Tube Angulation Effect on Radiographic Analysis of the Implant-Abutment Interface

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The purpose of this study was to determine the maximum permissible x-ray tube angulation that can be used to verify the fit of an abutment. An implant and an abutment were assembled with an abutment screw. A variety of openings were created between the abutment and the implant. Radiographs were taken combining the different gaps with various x-ray tube angulations. The radiographs were randomly presented to 8 clinicians, who judged the interface as open or closed. The results indicate that a radiographic analysis of interface openings becomes subjective with tube angulations of more than 5 degrees.
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Key words: abutment fit, dental implant, film positioner, interface, radiographs, tube angulation

Implant-supported restorations involve a biomechanical system. The implant, generally a root-form titanium structure placed into a prepared site in the bone, acts as an anchor. In an osseointegrated implant, bone grows around the implant, with no soft tissue interface. Because of its biology and architecture, the bone absorbs and dissipates the stresses applied to the implant. There is an individual site limit for maximum stress that the bone can withstand without being damaged. Beyond that limit is the possibility of increased bone loss rates and failure of osseointegration.[1] The functional and parafunctional forces applied on the prosthesis are transferred to the implant by the transmucosal component (abutment). In some situations[2,3] the prosthesis is directly connected to the implant by means of a UCLA-type abutment. In Skalak's model implants, the abutments and the prosthesis are firmly connected, acting as a unit to maximize the system's performance.[4] For a multiple implant–supported prosthesis, distribution of the forces applied to it depends on the stiffness of the components and the rigidity of the connection between them.

To assure a rigid system, the connection between implant and abutment must be secure and the prosthesis should fit passively. Failure to fulfill these conditions could lead to overload and failure of some part of the system; loss of osseointegration; fracture of the implant, screw, or prosthesis; or loosening of screws.

It is necessary to assure that the abutment is correctly seated on the implant, so as to determine the fit of the prosthesis. Radiographs may be the best method of verifying the implant-abutment interface, as well as the abutment-prosthesis interface, when the connection is subgingival. In the Brånemark protocol (Nobel Biocare, Göteborg, Sweden), a panoramic radiograph was originally recommended after second-stage surgery to verify the position of the implants and the implant-abutment fit. Later intraoral periapical radiographs obtained immediately after prosthesis connection were recommended instead of panoramic radiographs. One radiograph should be taken for each implant, with orthogonal projection (film parallel to the implant and with the x-ray tube perpendicular to the jaw axis). The reason for taking radio-

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graphs after placement of the prosthesis was to obtain a control to compare peri-implant tissues during follow-up visits. The use of a film positioner was also recommended.[5]

A film positioner developed in 1973 by Eggen for photographing the natural dentition was later modified by Cox and Pharoah for use in implant dentistry.[6] It was attached to the implant abutment to obtain consistently parallel images of the implant. The goal was to evaluate bone levels over time, but that required removing the prosthesis to make the measurements. To standardize intraoral radiographs, Duckworth et al employed bitewing projections in holders customized to individual segments of the dentition. The error obtained with this method was ± 2.3 degrees in the vertical axis.[7]

To make a correct diagnosis, it is important to reject radiographs that appear angulated. Some authors have studied angulation in radiographs of implants. Blurring of internal and external angles of the threads and distortion of the circular holes at the apex of the implant have been related to different degrees of angulation, starting at 9 degrees.[8–10] It has been shown that blurring of the internal angle of the implant threads occurs with an angulation of 9 degrees. When the external angle of the threads is blurred, it means that the x-ray tube is at an angle of more than 13 degrees.[11]

Hollender and Rockler studied the influence on the accuracy of bone level measurements from variations on radiographic projections along the long axis of root-form implants.[11] These authors recommended avoiding projections of more than 9 degrees. At this point, the authors were measuring bone levels around implants; thus, a film positioner was needed to ensure an exact film position and image projection over time.

The purpose of the present study was to answer 2 questions: *(1)* How much of an opening between an implant and abutment can be identified with a radiograph taken with the film parallel to the implant and the x-ray tube perpendicular to it; and *(2)* What is the maximum permissible x-ray tube angulation that can be used to verify the fit of an abutment?

Materials and Methods

A 3.75-mm-wide, 15-mm-long implant (Nobel Biocare) and a 5.5-mm standard abutment (Nobel Biocare USA, Westmont, IL) were joined together with an abutment screw. A deliberately open interface of 250 µm was left at this time. An imprint was made by placing the implant assembly into a transparent plastic container 3 × 3 × 1 cm filled with light body polyvinylsiloxane impression material (Reprosil, Caulk Co, Milford, DE). The implant was seated in the container such that the positioning of the abutment was verified by full contact with the bottom surface of the container. This ensured the horizontal placement of the implant. After setting, the implant was removed from the impression material. The band of impression material set in the 250-µm gap was removed with a scalpel blade. This permitted the repositioning of the implant in the impression when the implant assembly was replaced in the container with different gaps.

Gaps of 21 and 42 µm were obtained by placing 1 or 2 pieces of articulating film (Accufilm, Parkell, Formindale, NY) into the implant-abutment interface. Gaps of 50, 100, and 150 µm were formed by placing 1, 2, or 3 thicknesses of mylar matrix strips (H. Schein, Port Washington, NY) in the implant-abutment (I-A) interface. The abutment screw was placed using a manual screwdriver (Nobel Biocare USA) to avoid undue torque.

The implant assembly was placed into the positioning impression (Fig 1). An L-shaped working surface was utilized. A plastic angle protractor with an attached ruler was fixed to the vertical component of the table at the line angle where the vertical and horizontal surfaces were joined.

A 20-inch plastic ruler was affixed to the x-ray tube head by 2 bands of 0.5-inch masking tape placed 2 inches apart. To orient the x-ray tube, the larger ruler was aligned with the ruler of the angle protractor. This permitted the operator to control the angulation of the x-ray beam with the implant. A #2 Ektaspeed dental film (Kodak, Rochester, NY) was placed underneath the impression receptacle (Fig 2). Twenty-four radiographs were taken combining different I-A openings (0, 21, 42, 50, 100, and 150 µm) with various angulations of the x-ray tube at the I-A interface (0, 5, 10, and 15 degrees). A radiographic machine (Pennwalt, SS-White, Gloucester, United Kingdom) preset at 75 Kv, 10mA with 30 pulses, was used to take the radiographs. The ruler attached to the long cone of the machine was used to keep a constant focus and object distance of 33 cm. The radiographs were manually developed according to standard procedures (Kodak).

Four additional radiographs were taken of a closed interface at 0, 5, 10, and 15 degrees of angulation. The 4 radiographs were labeled and presented to the observers prior to the test to assure that the clinicians understood a zero angulation as opposed to 5-, 10-, and 15-degree angulations. These radiographs remained attached to the

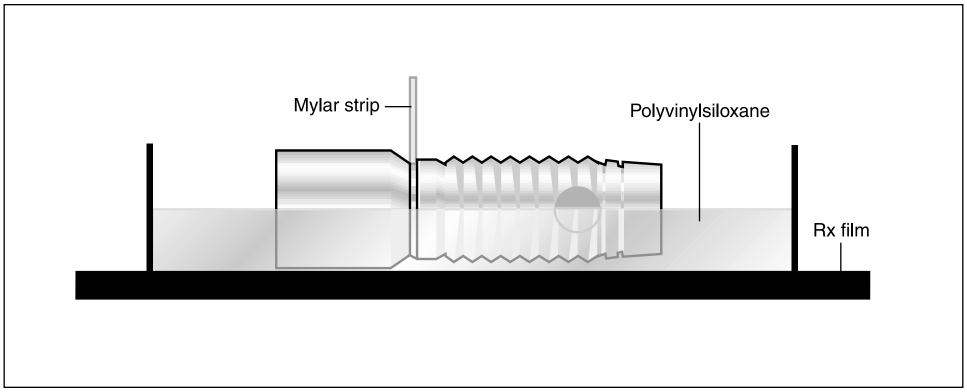


Fig 1 The implant-abutment assembly is placed in the polyvinylsiloxane imprint. A mylar strip is placed in the gap between the implant and the abutment. The x-ray film is placed underneath. The imprint has been trimmed to provide room for the abutment when the gap is open.

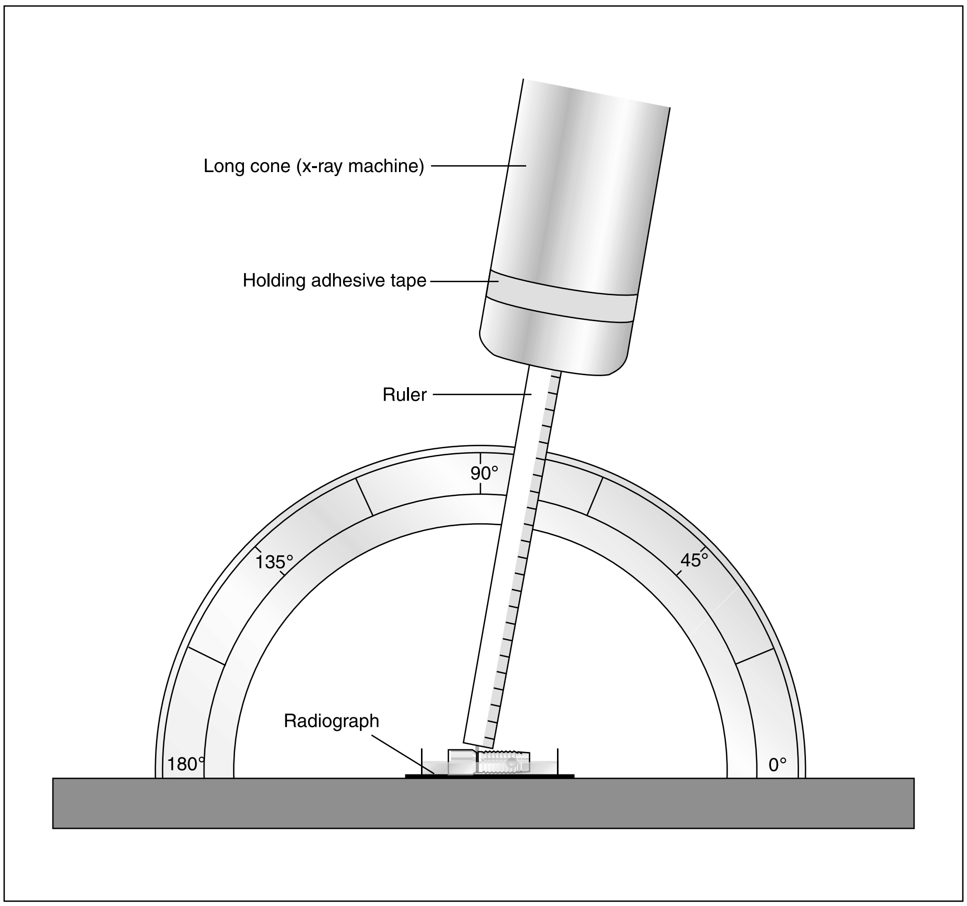


Fig 2 Drawing of the setup. The angle protractor is attached to the vertical part of the table. The long ruler is fixed to the x-ray tube, keeping the focus and object distance constant and indicating the angulation of the tube. The box containing the implant is placed on top of the film.

Table 1 Percentage of Clinicians Who Correctly Identified Gaps in the Implant-Abutment Interface*

	Gap size (µm)					
Angulation	Closed	21	42	50	100	150
0 degrees	87.5%	100%	100%	100%	100%	100%
5 degrees	87.5%	50%	87.5%	100%	100%	100%
10 degrees	100%	0%	25%	62%	62%	100%
15 degrees	75%	0%	0%	12.5%	0%	25%

*False positives are included.

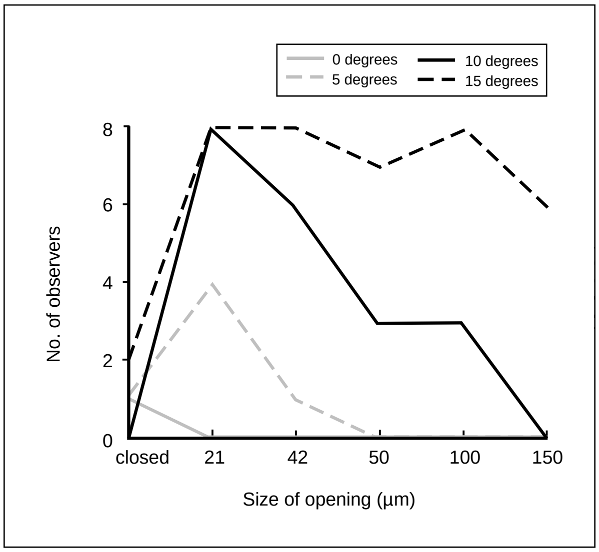


Fig 3 Graph indicating the number of observers who misinterpreted the radiographs, depending on the gap opening and tube angulation. Note that errors increase when the angulation of the x-ray tube rises from 0 to 15 degrees.

view box throughout the observer test and were used as a reference for assessing the effects of overangulation on radiographic images.

The 24 radiographs were presented randomly to 8 clinicians (4 prosthodontists and 4 postgraduate prosthodontic students). The observers were provided with a view box and a low-power magnifying glass (2×), and asked to judge whether the I-A interface was open or closed.

Results

A closed interface was detected by 87.5% of the clinicians when the x-ray tube was parallel to the I-A interface or angulated 5 degrees, by 100% of the clinicians when the x-ray tube was angulated 10 degrees with respect to the I-A interface, and by 75% of the clinicians when the x-ray tube was at a 15-degree angle (Table 1, Fig 3). A 21-µm gap was detected by 100% of the clinicians when the x-ray tube was parallel to the I-A interface, by 50% of the clinicians when the x-ray tube was at a 5-degree angle, and by none when the x-ray tube was at a 10- or 15-degree angle with respect to the I-A interface. A 42-µm gap was detected by 100% of the clinicians when the x-ray tube was perpendicular to the I-A interface, by 87% of the clinicians when the x-ray tube was at a 5-degree angle, by 25% of the clinicians when the x-ray tube was at a 10-degree angle, and by none when the x-ray tube was at a 15-degree angle. Gaps of 50 and 100 µm were detected by 100% of the clinicians when the x-ray tube was either perpendicular to or at a 5-degree angle to the I-A interface, by 50% of the clinicians when the x-ray tube was at a 10-degree angle, and by no one when the x-ray tube was at a 15-degree angle. A 150-µm gap was detected by 100% of the clinicians when the x-ray tube was perpendicular to or at a 5- or 10-degree angle to the I-A interface and by 25% of the clinicians when the x-ray tube was at a 15-degree angle.

Statistical Analysis

A chi-square test was used because the nature of the data was ordinal. Because of the number of observers, the test was applied first for gaps equal to or less than 50 µm and then for gaps larger than 50 µm. The null hypothesis used was: "The radiographic identification of an opening does not depend on the angulation of the x-ray beam." In both groups the hypothesis was rejected, so a pair comparison was done inside each group to identify at what angulation the effect was first visible. The results were as follows:

1. A 5-degree angle of the x-ray tube with respect to the implant axis does not significantly affect (98% confidence) the identification of openings equal to or less than 50 µm.

2. A 10-degree angulation of the x-ray tube significantly affects (99% confidence) the identification of openings equal to or less than 50 µm.
3. A 10-degree angulation of the x-ray tube does not significantly affect (95% confidence) the identification of openings of 100 and 150 µm.
4. A 15-degree angulation of the x-ray tube significantly affects (99% confidence) the identification of openings of 100 and 150 µm.

Discussion

At present, there is apparently nothing in the literature discussing how much of an open interface between an implant and abutment can be observed in a radiograph or how much the angulation of the x-ray tube affects the reliability of a radiograph.

In this study, openings as small as 21 µm were detected by 100% of the clinicians. This demonstrates that radiographs can provide a sensitive method for use in assessing the I-A interface. As the angulation of the x-ray tube increases, the ability to identify I-A gaps decreases. At a 15-degree angulation of the x-ray tube, gaps as large as 150 µm may not be visible. A 10-degree angulation affects the image in such a way that identification of gaps equal to or less than 50 µm is not predictable.

There were also false positives in this study. Some observers judged a closed interface as an open one. One clinician made a false positive reading when the projection was orthogonal (0-degree angulation of the tube). This finding may be explained by analyzing the topography of the implant construction. The contact area between the implant and a standard abutment is narrow and may be difficult to identify. Another possibility is that the interface was in fact open in that area due to a defect in the machined surface, and only one clinician detected it. One other false positive was also made for a 5-degree angulation. The reason for that finding was unknown.

Two other false positives were made in the 15-degree projection. The observers recognized a hyperangulation and suspected that there might have been an opening when in fact there was a closed interface. Two points that became apparent in this discussion: *(1)* how does one know when to reject a radiograph?; and *(2)* how does one consistently and correctly position a radiograph?

To make a correct diagnosis, it is important that radiographs with signs of angulation be rejected. Some authors have studied the signs of angulation in radiographs of implants. It has been shown that blurring of the internal angle of the implant threads occurs with an angulation of 9 degrees. When the external angle of the threads is blurred, it means that there are more than 13 degrees of angulation of the x-ray tube. From the results of the present study, it can be concluded that the limit at which one could misinterpret a radiograph is between 5 and 10 degrees of angulation. Therefore, blurring of the internal angle of the implant threads can hide an open interface of up to 50 µm between the implant and abutment.

Film positioners have been developed by dentists to observe and measure bone changes around teeth and implants over time.[6,7,12–14] It is important to use a film positioner to obtain reliable radiographs. It could be helpful to develop a positioner for use at the time of prosthesis connection and during follow up, so that the prosthesis would not need to be removed.

Clinical Significance

The correct fit between implant and abutment is a key factor in ensuring the success of implant-supported restorations. One radiograph per implant should be taken at the time of abutment connection. A radiograph taken with the film parallel to the implant and with the x-ray tube perpendicular to it is a reliable method of verifying fit. With this technique, one can observe openings of at least 21 µm.

More than 5 degrees of angulation of the x-ray tube with respect to the I-A interface makes for subjective interpretation of radiographs when trying to identify gaps equal to or less than 50 µm. Therefore, radiographs should be taken with the aid of a positioner to assure a perpendicular relationship of the x-ray tube and the long axis of the implant. One advantage of using the positioner is to reduce the overall radiation to the patient by minimizing the number of exposures. The film positioners on the market for paralleling technique can be a useful aid in obtaining the orthogonal projection, not only at the time of abutment connection, but also prior to impression making and during framework try-in.

If disposable blocks (Rinn, Rinn Corporation, Elgin, IL) are used, it is important to first determine the angulation of the implant, ie, locating a perio probe in the access hole, then fixing the x-ray tube position, and finally placing the bite block with the film (Fig 4). This technique is time-consuming and requires the patient's compliance. Another option is using the XCP-Rinn System for paralleling technique (Rinn Corporation) and modifying it by drilling a hole in the bite block. The hole should be parallel to the ring and same

Fig 4 Radiograph verification of metal framework fit during try-in.

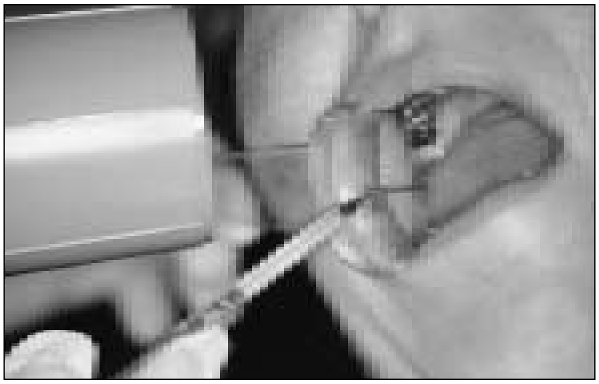


Fig 4a If disposable holding blocks are used, it is important to determine implant orientation and fix the position of the x-ray tube prior to placing the film.

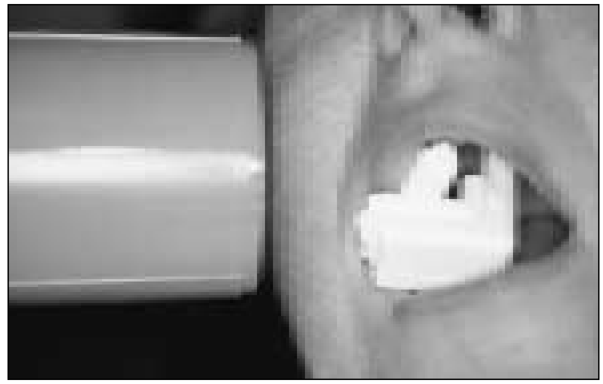


Fig 4b The film holder is stabilized in the mouth with a cotton roll.

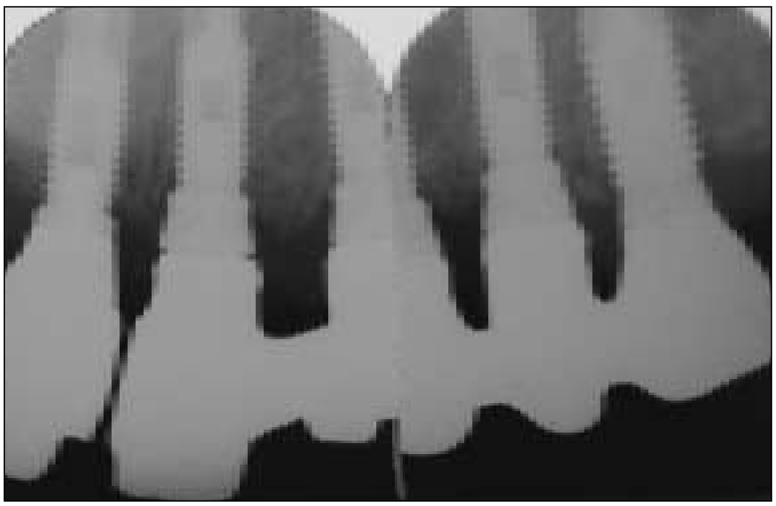


Fig 4c The resulting radiograph shows framework misfit.

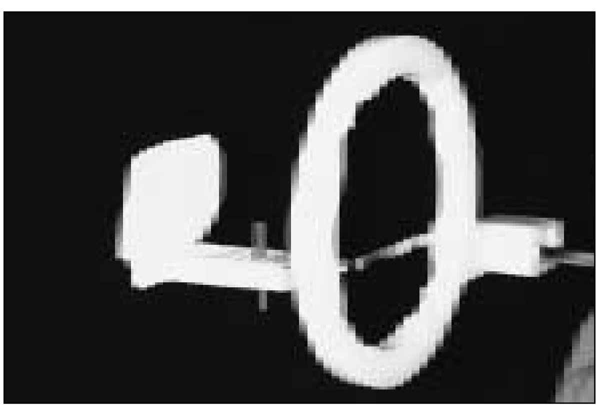


Fig 5a The modified XCP-Rinn positioner. A hole is drilled in the bite block for anterior and posterior teeth. The shank of a lab bur has been cut and placed in the hole. The clinician should check that the bur is parallel to the ring. The diameter of the lab bur fits in the access hole of the RP Nobel Biocare system. For any other system, a long guide pin can be used, drilling a hole of the same diameter.

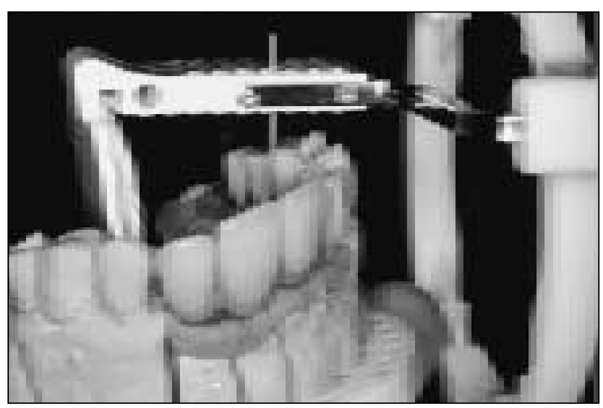


Fig 5b The modified positioner in the model to show how it will fit in the mouth. The bur will be cut to a convenient length. The positioner is stabilized in the mouth with cotton rolls if needed. In the posterior maxilla, film number 0 will be needed in a horizontal position.

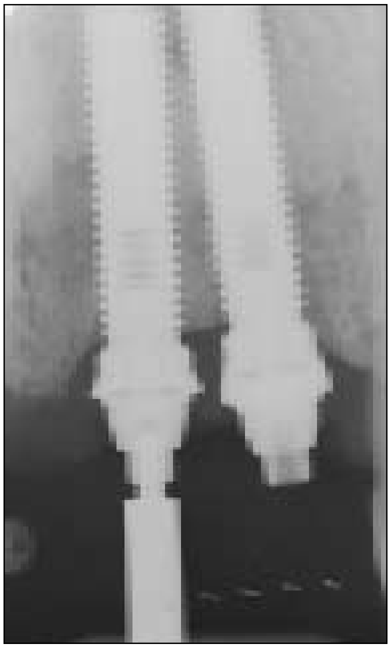


Fig 6 *(Left)* Radiograph taken to verify the fit of an abutment and the quality of the surrounding bone. A guide pin has been screwed into the abutment screw and inserted into the hole of the film holder. The result is an orthogonal projection.

Fig 7a *(Below)* Radiograph taken at prosthesis delivery using the XCP-Rinn modified positioner.

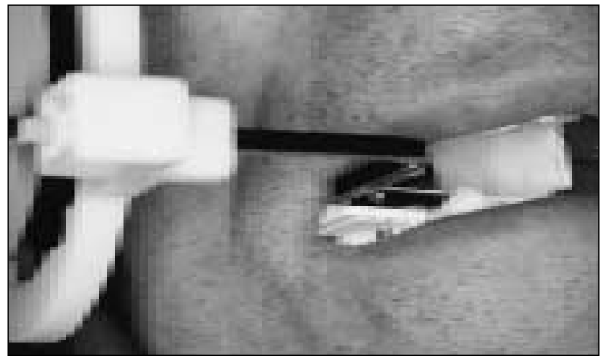


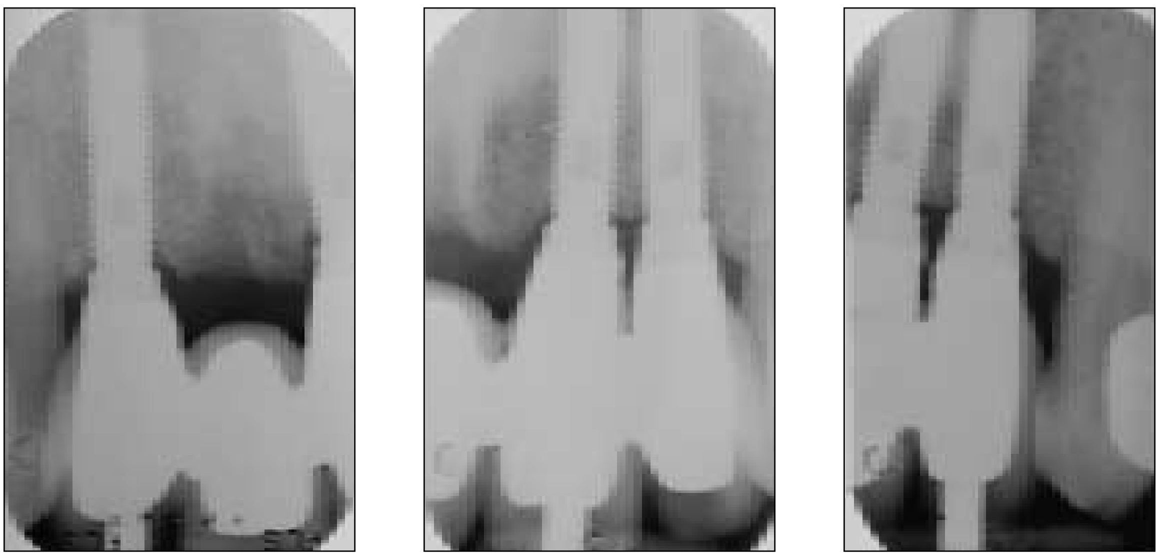
Fig 7b Radiograph of patient shown in Fig 7a, showing a misfit in the implant at the maxillary right second premolar position. The radiopaque image, which showed a submerged radicular rest, was impinged by the porcelain under the pontic.

Fig 7c Good fit of the same prosthesis was obtained after the radicular rest was removed.

diameter as the guide screw (Fig 5). The guide screw itself can be passed through the hole, fixing the position of both film and tube, to verify the seating of the impression post. A long guide pin screwed into the abutment can be passed through the hole of the bite block to verify the seating of an abutment (Fig 6). If the seating of a framework needs to be checked, engaging half the shank of a lab bur (about the same diameter as a Nobel Biocare RP guide screw) or a long guide pin on the biting block and inserting it in the access hole, fixing the position of both film and tube, will suffice (Fig 7). On most occasions, film size number 0 will be needed. Although it has not been measured (ie, the fidelity of this technique), the radiographs obtained in this way do not display the aforementioned signs of angulation. The same method can be used at the time of prosthesis delivery to check for fit and to obtain a baseline for bone level follow-up (Fig 8).

The use of an XCP-Rinn positioner, as marketed, can provide false orthogonal projections, since the angulation of the implant can differ from that of the prosthetic tooth (Fig 9).

Fig 8 This method can also be used at prosthesis delivery to obtain a baseline for bone level follow-up.



Summary

When the x-ray tube is properly placed, radiographs can confirm the closure of an implant-abutment interface. X-ray tube angulation should not exceed 5 degrees. The use of an x-ray tube positioner is recommended.

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Fig 9a The use of the XCP-Rinn positioner, as marketed, can provide false orthogonal projections since the angulation of the implant may be different from that of the tooth. This is what happened during the radiograph verification of the metal framework try-in in this patient.

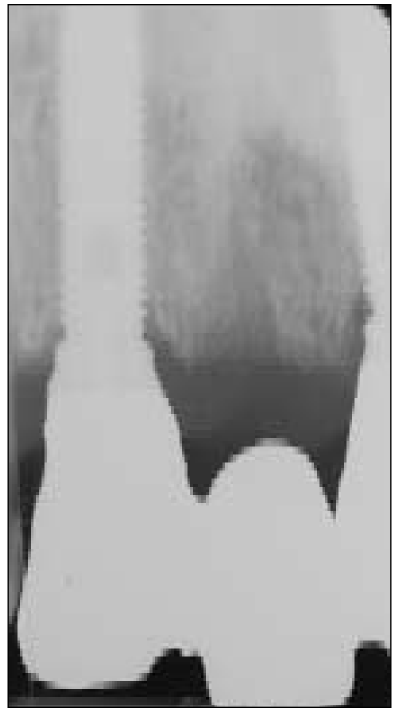

Fig 9b *(Right)* Radiograph taken at the implant in the maxillary right lateral incisor position shows apparently good framework fit.

Fig 9c Radiograph taken at the implant in the maxillary right second premolar position shows the posterior prosthesis fit is correct, but it accidentally displays a misfit in the implant in the maxillary right lateral incisor position. (Notice the radiopaque linear image under the pontic.)

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