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Accuracy of digital bitewing radiographs with and without applying horizontal tube shift in the diagnosis of residual excess cement around dental implants: An *in vitro* study.

Precisión de las radiografías digitales bitewing con y sin aplicación de desplazamiento horizontal del tubo en el diagnóstico del exceso de cemento residual alrededor de los implantes dentales: Un estudio *in vitro*.

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Abstract: Purpose: This study was designed to evaluate the diagnostic value of digital Bitewing (BW) radiographs with and without horizontal tube shift in detecting Residual excess cement (REC) on the proximal and non-proximal surfaces of implant restorations. **Material and Methods:** Eight mandibular models were fabricated with two implants placed on each side in the premolar and first molar positions. Excess cement was applied to either proximal or non-proximal surfaces of the restorations intentionally during the process of crown cementation. BW radiographs with and without applying horizontal tube shift were acquired. Three maxillofacial radiologists were asked to determine the presence and location of REC in the radiographs. Sensitivity and specificity of the radiographic technique were assessed according to the restoration surface that contained REC. **Results:** Sensitivity of BW radiographs was 100% for the detection of REC on the proximal surfaces and 41-18, 80% on the non-proximal surfaces. Specificity of the technique was 85.71%-100% for the proximal surfaces and 75-94. 12% for the non-proximal areas. Specificity of the radiographic method was generally greater than its sensitivity for the non-proximal surfaces while in the proximal areas, the two variables had quite similar values. **Conclusion:** Digital BW radiography is generally more useful for detection of REC on the proximal surfaces. Higher specificity of this technique for the bucco-lingual surfaces suggests more reliability of the negative diagnoses in the non-proximal areas.

Keywords: Radiography, Dental, Digital; Radiography, Bitewing; Dental cements; Dental Implants; Crowns; Radiologists.

Resumen: Objetivo: Evaluar el valor diagnóstico de las radiografías digitales bitewing (BW), con y sin desplazamiento horizontal del tubo, para detectar el exceso de cemento residual (ECR) en las superficies proximales y no proximales de las restauraciones con implantes. **Material y Métodos:** Se fabricaron ocho modelos mandibulares con dos implantes colocados a cada lado en las posiciones premolar y primer molar. El exceso de cemento se aplicó intencionalmente en las superficies proximales o no proximales de las restauraciones durante el proceso de cementación de la corona. Se adquirieron radiografías BW con y

sin aplicación de desplazamiento horizontal del tubo. Se pidió a tres radiólogos maxilofaciales que determinaran la presencia y ubicación de ECR en las radiografías. La sensibilidad y la especificidad de la técnica radiográfica se evaluaron según la superficie de restauración que contenía ECR. **Resultados:** La sensibilidad de las radiografías de BW fue del 100% para la detección de ECR en las superficies proximales y del 41,18-80% en las superficies no proximales. La especificidad de la técnica fue 85-71, 100% para las superficies proximales y 75-94, 12% para las áreas no proximales. La especificidad del método radiográfico fue generalmente mayor que su sensibilidad para las superficies no proximales, mientras que en las áreas proximales, las dos variables tuvieron valores bastante similares. **Conclusión:** La radiografía digital BW es generalmente más útil para la detección de ECR en las superficies proximales. La mayor especificidad de esta técnica para las superficies buco-linguales sugiere una mayor confiabilidad de los diagnósticos negativos en las áreas no proximales.

Palabra Clave: *Radiografía Dental Digital; Radiografía de Mordida Lateral; Cementos Dentales; Implantes Dentales; Coronas; Radiólogos.*

INTRODUCTION.

Use of endosseous implants is a routine and accepted treatment for the replacement of missing teeth as a part of oral rehabilitation for partially or totally edentulous patients.[1] Implant supported restorations are categorized as screw or cement retained. Screw retained restorations have several disadvantages including screw loosening and esthetic problems which have ultimately resulted in the increased use of cement-retained restorations.[2]

Cement retained restorations are superior in several aspects including flexibility of implant positioning which results in better esthetics, more easily obtained passivity, better control over the occlusion, more accessibility, less cost and easier fabrication technique. Nevertheless, cement-retained restorations are not completely flawless. One of the main shortcomings of these restorations is their unpredictable retrievability.[3-6] Furthermore, it has been reported that the health condition of the periimplant soft tissues tends to be poorer with the use of cement-retained restorations.[7,8]

Clinical reports have shown the adverse effects of residual excess cement (REC) extruded into the periimplant soft tissues.[9,10] REC is a common complication of cement retained restorations resulting in local inflammation which has been documented as a certain cause of periimplant disease.[11-13] When cement accidentally enters the periimplant tissues or is left as an overhang, it should be promptly detected and removed.[10] Prevention of cement extrusion beyond the restoration margins during the cementation process should not be overlooked; however, this may be more difficult than it appears. Different methods have been used to diagnose REC in order to avoid peri-implantitis including the use of dental endoscope[14] and more invasively, open flap debridement[9,10] which allows direct inspection of the area. Another diagnostic tool is the use of radiographs that are potentially able to reveal the presence and location of REC on the restorations.[15-17]

In this *in-vitro* study, the diagnostic accuracy of digital Bitewing (BW) radiographs with and without applying horizontal shift in the x ray tube was evaluated to diagnose REC on both the proximal and non-proximal areas of the restorations. In this type of radiography, we are able to evaluate the cervical areas of the posterior teeth perfectly as the object and the image receptor are close together. If proved to be useful, this radiographic technique could be introduced as a new and feasible complementary approach for the detection of REC.

MATERIALS AND METHODS.

This *in-vitro* study was approved by the Research Ethics Committee of Guilan University of Medical Sciences (Approval ID: IR.GUMS.REC.1395.18).

Dry human mandibles were used for fabricating eight mandibular plaster models based on the method previously described by Kajan *et al.*,[18] Prior to the complete setting of the casts, two submerged GT2 implants (UFit, Gyeonggi, Korea) were inserted in the first molar and first premolar locations on each side. The risk of cement extrusion beyond the restoration margins varies with the position of the restoration margins. We used submerged implants to more readily induce the accumulation of REC.

Tooth-implant arrangement was in such a way that each implant was in contact with a tooth on its proximal surfaces. The teeth were coated with melted wax prior to be placed within the models to simulate the periodontal ligament space. Subsequently, direct abutments with 2mm gingival height were selected so that the abutment part of the implant would stand 2 mm outside the crestal portion of the models and the analog platform would be placed at the same level as the gypsum cast.

During cementation of the restorations with zinc polycarboxylate (Durelon, 3M, ESPE, US), excess cement was intentionally applied on the proximal or non-proximal surfaces as small as the tip of a ball-point cement applicator (Kerr, CA, USA). The amount of the applied cement as well as its vertical position relative to the abutment was standardized and similar for all the test models.

The crowns that were used in the present study were PFM type. Preparation of the test samples was eventually in a way that 32 out of 64 available proximal surfaces contained REC.

Likewise, excess cement was applied on half of the available buccal or lingual surfaces (n=32). Gingival mask made of additional silicone (Bonasil A+, DMP, Greece) was injected on the cervical portions of the teeth, 2mm above the finishing line and 4mm higher than the platform of the abutments to simulate the gingival tissue. The casts were numbered and the presence/location of REC on the implant restorations of each cast were recorded. (Figure 1A)

Maxillary casts were also prepared to establish the occlusion with the mandibular models. The casts were halved in two parts from the midline with the use of a plaster cut device (Renfert, Germany). Subsequently, each half was fixed on the right or left side of the mandibular casts by condensation type polysiloxane impression material (Speedex, Coltene, Germany). (Figure 1B)

Digital BW radiographs were acquired from the models with the use of PSP sensors (Digora Optime, Soredex, Tuusula, Finland) and with the same exposure parameters (70 kV, 7 mA, 0.32 s) set on the intraoral radiographic tube (Minray, Sordex, Tuusula, Finland). A BW holder device (Hawe Super-Bite, Kerr Hawe SA, Switzerland) was used. Digital BW radiographs were taken by adjustment of the horizontal tube angle in 0°, 10° mesial and 10° distal positions for each side of the models. Mesial and distal shifts were defined by attaching two toothpicks on the holder device with the corresponding angles and subsequent adjustment of the horizontal projection angle with the direction of the tooth picks. We did not place the premolars in the curved region of the dental arch. Instead, they were positioned with the same angulation as the molars. In this way, the molar and premolar proximal contacts could be opened with the same BW projection.

The radiographic series (with and without shift) were evaluated by three maxillofacial radiologists independently. The triple set of radiographs including the right angle and the shifted ones were assessed together, as one assessment for each test sample. (Figure 2A at Figure 2C and Figure 3A at Figure 3C)

The observers were totally unaware of the presence and location of REC in the samples. Also, they were initially calibrated with regard to the diagnosis of the radiographic appearance of REC.

All images were viewed by the Scanora software (version 4.31, Soredex, Tuusula, Finland) on the same display monitor (S22D300, Samsung, Korea) in a fixed viewing room condition. The observers were allowed to use any viewing enhancement tool of the software as personally desired for better REC detection on the images. Data were transferred to the SPSS software (version 22, IBM Corporation, Armonk, NY, USA). Kappa coefficient was used for determination of the intra and inter-observer agreements. The diagnostic accuracy of the radiographic technique was expressed in terms of sensitivity and specificity.

RESULTS.

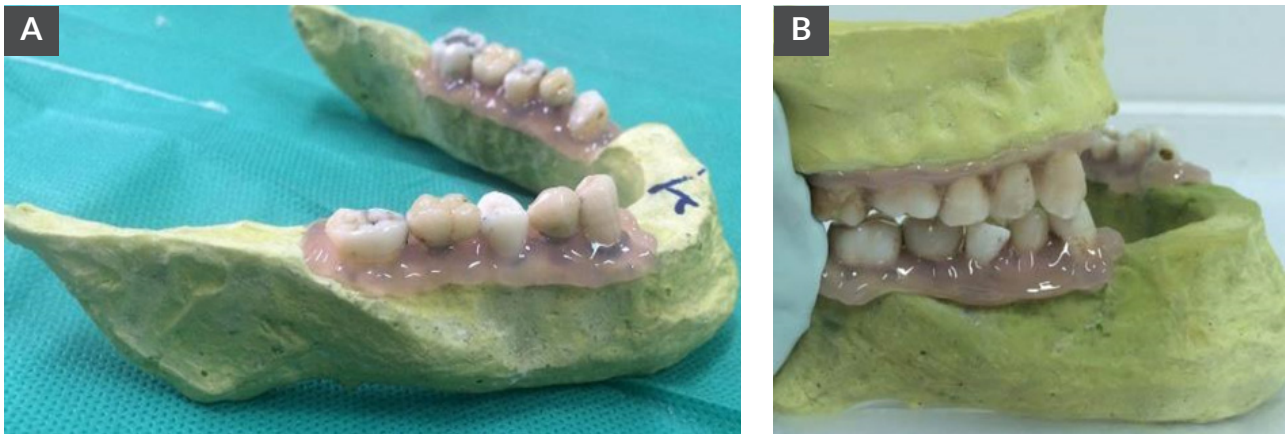
The inter-observer agreements in the present study were generally good, calculated to be at least 0.7.

Table 1 shows the kappa coefficient values regarding the agreements. The intra-observer agreements were variable from 0.93 to 0.95 for the three observers.

According to Table 1, the highest amount of agreement was seen between the observers number 1 and number 2. The agreement levels among all the observers were significant (p<0.001). The values were good and with a statistically significant difference for the detection of the excess cement on the mesial and distal surfaces. On the buccal surfaces, pairwise agreement of the observers was fair (0.45- 0.52). Meanwhile, on the lingual surfaces this agreement varied from poor to good (Table 2).

As presented in Table 3, the diagnostic accuracy of the digital BW radiography which was described in terms of sensitivity and specificity, was excellent for REC detection on the proximal areas. The diagnoses for the mesial surfaces were absolutely sensitive and specific by all the observers. Distal surface diagnoses were also completely sensitive; however, their specificity was slightly less than the mesial surfaces. On the non-proximal areas, both sensitivity and specificity of the radiographic technique was obviously less than the proximal surfaces. However, specificity of the diagnoses for these areas was generally greater than their sensitivity, implying that the negative diagnoses are more reliable (Table 4).

Figure 1. Mandibular and Maxillary models.

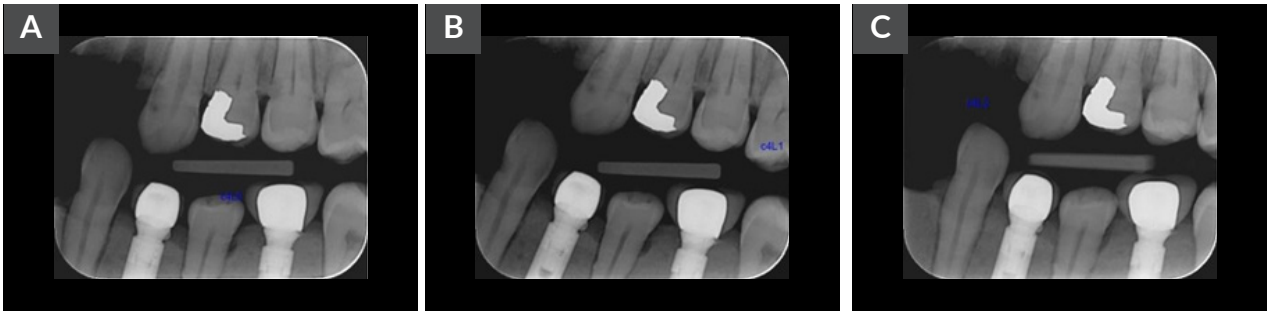


A. A mandibular model containing teeth and abutments cervically covered by gingival mask. **B.** Maxillary and mandibular models held in occlusion to be imaged with the BW radiographs.

Figure 2. Radiographic series with and without shift.

A. Digital BW without horizontal tube shift. **B.** Digital BW with mesial tube shift. **C.** Digital BW with distal tube shift revealing REC on the proximal surfaces of the implant restorations.

Figure 3. Radiographic series with and without shift



A. Digital BW without horizontal tube shift. **B.** Digital BW with mesial tube shift. **C.** Digital BW with distal tube shift of a case in which REC on the mesial side of the buccal surface of the first premolar implant restoration was not detected.

Table 1. Pairwise agreement of the observers regarding REC detection.

Observers	Kappa coefficient value	*p*-value
1 and 2	0.81	< 0.001
1 and 3	0.70	< 0.001
2 and 3	0.73	< 0.001

Table 2. Agreement between the observers in detecting residual cements based on the restoration surfaces.

	Kappa Coefficient				
Groups	Mesial	Distal	Buccal	Lingual	Non-proximal
Observer 1 and 2	1	0.94	0.5	0.72	0.50
p-value	< 0.001	< 0.001	0.004	0.001	0.003
Observer 1 and 3	1	0.93	0.45	0.37	0.50
p-value	< 0.001	< 0.001	0.01	0.022	0.002
Observer 2 and 3	1	0.87	0.52	0.5	0.594
p-value	< 0.001	< 0.001	0.03	0.003	0.001

Table 3. Diagnostic accuracy of digital BW radiography for REC detection on the proximal surfaces

		Mesial		Distal	
Observers	Diagnostic value	*p*-values	95% CI	*p*-values	95% CI
1	Sensitivity	100	73.24 - 100	100	78.12 - 100
	Specificity	100	78.12 - 100	92.86	64.17 - 99.63
2	Sensitivity	100	73.24 - 100	100	78.12 - 100
	Specificity	100	78.12 - 100	100	73.24 - 100
3	Sensitivity	100	73.24 - 100	100	78.12 - 100
	Specificity	100	78.12 - 100	85.71	56.15 - 97.49

CI: Confidence interval.

Table 4. Diagnostic accuracy of digital BW radiography for REC detection on the non-proximal surfaces.

		Mesial		Distal	
Observers	Diagnostic value	*p*-values	95% CI	*p*-values	95% CI
1	Sensitivity	41.18	19.43 - 66.55	53.33	27.42 - 77.72
	Specificity	86.67	58.39 - 97.66	88.23	62.25 - 97.94
2	Sensitivity	58.82	33.45 - 80.57	73.33	44.83 - 91.09
	Specificity	93.33	66.03 - 99.65	94.12	69.24 - 99.69
3	Sensitivity	58.82	33.45 - 80.57	80	51.37 - 94.68
	Specificity	86.67	58.39 - 97.66	76.47	49.76 - 92.18

CI: Confidence interval.

DISCUSSION.

Presence of excess cement in the gingival sulcus which is more commonly encountered in the restorations with subgingival margins is associated with periimplant tissue damage and subsequent implant failure.[19]

Over-contour of cement results in oral bacteria accumulation which along with soft tissue toxicity and more exuberant inflammatory reactions jeopardizes the health of the periimplant soft and hard tissues. Hence, a growing tendency has arisen toward the use of less retentive cements to minimize the risk of tissue toxicity.[20] Various factors can influence the amount and location of REC, some more important to mention are the amount of cement used, viscosity of the cement, applied cementation forces, and marginal integrity.[13]

It has been proved that the detection of REC and its location solely on the basis of visual and tactile methods is not much reliable.[15] Therefore, radiographic evaluation might be a further guide for the detection of the excess cement, though its success is strongly influenced by the composition, thickness, location and the extrusion pattern of the cement.[13,19] Linkevicius *et al.*,[21] emphasized that the deeper the subgingival restoration margin is positioned, the higher is the risk of undetected excess cement. They concluded that the role of radiographs in the detection of the excess cement is questionable.[22]

Studies that have evaluated the success rates of the different radiographic techniques for the detection of REC are scarce.[13,23] Considering the conflicting results of the previous studies with regard to the role of radiographs, it is necessary to perform investigations in order to find out which radiographic technique detects REC with the highest accuracy as well as the optimal patient radiation dose. Digital bitewing (BW) radiography has been used in various studies as a diagnostic tool in detecting proximal tooth caries and interproximal bone loss.[15] In the present study; it was applied as a means of REC detection around the implant restorations. To the best of our knowledge, this is the first investigation to assess the diagnostic accuracy of the BW radiographs —in two forms of parallel and shifted— for the diagnosis of REC.

The pairwise agreement between the observers was mainly good. However, surface-specific evaluations revealed that the agreement was good at proximal areas while fair in the buccal and poor in the lingual surfaces. This difference in the agreement levels for the non-proximal areas is due to the limitation of the radiographic technique and at the same time unfamiliarity of the practitioners with the REC detection on the BW radiographs that are taken with different horizontal angles.

Regarding the radiographic technique sensitivity, presence of REC on the mesial and distal surfaces was correctly diagnosed in all the test samples. Conversely, excess cement on the lingual and in particular buccal surfaces was not detected with the same accuracy as the proximal areas. The reason for this inconsistency is mainly related to the greater experience of the observers in diagnosing proximal abnormalities on BW radiographs. Furthermore, the location of REC is of great importance as it is more easily detected when the x ray beam passes tangentially through it and results in the peripheral egg shell phenomenon.[13]

Specificity of the BW technique was excellent for the proximal surfaces. On the non-proximal areas, it was better than the sensitivity. This suggests that the radiographic method is generally more diagnostic in cases with no excess cement. In a clinical report by Wadhwani *et al.*,[13] patients with inflammation around their implants were examined radiographically with right angle periapical views to detect any remaining cement. They found that the location of the cement and its diffusion pattern make it difficult to diagnose the excess material on the radiographs.

Antonijevic *et al.*,[23] compared conventional and digital radiographs with regard to the detection of the different thicknesses, heights, and depths of cement overhangs on the implant restorations. They concluded that for a 0.1mm thickness of excess cement to be visible radiographically, its radiopacity should be 1.7mm aluminum for the digital radiographs and 2.2mm for the film-based radiographs. This implies that digital radiography offers better visualization of cement excess compared to the conventional radiography.

A retrospective case analysis by Linkevicius *et al.*,[24] revealed that the implants with cement remnants in patients with history of periodontitis are more prone to develop early and late onset peri-implantitis compared with the ones with no previous history of periodontal disease.

Composition of the cement is of great importance for its radiographic detection since different materials produce a range of different optical densities on the radiographs.

Wadhwani *et al.*,[13] provided a comprehensive survey of the radiographic densities of various cement materials and concluded that the zinc-containing agents produce the highest density, while resin-based cements appear radiolucent on the radiographs and are more difficult to be diagnosed. Pette *et al.*,[25] also evaluated the relative radiopacity of the different luting agents with an aluminum step wedge. Many of the tested materials were radiolucent, hence not easily detectable in the peri-implant region and resulting in the increased risk of cement induced periimplantitis.

Evidence exists that bleeding on probing, pocket suppuration and periimplant bone loss are greater with the use of methacrylate cements instead of zinc-based cements due to the lower radiographic detectability of the former which results in less chance of removal.[8] The material of choice in the present study was zinc polycarboxylate since it provides good radiographic visibility due to the zinc content and at the same time high retention for the implant abutments. However, it should be noted that due to the potential of titanium corrosion, currently this type of cement is not so widely used with the implant-supported restorations.[26]

In our study, BW radiographs were acquired with different horizontal angles As previously discussed, both the presence and absence of the proximal REC were recorded accurately while in the non-proximal areas, the absence of excess cement was more reliably diagnosed compared to its presence. In other words, in the clinical situations where residual cement is not detected by probing exploration, digital BW radiographs are unlikely to provide additional diagnostic information.

CONCLUSION.

Digital BW radiographic series with and without applying horizontal tube shift could be considered a useful method to aid in the diagnosis of REC particularly on the proximal areas of the implant-supported restorations.

Ease of use and availability of the method in addition to the applicability of the different digital image enhancement filters further add to the desirable features of this technique.

Conflict of interests: All authors declare no conflict of interest.

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