotation could be result of hexagonal, octagonal, tri-channel and cross-fit features. It has been suggested that a tapered internal connection (Morse taper) will increase resistance against mechanical failure [5-7]. This connection enables an accurate fit in abutment-implant interface, however personal experience of prosthodontists have shown that evaluation of full seating of abutment since a lack of distinct margin in abutment-implant connection is often difficult [8]. Platform switching is an aspect in internal connection implants that was introduced in the late 1980s as a way for an abutment, with a small width compared with the implant interface, to move horizontally toward the center of the implant axis and so that it can reduce bacterial penetration, fine movements and occlusal force and decrease marginal bone resorption [9].

Cameron et al. [10] radiographically verified implant abutment seating and obtained a diagnostic radiograph by maintaining the tube head at less than 20° deviation from the long axis of the implant irrespective of the film angle. Papavassiliou et al found that the degree of X-ray tube angulation significantly affected the ability to detect gaps at the implant-abutment interface. Negative inclines decreased the gap sooner than positive inclines (towards the prosthetic abutment). In all tests, a gap was not detected at >20° angulations. Visual examination at 25° and 30° enables an average clinician to detect the distortion [4]. Ormaechea [11] suggested that the maximum tube angulation that can be used to detect an implant-abutment gap should not exceed 5°. Kano et al. [12] introduced a classification system for measurement

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of the implant-abutment gap including both the horizontal and vertical components.

A few studies are available on detection of gaps at the abutment-implant interface; however, to the best of our knowledge, no study has evaluated gaps at the impression coping-implant interface and different connection designs. The radiographic opacity of the impression coping and abutment are different. Thus, the results of studies on the abutment-implant interface cannot be generalized to the impression coping-implant interface. Given the importance of this issue that different connections how affect the radiographic interpretation of presence or absence of gap, the objective of this experimental study was to assess the effect of the implant connection design on the detection of experimentally-created marginal gaps at the implant-impression coping interface at various tube angulations.

Materials and Methods

Models were prepared, each containing a regular implant (RP) (Nobel Biocare USA, Inc., Westmont, Illinois), and one of the following three implant systems: Brånemark System® Mk III TiUnite® RP (B)(4-mm-wide, 13-mm-long) for external connection; Nobel Replace RP (NR)(4.3-mm-wide, 13-mm-long) for internal tri-channel connection; and Nobel Active RP (NA) for internal conical connection (4.3-mm-wide, 13-mm-long). The implants were mounted in acrylic resin (Acropars, Marlic Medical Industries Co., Eshtehard, Iran) ensuring that the implant long-axis was aligned with the vertical axis. Impression copings of each system were screwed onto the implants once with no spacer and then with a gap. A rigid thermoplastic sheet (0.5 mm thick) was placed between the implant and the impression coping to create the desired gap and the fixing screw was tightened. A plastic box was filled with putty C-silicone impression material (Coltene/Whaledent AG, Alstatten, Switzerland). First the X-ray film was embedded in the impression material on the floor of the plastic box (Kodak CS 2100,Carestream Health, Inc., Rochester, New York, USA) and then the implant-impression coping was placed on it. Care was taken to ensure the parallel placement of the implant relative to the film. An angle-measuring device was stabilized at the edges of the box. The X-ray tube was positioned above the box at an angle of 0°. A 20-cm long straight ruler was attached to the tube end and placed vertical to the implant and the X-ray film. The ruler enabled exact measurement of tube angulation relative to the implant (*Figure 1*). 54 Digital radiographs were obtained for vertical and horizontal inclines of -20°, -10°, 0°, 10° and 20° (9 position) of 3 systems with and without gap (*Figures 2 and 3*). Settings on the digital radiography unit were 60 kV, 0.2 s and 7 mA during exposure. Each of the images received a blinded identity code using the block randomization method. In the next step, the 54 images were arranged randomly and shown to 10 prosthodontists. Each examiner evaluated the images twice, using a10-day interval to ensure intra-examiner reliability.

Data were analyzed using IBM SPSS Statistics 21 (IBM Corporation 1989, 2012, USA). The intraclass correlation coefficient (ICC) was calculated using a two-way random model with an absolute agreement type. The Chi-square test

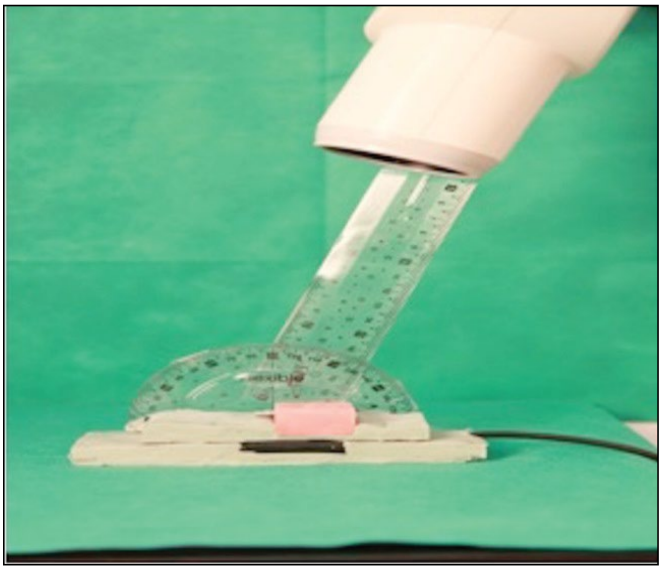

Figure 1(A). *Tube angulation in the vertical long axes.*

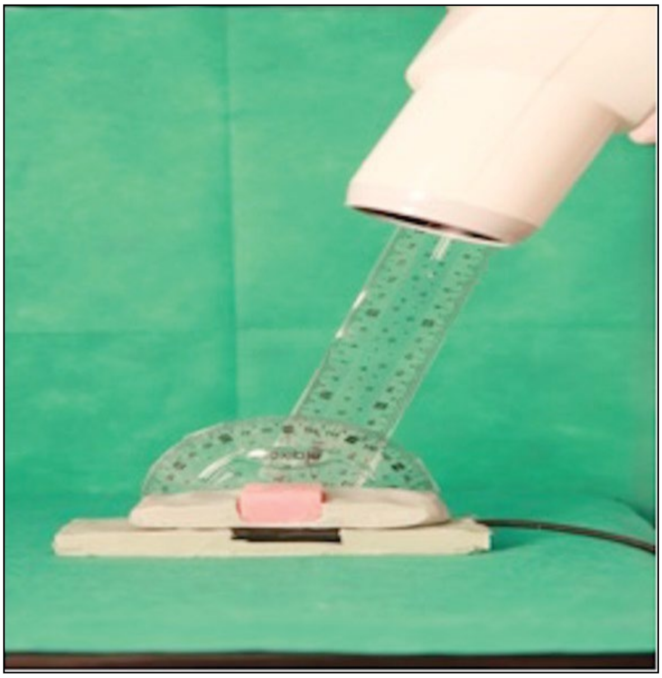

Figure 1(B). *Tube angulation in the horizontal long axes.*

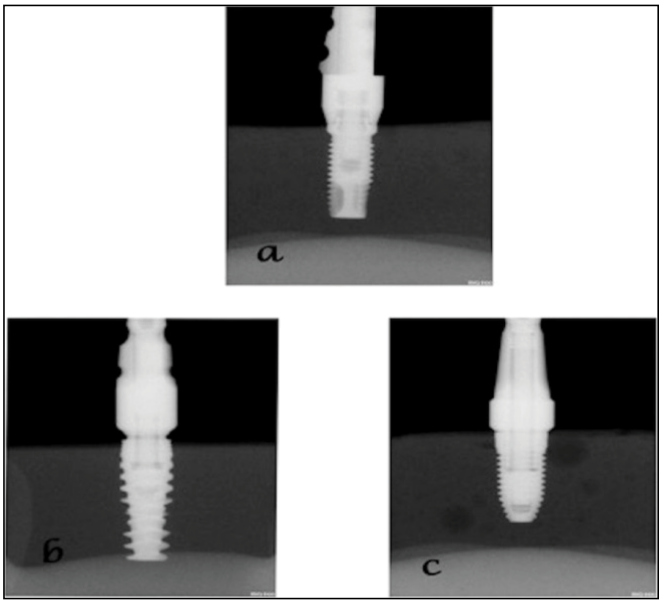

Figure 2. *Radiographic images in 0° tube angulation without gap: a) system B, b) system NA, c) system NR.*

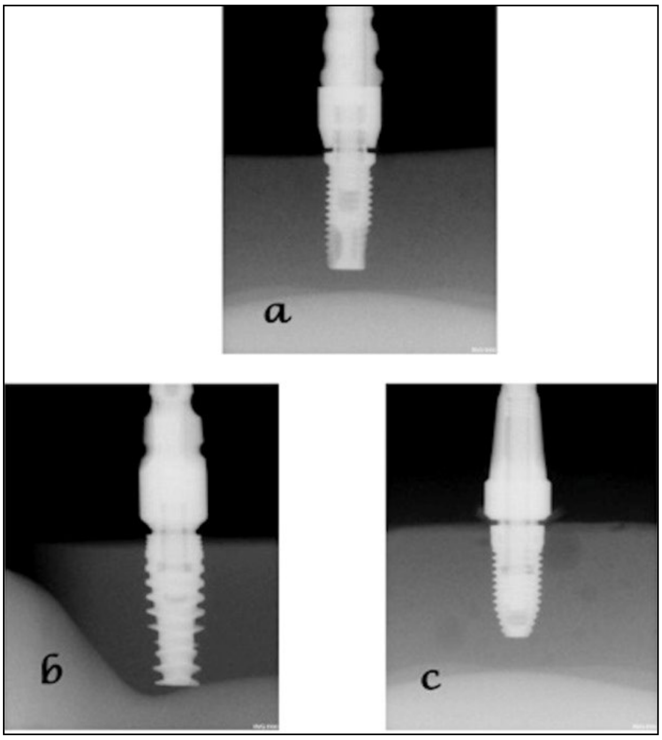

Figure 3. *Radiographic images in 0° tube angulation with gap 0.5 mm: a) system B, b) system NA, c) system NR.*

was used to evaluate the effect of each independent variable (system, angulation, direction, side) on the dependent variable (accuracy of diagnosis by clinicians). Fisher's exact test was used to assess whether significant differences existed among the three systems with regard to the frequency of correct diagnoses. P≤0.05 was considered statistically significant.

Results

In this study, radiographic sensitivity was defined as the capability to correctly detect a gap. Radiographic specificity was defined as the capability to correctly diagnose the absence of a gap. Youden's statistic was the sum of the sensitivity and specificity out of 1. The closer the value is to 1, the more accurate is the diagnostic test. ICC for all observations based on the presence or absence of gap generally and in every system, respectively is shown in *tables 1 and 2* also results are summarized in *table 3*.

At 0° angulation, the specificity value was significantly different in the B, NA and NR systems; however, NA was not significantly different from NR. At -10° vertical angulation, the three systems were not significantly different (P=0.321), and at +10° vertical angulation, the three systems were also not significantly different (P=0.089). At -20° horizontal angulation, B and NA and also NA and NR were significantly different (P=0.037 for both) but B and NR were not significantly different at this angle. At -20° vertical angulation, the three systems were not significantly different (P=1.000).

At 0° angulation, sensitivity of B was significantly different from that of NA and NR (P=0.006), but NA and NR were not significantly different at this angle. At -10° horizontal angulation, the sensitivity of B was significantly different from that of NA and NR (P=0.011), but NA and NR were not significantly different at this angle. At +10° horizontal angulation, the sensitivity of B was significantly

Table 1*. ICC for all observations based on the presence or absence of a gap.*

	ICC*	p-value
Total	0.39	<0.001
Gap	0.41	<0.001
No Gap	0.39	<0.001

**Intraclass correlation coefficient*

Table 2. *ICC based on the presence or absence of gap in the three systems.*

		ICC*	p-value
Gap	Branemark	0.35	<0.001
	Noble Active	0.04	0.147
	Noble Replace	0.1	0.01
No Gap	Branemark	0.12	0.003
	Noble Active	0.08	0.03
	Noble Replace	0.61	<0.001

** Intraclass correlation coefficient.*

different from that of NA and NR (P=0.006), but NA and NR were not significantly different. At -10° vertical angulation, the sensitivity of B was significantly different from that of NA and NR (P<0.001), but NA and NR were not significantly different. At +10° vertical angulation, the sensitivity of B was significantly different from that of NA and NR (P=0.002) but NA and NR were not significantly different. At -20° horizontal angulation, B and NA and also NA and NR had a significantly different sensitivity (P<0.001 for both), but B and NR were not significantly different. At +20° horizontal angulation, significant differences were noted between B and NR and also NA and NR (P=0.006), but B and NA were not significantly different. At -20° vertical angulation, the sensitivity of B was significantly different from that of NA and NR (P=0.037), but NA and NR were not significantly different at this angle. At +20° vertical angulation, all three systems (B, NA and NR) were not significantly different (P=0.080).

Based on the results in all three systems, the specificity values were higher at vertical angulations (accurately diagnosing the absence of a gap) while the sensitivity values were higher at horizontal angulations (accurately diagnosing the presence of a gap). Also, sensitivity and specificity values (accurately diagnosing the presence and absence of a gap) yielded similar results at different angulations and one was not superior to the others.

Youden's statistic and LR+ showed that the three systems were equal. The closer the Youden's statistic is to 1, the higher is the frequency of a correct diagnosis. Thus, in system B, the highest frequency of correct diagnosis (0.8) was achieved at 0° and +10° horizontal angulation followed by -10° and -20° vertical angulations (0.7). In the NA system, Youden's statistic and LR+ showed that the frequency of correctly diagnosing the presence or absence of a gap was low. In the NR system, the highest value of Youden's statistic (0.6) was obtained at +20, -20° and +10° vertical angulations.

Discussion

Use of dental implants, particularly the bone-level types, has greatly increased. However, in bone level implants, gingival tissue makes clinical detection of a gap between the implant and the impression coping difficult. Periapical radiography is a commonly-used method to assess of the precision of

Table 3. *Mean of Specificity and sensitivity in Branemark, Noble Active and Noble Replace systems and related p-value.*

Angle	Side	Branemark		Noble Active		Noble Replace		P-value of Specificity	P-value of Sensitivity
		Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity		
0	None	0.8	1	0.7	0.4	0.1	0.9	0.004	0.006
-10	Horizontal	0.5	1	0.9	0.4	0.1	0.8	0.002	0.011
10	Horizontal	0.8	1	0.7	0.4	0.3	0.9	0.111	0.006
-10	Vertical	0.8	0.9	1	0.1	0.7	0.8	0.321	0
10	Vertical	0.7	0.9	1	0.1	1	0.6	0.089	0.002
-20	Horizontal	0.6	1	0.8	0.2	0.2	1	0.037	0
20	Horizontal	0.4	0.9	0.8	0.4	0.1	1	0.008	0.006
-20	Vertical	0.9	0.8	1	0.2	1	0.6	1	0.037
20	Vertical	1	0.3	1	0.1	1	0.6	0	0.08

fit between the impression coping and the implant. The position of the film and implant in the oral environment and the intraoral anatomical conditions make it difficult to take radiographs using the parallel technique. Radiography can be used as a diagnostic test for different types of connections irrespective of the tube position only if it can provide high sensitivity (accurately diagnose the presence of a gap) and high specificity (accurately diagnose the absence of a gap). Radiographs are often taken in situations where the film, implant and tube are not parallel. This can result in superimposition and complicates the accuracy of the precision of fit assessment between implant components. Considering the lack of study on the gap between the implant and the impression coping, this study aimed to compare sensitivity and specificity of radiography in assessing the presence of a gap at the implant/impression coping in three different types of connections. Several studies have evaluated the vertical position of the tube relative to the implant assembly and they showed that obtaining radiographic images using a parallel device increased radiograph resolution [13-19]. Thus, since high-resolution radiographs are required to assess the precision of fit, studies have mainly emphasized the use of paralleling devices [13-19]. In the current study, the film and implant were parallel to one another but the angulation of the tube head relative to the assembly was variable.

Ormaechea et al. [11] stated that increasing the angulation to more than 5° significantly decreased the resolution of the images . In studies by Papavassiliou and Cameron, radiography at an angle of greater than 0° had diagnostic value and increasing the radiation angle to more 20° resulted in inaccurate gap diagnosis [4,10]. Papavassiliou et al. showed that no gap was detectable at angles over 20° [4]. Cameron et al. [10] stated that the film could be positioned at any angle up to 45° and yield acceptable results and the tube head at an angle less than 20° yields diagnostic images. Thus, we evaluated 0°, 10° and 20° angles. Considering the mean sensitivity values in our study, increasing the radiation angle irrespective of direction caused a reduction in sensitivity (accuracy of diagnosing the presence of a gap) in the B and NA systems. In the NR system, increasing the angulation from 0° to 10°reduces the sensitivity, but increasing the angle of radiation from 10° to 20° caused no significant change in sensitivity. The results were similar for 10° and 20° angles. Sharkey et al. [20] stated that the ratio of radiographic angle to gap size significantly affected clinicians' diagnostic ability. An implant component misfit as small as 12.7 µm was detectable in radiographs taken at 0° to 5° radiation angles. The situation for a misfit of 25µm to 38 µm at an angle of 10° was similar to that of a 51-µm misfit with an angle of 15°. They concluded that the angle of radiation relative to the implant must be controlled when using radiography to detect a misfit among the implant components. In our study, the results showed that increasing the radiation angle decreases the diagnostic power for gap detection. There was no similar study available in the literature, so comparison of these results was not possible.

The mean specificity was 0.7 in system B, 0.9 in system NA and 0.5 in system NR. The mean sensitivity was 0.9 in system B, 0.3 in system NA and 0.7 in system NR. Considering that the value of Youden's statistic was 0.6 for B, 0.1 for NA and 0.3 for NR, radiography is an acceptable diagnostic test for B but not for NA or NR. Definite interpretation of these results and their relation to the connection designs is not easy and to generalization, further studies are necessary. Despite the likeness of B and NR in but joint connection area, Youden's statistic in NA and NR were more similar and this is possibly because of steepen flare that there is in the meeting point of impression coping in NR system (like NA as an internal conical connection) and may cause mistake in radiographic interpretation of presence or absence of gap. This means that in spite of connection design, the configuration of impression coping in connection area could be an important factor in radiographic interpretation of presence or absence of gap.

Conclusions

Given the limitations of this study, the following conclusions were made:

- Radiography is a reliable diagnostic test for system B but not for NA or NR.
- Positive or negative angulation had no effect on the resolution of radiographs in the three connection types.
- Vertical angulation of radiation in the absence of a gap and horizontal angulation in the presence of a gap affects the radiograph resolution and the clinicians' diagnosis.
- To ensure precision of fit for the implant components, horizontal and vertical radiographs must be obtained while taking the impression.

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