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Original Article

Dentistry Section

Diagnostic Value of Digital Radiography in Gap Detection of Implant-Abutment Connection with Zirconia Abutments in Different Vertical X-ray Projection Angles

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ABSTRACT

Introduction: Accurate seating of abutments on implants is an important factor for long term success of implant supported restorations. Among different methods of evaluating abutment seating, radiography is most commonly used, while some clinical factors such as angulation of radiography film and radiography tube can adversely affect its diagnostic value.

Aim: To evaluate diagnostic value of digital periapical radiographs in terms of sensitivity, specificity and accuracy of gap detection at implant-abutment connection with different angles of X-ray projection when using a zirconia abutment.

Materials and Methods: In this in vitro study radiographs were made of three different implant connections (internal tri-channel, external hex and internal hex with platform switching) to which zirconia abutments were fastened, once with and once without using a spacer between implant and abutment. Radiographs were taken at different projection angles of -20, -15, -10, -5, 0, +5, +10, +15, and +20. Then 10 prosthodontists were asked to assess all the radiographs, two times for each one with an interval of 10 days. Sensitivity, specificity and accuracy indices were calculated for each system.

Results: Findings showed that sensitivity of gap detection in all study groups was amongst acceptable range (85-100%). In general external hex connection system showed better results (95-100%) while the platform switching internal hex system had the weakest results (85-100%).

Conclusion: Angle of X-ray projection is better to be between -10 to +10 when evaluating complete seat of zirconia abutments on implants especially if a platform switching system is used.

Keywords: Implant connection system, Internal and external connection, Platform switching

INTRODUCTION

It is ideal to eliminate any potential factor that jeopardizes osseointegration of implants or their surrounding bone. It has been shown that the implant-abutment connection is a critical zone where functional and parafunctional forces are transmitted from abutment to implant [1]. Presence of any gap at implant-abutment connection, which happens when abutments are not accurately assembled on implants or a mismatch between them prevents accurate seating of abutments on implants, leads to uneven distribution of forces at whole implant surface and non-axial loading of implant that eventually increases possibility of fracture of retaining screw, rotation of abutment, screw loosening and also decreases the preload [2,3].

Studies have shown that accumulation of inflammatory cells around implant-abutment connection is common which is thought to be caused by microleakage and accumulation of microorganisms and biologically active molecules [4-7]. Gingivitis and marginal bone loss can be induced by the succeeding inflammatory reaction [3].

Several attempts have been made to decrease this gap and its effects. Rimondini L et al., used a polymeric washer device to seal the implant-abutment connection [8]. Piattelli A et al., suggested placing the implant-abutment connection above crestal bone level [9]. One-piece implants and different designs of connections including various internal and external connections and interference-fit connections have also been investigated [4,10-12].

Ceramic abutments such as zirconia have been introduced to satisfy patient's demands for the most aesthetic and natural appearance of restorations especially for anterior teeth [13]. Zirconia abutments demonstrate good colour match and biocompatibility with desirable strength [14]. These abutments may be prefabricated or customized with Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) or Manually-Aided Design/Manually-Aided Manufacturing (MAD/MAM). Milling of zirconia blocks cannot produce abutments as precisely as metal ones are, hence more attention must be paid regarding fitting on the implant [15].

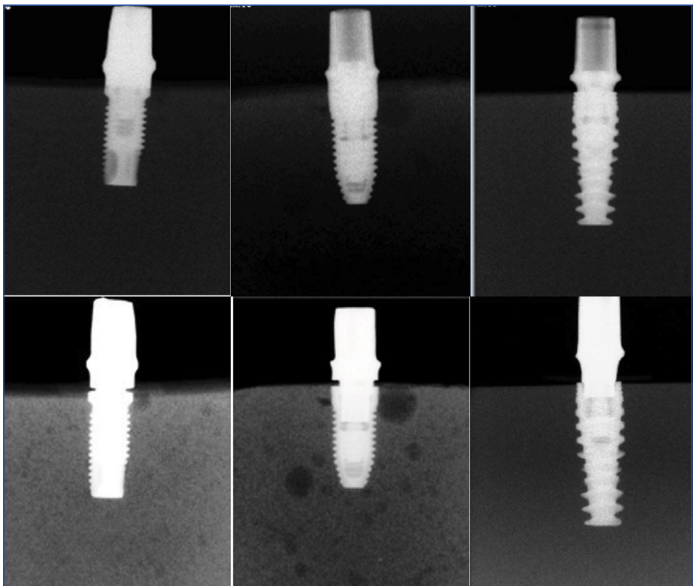
There are various clinical methods for verifying the abutment fit on implant including visual control, dental explorers, periotest device, and most common of all, intraoral radiographs [2,3]. Moreover, radiographs are used in longitudinal studies evaluating implants and their surrounding bone in long-term [16]. It is desirable for radiography film to be parallel to implant long axis so that the central beam of X-ray can be projected perpendicular to both of them to achieve the most accurate image of the implant leading to best diagnosis of any problem. However, many anatomical limitations such as large tori, shallow palates and severely resorbed ridges impose difficulties in appropriate placement of radiography films [17]. Despite these limitations, low dosage of radiation as well as availability and cost-effectiveness makes conventional technique as the first choice for clinicians. However, the degree to which a deviation from orthogonal projection may lead to misdiagnosis needs to be determined. Since, current literature seems to be inconsistent and insufficient knowledge is available about diagnostic value of digital radiography in gap detection of zirconia abutments, this study aimed to evaluate sensitivity, specificity and accuracy of digital periapical radiographs to detect gap at implant-abutment connection using different vertical angles of X-ray projection in three different implant connection types. The null hypothesis of this study was that different vertical angles of X-ray projection would not affect sensitivity, specificity and accuracy of digital periapical radiographs in gap detection.

MATERIALS AND METHODS

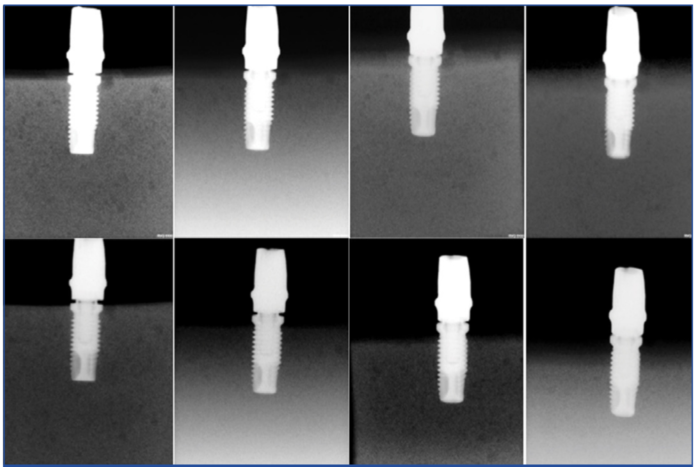
In this study three different systems of Nobel Biocare (Nobel Biocare AB, Goteborg, Sweden) were used: Branemark (Nobel Biocare AB, Goteborg, Sweden) with external hexagon connection, Replace (Nobel Biocare AB, Goteborg, Sweden) with internal tri-channel connection and Nobel Active (Nobel Biocare AB, Goteborg, Sweden) with platform switching internal hexagon connection. All implants were regular size: 10 mm height and 4 mm (Branemark and Replace) or 4.3 mm (Nobel Active) diameter. Each implant was vertically placed in an acrylic cube. Zirconia abutments for each system were fabricated using MAD/MAM with 10 milling burs (Zirkonzahn, GmbH, Sand in Taufers, Italy) and two guide burs copying an Easy Abutment (NobleBiocare, Goteborg, Sweden).

Milled abutments were soaked in A2 colour solution (ZirkonZahn GmbH, Sand in Taufers, Italy) for three seconds and dried using infrared drying lamp (Zirkonzahn, GmbH, Sand in Taufers, Italy) and then placed in sintering furnace (ZirkonZahn GmbH, Sand in Taufers, Italy) reaching 1500°C temperature in 3 hours and kept at this temperature for two hours. Abutments were first attached to implants with no gaps between them, the second time a standard 0.5mm thick rigid thermoplastic sheet (Kitronik, Nottingham, UK) was used as a spacer to create a uniform gap. Radiographs (Kodak CS, Carestream Health, NY, USA) were taken using radiovisiograph (Kodak RVG 6100 Carestram Health, NY, USA) with radiation parameters of 60 kvp, 0.2 second and 0.7 mA with the same x-ray apparatus, each parameter checked before exposure. For taking the radiographs, the acrylic cube was placed so that the implant-abutment assembly would be perpendicular to horizon. Then the RVG sensor was placed parallel to the implant-abutment assembly while the radiography apparatus was located on the opposite side with the desired angulations. Eighteen digital radiographs were obtained from each implant with vertical angulations of -20, -15, -10, -5, 0, +5, +10, +15, +20 but same horizontal angulation of zero [Table/Fig-1-4]. Each radiograph was coded so that blindness for investigators could be done.

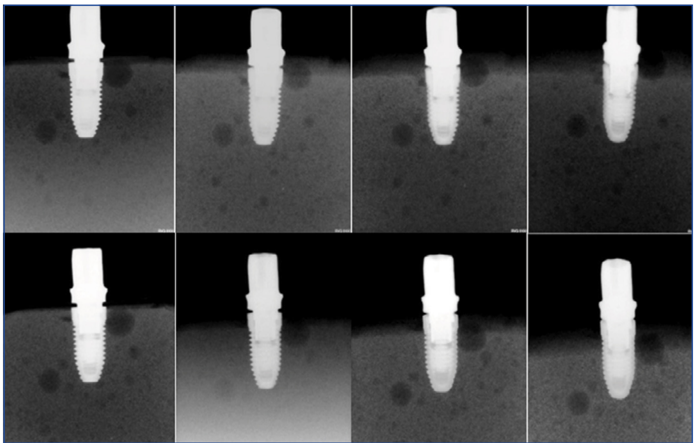
Ten prosthodontists who had at least 10 years of experience in the field of oral rehabilitation using implant-supported restorations, and who were blind to this study by only knowing the codes of radiographs were asked if they could recognise a gap. All radiographs were shown to each of them twice with an interval of 10 days.



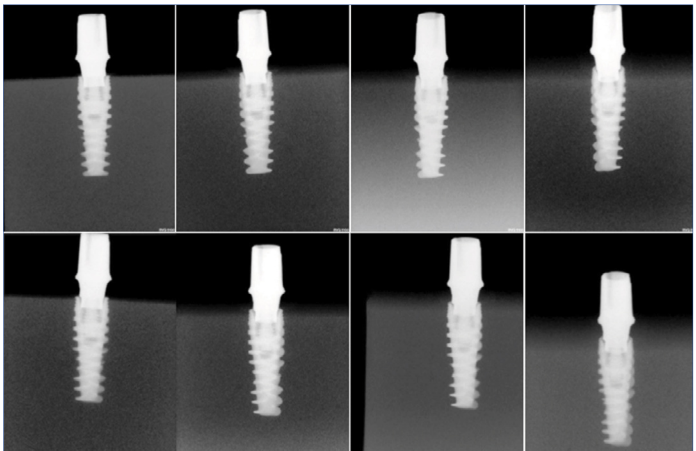
[Table/Fig-1]: Left to right: radiographs of external hexagon, internal tri-channel and platform switching implants without gap at implant-abutment interface (upper) and with a 0.5 mm gap at implant-abutment interface (lower) with perpendicular projection of x-ray.



[Table/Fig-2]: Left to right: radiographs with angulated x-ray projection of +5 to +20 (upper) and -5 to -20 (lower) to external hexagon implant with a 0.5 mm gap at implant-abutment interface.



[Table/Fig-3]: Left to right: radiographs with angulated x-ray projection of +5 to +20 (upper) and -5 to -20 (lower) to internal tri-channel implant with a 0.5 mm gap at implant-abutment interface.



[Table/Fig-4]: Left to right: radiographs with angulated x-ray projection of +5 to +20 (upper) and -5 to -20 (lower) to platform switching implant with a 0.5 mm gap at implant-abutment interface.

STATISTICAL ANALYSIS

Collected data were analysed using SPSS version 22.0. To assess inter-rater agreement between investigators, Intra-class Correlation Coefficient (ICC) -the absolute agreement type with a two-way random model was reported. To assess observers' response consistency for the two times of evaluation, Cohen's kappa coefficient was reported. The agreement level was considered almost perfect, moderate or poor for kappa coefficient ranges of more than 0.75, 0.4-0.75 and less than 0.4 respectively [18]. Three statistical indices of diagnostic sensitivity, specificity and accuracy were calculated for each implant system as explained in results.

RESULTS

The ICC was calculated 0.68 for the first time of evaluation (p<0.001) and 0.95 for the second time (p<0.001). Cohen's kappa coefficient for all observers were more than 0.75 interpreted as almost perfect agreement (p<0.001).

Three statistical indices were calculated in this study. Sensitivity shows radiography ability to correctly detect presence of gaps when they do exist. In other words it reports what percentage of radiographs with gap was correctly detected by investigators. Specificity shows radiography ability to confirm absence of gap when abutments are accurately seated in place with no gaps. That is, it reports the percentage of radiographs without gap which were correctly detected by investigators. Accuracy shows the ability to correctly detect presence or absence of gap in either situation. It is calculated by dividing the number of correctly detected radiographs (whether with or without gap) by the total number of radiographs which were investigated. The [Table/Fig-5] summarises percentage of correctly diagnosed presence/absence of gap in radiographs by investigators in three different connection systems once with and once without gap at implant-abutment connection. [Table/Fig-6] shows radiographs diagnostic sensitivity, specificity and accuracy indices of gap detection in three different connection designs with different radiation angulations.

Results, as shown in [Table/Fig-6], demonstrated diagnostic sensitivity of radiographs for all groups were in acceptable range (85-100%) while the most sensitivity was seen in internal tri-channel design (100% at any angle). External hexagon design showed best results in terms of sensitivity, specificity and accuracy (95-100%). Overall, the least sensitivity, specificity and accuracy were seen in platform switching design.

may also influence accurate diagnosis of implant-abutment gaps. Papavassiliou H et al., showed that there was significant difference between internal hex and external hex implants for gap detection via radiography and it would be more complicated to detect the gap, especially if the angulation was towards the implant rather than the abutment [2]. In another study, Tsuge T et al., evaluated five different implant systems, three internal and two external connections in terms of vertical and horizontal discrepancies and microgaps [19]. Their study showed that implant-abutment microgaps occur in both internal and external connection geometries and using scanning laser microscope and scanning electron microscope showed no relationship between magnitude of microgaps and connection configurations. Other studies showed that gaps occur in both internal and external connections but the diagnostic value of radiographs to detect this gap may vary in different types of connection [1,3,6,16]. An alteration in implant-abutment connection that is supposed to help decrease marginal bone loss around implants in long term is platform switching [20]. This concept suggests inwardly repositioning of the outer edge of abutment at implant-abutment interface. This potentially imposes more difficulty in radiographic interpretations due to more complexity of implant-abutment interface configuration.

This study evaluated diagnostic value of radiographs at different angles of X-ray projection in three different implant connections of internal tri-channel, external hexagon and platform switching internal hexagon. Results revealed internal tri-channel design showed best results especially if there existed a gap, all observers could recognize it in all tube angulations. It is also shown that the most inaccurate results belonged to platform switching design. Papavassiliou H et al., reported that implant-abutment connection

System		Angulation								
		-20	-15	-10	-5	0	+5	+10	+15	+20
Platform switching	No spacer used to create gap	100	55	60	55	90	50	70	50	65
	Spacer used to create gap	100	100	90	100	40	90	100	85	95
External hexagon	No spacer used to create gap	90	95	95	100	90	90	90	90	100
	Spacer used to create gap	100	100	100	100	100	100	95	100	95
Internal tri-channel	No spacer used to create gap	90	95	95	100	85	80	90	75	95
	Spacer used to create gap	100	100	100	100	100	100	100	100	100

[Table/Fig-5]: Percentage of correctly detected radiographs in terms of presence/absence of gap in study groups.

System		Angulation								
		-20	-15	-10	-5	0	+5	+10	+15	+20
Platform switching	Sensitivity	1	1	0.9	1	0.9	0.9	1	0.85	0.95
	Specificity	1	0.55	0.6	0.55	0.6	0.5	0.7	0.5	0.65
	Accuracy	1	0.55	0.5	0.55	0.5	0.4	0.7	0.35	0.6
External hexagon	Sensitivity	1	1	1	1	1	1	0.95	1	0.95
	Specificity	0.9	0.95	0.95	1	0.9	0.9	0.9	0.9	1
	Accuracy	0.9	0.95	0.95	1	0.9	0.9	0.85	0.9	0.95
Internal tri-channel	Sensitivity	1	1	1	1	1	1	1	1	1
	Specificity	0.9	0.95	0.95	1	0.85	0.8	0.9	0.75	0.95
	Accuracy	0.9	0.95	0.95	1	0.85	0.8	0.9	0.75	0.95

[Table/Fig-6]: Sensitivity, specificity and accuracy of gap detection in study groups.

DISCUSSION

Radiography is the most valuable and most frequently used diagnostic tool in dentistry. Different variables such as angle of central beam to implant and film, properties of radiation and dentist's experience can influence interpretation of a radiograph. Radiographic evaluation of abutment seating on implant has been investigated in several studies [1,2,16]. Different connection types of implant like internal hex, external hex and platform switching gap diagnosis may be significantly affected by angulation of X-ray and angulations higher than 20° lead to inability of gap detection while image distortion due to non-parallel projection of X-ray in angulations lower than 25° could not be visually understood [2]. In another study Cameron SM et al., evaluated radiography value in verifying complete seating of abutment in two situations of different angulation of X-ray tube from 0° to 45° with the film parallel to implant, and different angulation of film from 0° to 45° while the central X-ray remained perpendicular to implant long axis [16]. Their study showed that implant-abutment gap could not be detected if tube angulation was more than 20°; however, changing film angle did not affect diagnostic value of radiographs. Results of this study are consistent with these findings. Sensitivity of gap detection in all groups was acceptable with confidence interval of 95% within -20 to +20 degree of central X-ray inclination. In a review study by Liedke G et al., it was shown that up to 15° of angled projection would allow a proper detection of gap [21]. That is why the range of angulation in this study was slightly larger, between -20 to +20.

Zirconia is shown to have high radiopacity similar to Cr-Ni alloy and gold, while titanium has moderate radiopacity [22]. One limitation to this study was that in this study zirconia abutments and titanium implants were used therefore high contrast between implant-abutment connection with surrounding absolute radiolucent environment may cause a visual delusion leading to false diagnosis of gap. This phenomenon is called mach-band effect and might explain the reason why 0° degree of radiation did not lead to 100% accuracy [23,24]. If the results of this study can be generalised for abutments made from different materials seems to be a matter of degree of radiopacity of them and needs further investigations to confirm.

LIMITATION

One limitation of this study, as mentioned above, was that it only focused on zirconia abutments. Moreover, it was conducted under an in vitro design in which both hard and soft tissue that naturally surround the implant body and might superimpose their shadows on radiographs were eliminated.

CONCLUSION

Within the limitation of this study, it was shown that radiography is a sensitive tool and to a lesser degree a specific tool for detection of gap in implant-abutment interface. The accuracy of radiography for gap detection was within acceptable range, however, it was suggested that more attention be paid to parallel positioning of film to implant long axis and perpendicular projection of X-ray when evaluating abutment seat on implant via radiography especially if a switching platform system is used. Future investigations with in-vivo study designs and various abutment materials would be desirable.

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