10 Intraoral Radiography and Implant Restoration

Chandur P.K. Wadhwani, Kevin C. Lin, and Curtis S.K. Chen

Abstract

One of the most useful tools available for implant dentistry is radiography, from initial assessment all the way through to long-term health monitoring of the peri-implant tissues. The restorative dentist frequently uses intraoral radiography to conduct evaluations on implant component fit and the bone related to the implant. However, limitations exist arising from the way radiographs are made as well as how they are interpreted. Clinically significant factors will be discussed in this chapter, as well as ways to improve the diagnostic value of intraoral radiographs.

Introduction

The planning and surgical phases of implant dentistry often involve modern, sophisticated three-dimensional imaging equipment and techniques, which few dental offices currently possess. This is in contrast to the implant restorative and follow-up phases, where more traditional two-dimensional intraoral radiography (IOR) is more commonly used as a diagnostic tool, with the equipment necessary readily available in most dental offices. When used appropriately, IOR can provide clinically relevant information in a minimally invasive, inexpensive, and immediate manner. It remains the preferred method for most clinicians when evaluating hard dental tissues, especially bone where implants are involved.

Intraoral Radiography: Uses and Limitations

Intraoral radiography (IOR) has been useful for the detection of pathology, visualization of trabecular bone pattern, and highlighting of anatomical aberrations and adjacent tooth angulations that may affect the restoration path

C.P.K. Wadhwani, BDS, MSD (✉)
Department of Restorative Dentistry,
University of Washington, Seattle, WA, USA

Private Practice Limited to Prosthodontics,
1200, 116th Ave NE #A, Bellevue, WA 98004, USA
e-mail: cpkw@uw.edu

K.C. Lin, DDS
Department of Integrated Reconstructive Dental Sciences, University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, CA, USA

C.S.K. Chen, DDS, MSD, PhD
Department of Oral Medicine,
University of Washington School of Dentistry,
Seattle, WA 98195, USA
e-mail: cskchen@uw.edu

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Fig. 10.1 Histological section of an osseointegrated implant. The red part is the bone; the black item is the implant. Notice the tight adaptation of bone to the implant. Thirty-five percent to 40 % of the mineralized content is in contact with the implant surface

of insertion. It can also offer useful information with respect to the mechanical alignment and union of the implant components, which is considered vital for the long-term success of the implant restoration. Radiographs have also been used to evaluate the success of dental implants as well as to provide a means of monitoring their long-term health. This is accomplished by comparing successive images to baseline records over a period of time.

However, as with any diagnostic test, limitations exist. Some are the result of the radiographic processes in general; others have to do with the technique-sensitive nature of the equipment and making the radiographic image. Also, the diagnostic value of any given radiograph varies, depending upon the pathological process being examined, as well as the ability or expertise of the clinician evaluating the radiographic image. It is also known that IOR can give false negatives; in other words, a disease process or issue may present but may not be detected, especially in the early pathological and/or bone remodeling phase (Fig. 10.1). Given this information, the prudent clinician will use IOR as part of the evaluation process along with other clinical assessment methods. Specifically with implant therapy, IOR can supplement the clinical implant site examination along with other signs, for example, inflammation, recession, probing pocket depth, and mobility. Consistent with all radiographic examinations, IOR should be applied according to a strategy to reduce patient exposure to radiation. The radiograph should be made and developed to be of the highest quality possible to provide as much information as possible to the clinician.

Even given these limitations, IOR still provides some degree of quantitative and qualitative analysis that may be extremely useful. The purpose of this chapter is to evaluate and give guidance to the clinician regarding the appropriate use of IOR, specifically during the restorative phases of implant therapy and subsequent monitoring and follow-up.

IOR, Bone-to-Implant Contact and Health of the Tissues

Implant dentistry frequently focuses on the bone directly adjacent to the implant. In fact, osseointegration is defined as "the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening connective tissue." Although radiographic assessments of bone adjacent to the dental implant are made, it should be understood that direct implant–bone contact cannot be accurately determined. Because IOR is two-dimensional, there exists an inability to discern bone levels directly facial and lingual to the implant body, as these sites will be obscured by the implant itself. Even at interproximal sites adjacent to the implant, bone attachment cannot be easily determined.

A study on the accuracy of radiographs to diagnose radiolucencies surrounding implants was undertaken by Sewerin. A series of implants were inserted into bone, some with intimate contact to bone, while others had an intentional gap of varying size created between the implant and the socket. These were radiographed under standardized conditions and then evaluated by 10 experienced implant clinicians who were asked to judge the likelihood that a space was present. The interobserver agreement was low and the diagnostic accuracy was greatest only when a 0.175 mm space existed. It was concluded that, in general, radiographs were an unreliable method for diagnosing peri-implant spaces. However, their value improved with increasing space widths up to 175 μm between the implant and surrounding bone. Clinically, the study has implications in that radiology cannot be relied on as the only means of determining the extent of bone to implant contact.

Fig. 10.2 An example of alveolar space. The endodontist has used calcium hydroxide as an interim treatment. During the process of placing this into the root canal system, some has been extruded. Note the radiopacity in areas of the alveolar spaces that were previously occupied by marrow space

Bone-to-implant contact is the amount of bone that generally contacts the implant body. Bone is composed of both mineralized and non-mineralized material of varying degree and is in large part dependent upon the type or character of bone being examined. This results in the actual mineralized bone contact often being limited to only 35–40 % of the implant surface, as seen in Fig. 10.1, which further compounds the ability to determine how much bone is truly in contact with an implant when relying on IOR.

Implants are generally placed into cancellous or alveolar bone. The word alveolar is derived from the Latin "alveolus" meaning "little cavity." Therefore, this bone is not solid, but rather consists of many little cavities within it. The alveolar or marrow spaces, which are filled with readily displaced non-mineralized tissue, can frequently be highlighted by endodontic processes (Fig. 10.2) with the intrusion of radiopaque material.

The ability to assess the status of implants at any stage is important, and apart from routine monitoring it should be considered a prerequisite to know and record the health status prior to reconstruction, at the commencement of a restoration, or when a replacement prosthesis is being considered. Radiographs can also provide a baseline standard against which subsequent radiographs can be compared to monitor changes over time, provided there is adherence to some form of standardization (Fig. 10.3).

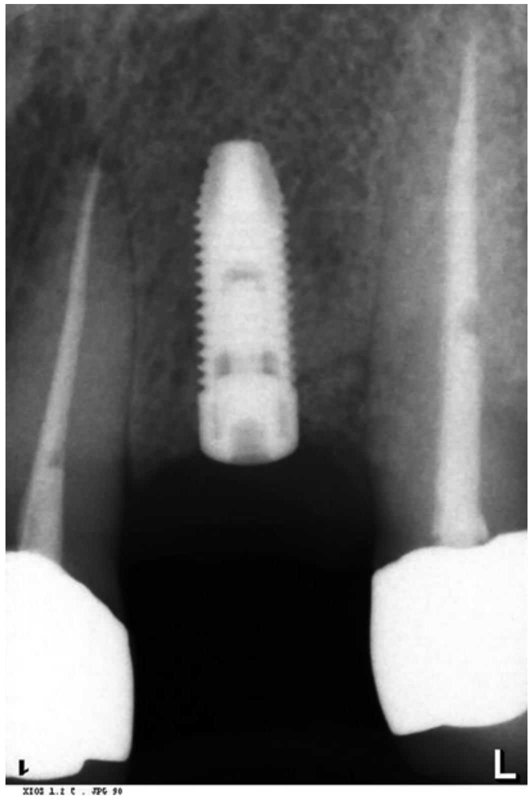

Fig. 10.3 This radiograph was made prior to the commencement of the final restoration. It provides some information about possible pathological issues, the type of bone, how deep the implant is placed, and potential angulation issues with adjacent teeth. It can also be used as a reference to compare future serial radiographs against to evaluate long-term changes, provided they are all standardized

Marginal bone height around implants has been used as a measure for monitoring bone health. Again, in vitro studies have reported on potential errors, suggesting in clinical cases distortion of buccal and lingual bone margins may result in an overestimation of bone heights. The degree of overestimation is influenced by the buccolingual position of the implant. Again, even given these limitations, it is advised that a baseline record should be made with an exacting technique that controls for factors such as position and angulation relative to the implant position prior to the fabrication of a new or replacement restoration.

Mechanical Connection of Implant Components

Visual examination may be possible if the implant head connection to the impression coping is above or very near the free gingival margin. If not, tactile perception may be considered, but a radiograph made with the correct angulation may provide the most useful data.

Periapical radiographs can be a useful adjunct to determine the accuracy of fit for a prosthesis. They provide high-dimensional accuracy, image detail, and minimal magnification and distortion when they are made correctly. To utilize the advantage of intraoral radiography, it is absolutely critical to maintain the X-ray beam perpendicular to the implant's component connection junction (CCJ). The component connection can be at the crown–abutment junction or abutment–fixture junction. When the proper long-cone paralleling technique is adopted, they offer significant diagnostic value for the dentists and minimal negative health impact on the patients. Inadequate fit of components may result in failure of the prosthesis and the retaining screws connecting the implants to the superstructure and may also have the potential to cause implant-to-bone changes (Fig. 10.4).

Fig. 10.4 The restoration was placed on an implant, which trapped tissue between the implant body and abutment (CCJ). Once the tissue was released, the inflammation resolved. Follow-up revealed no further lesions

Proper radiographs can help clinicians evaluate the fit at the CCJ, but improper alignment between the fixture and the X-ray beam could result in not detecting a misfit and mislead clinicians about the true fit of the implant components. Radiographically detectable edges of the abutment and head of fixture become smaller as the divergence of the X-ray beam increases. Laboratory studies have also confirmed that as the angulation of the X-ray tube diverges away from the angle perpendicular to a restorative margin or the long axis of the implant fixture, identifying misfit becomes increasingly difficult. A model was fabricated with an implant and a spacer providing a gap of 100 μm with the healing cap. Radiographs were made at 0° (orthogonal), 10°, 20°, and 30°. The radiographs produced are seen in Fig. 10.5a–g.

The angulation of the X-ray tube head relative to the implant long axis is critical. Under optimum conditions, gaps of 0.05 mm may be detectable, but become obscured when deviations of the X-ray tube head are 5° or more to the long axis of the implant. Gaps of 0.1 mm or larger can also be detected with 10–15° X-ray beam incidence away from the long axis. However, when the incident beam is greater than 10–15°, as seen in Fig. 10.5e, f, these gaps also become obscured. Other factors that also alter the ability to detect gaps include radiographic focal spot size and Focus film distance (FFD). This is the distance between the X-ray source and the film or sensor receptor in diagnostic radiography.

If the goal of treatment is to determine exacting component fit, then clearly the tube angulation must be strictly controlled. This becomes more of a challenge when restorations are splined (Fig. 10.6a, b). The fit of a splinted restoration on implants or a fixed partial denture may present with particular issues related to non-passive fit. Laboratory processes, along with embedment relaxation effects that occur when metal components are connected with screw joints, make multiple implant connection particularly susceptible to non-passive fit errors. When evaluating the seating of such a prosthesis, the individual implant positions must be accounted for with each attachment site (Fig. 10.7a, b).

It is clear that in evaluating for the fit of implant components, the radiographic image is subject to distortions as a result of angulation

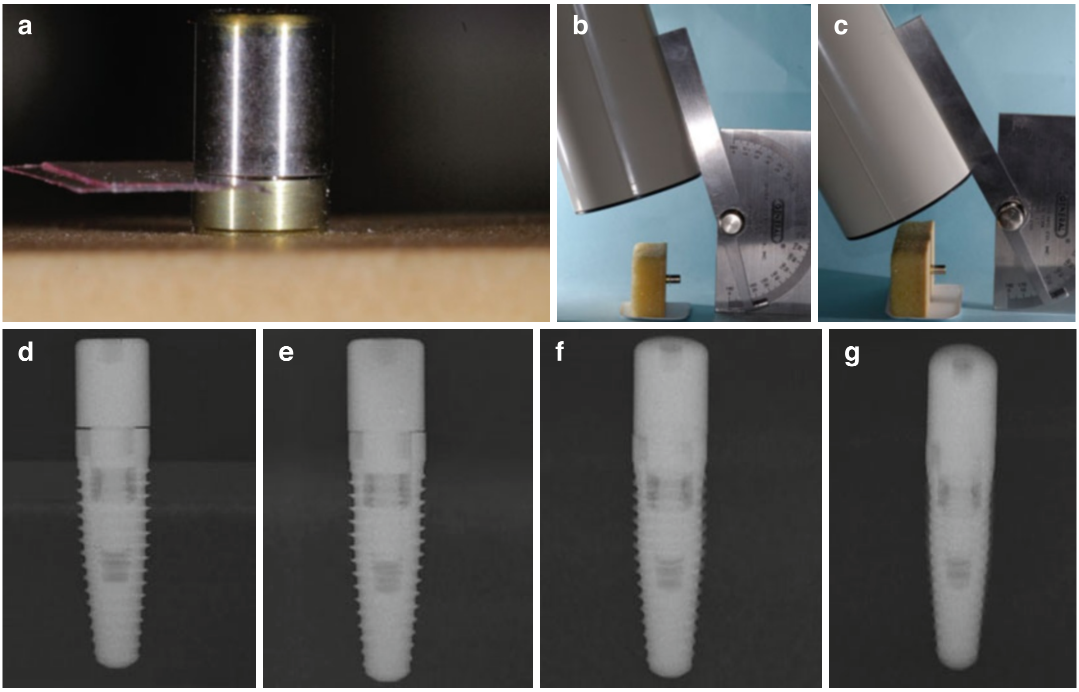

Fig. 10.5 (**a**–**g**) These radiographs were made by altering the X-ray cone relative to the implant and healing abutment by (**d**) 0°, (**e**)10°, (**f**) 20°, and (**g**) 30°. They show how minor errors in angulation alter the ability to detect component fit

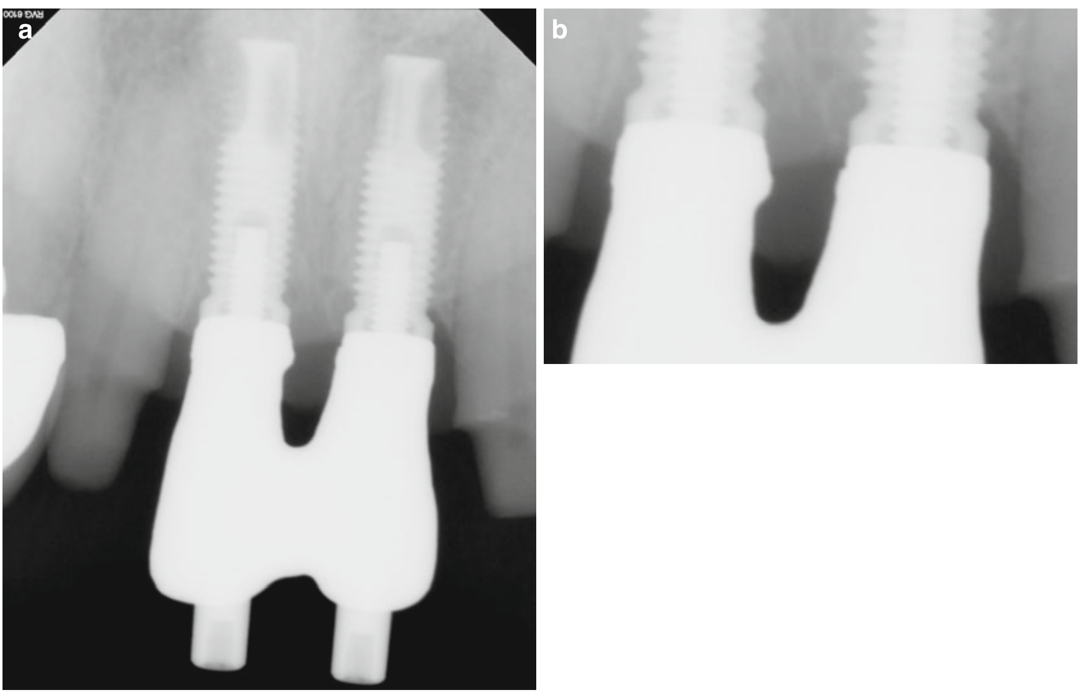

Fig. 10.6 (**a**, **b**) Radiograph at metal try-in appointment. Enlarged image shows intimate contact of both abutments with the implants

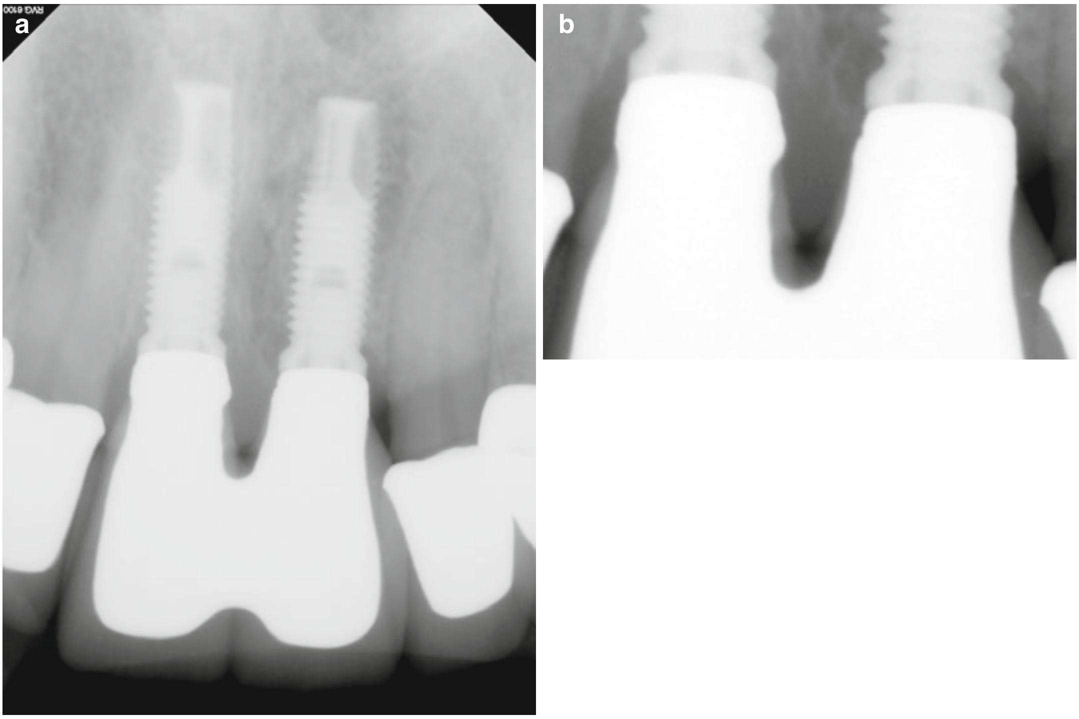

Fig. 10.7 (**a**, **b**) On final delivery, an orthogonal radiograph indicates a misfit on the left central implant. The prosthesis was remade

effects. Several studies have evaluated these artifacts and how they develop, assessing the relative angulations of X-ray tube, implant body angle, and film or image sensor angulation. The findings from these investigations suggest the following: determine the angle of the implant with respect to the surrounding occlusal plane prior to radiographing, if possible (Fig. 10.8a, b).

However, if the implant has been previously restored, it may be more difficult to determine the orientation without first removing the restoration. The angulation of the X-ray tube head relative to the implant long axis is critical. If the goal of treatment is to determine exacting component fit, then clearly the tube angulation must be strictly controlled. In the horizontal plane, if the incident X-rays are perpendicular to the long axis of the implant (orthogonal), the mesial and distal tube head angulations are not critical as long as the gap size is uniform; it will be detected from any angle. As a result of this information it is suggested that, given a knowledge of the implant angulation, the tube head orientation in the vertical plane is most critical. To standardize sequential radiographs, a paralleling device may be of use, for example, RINN systems (Dentsply Rinn, Elgin, IL USA). However, the holder should be orientated relative to the implant long axis rather than the occlusal surfaces, which more commonly occurs and produces information that may be inaccurate.

Understanding the component structures and how these relate to the radiographic images seen is also vital for diagnosis of component fit (Fig. 10.9). Implant components come with a variety of matching surfaces that can lead to misinterpretation of a radiographic image (Fig. 10.10a, b). When an implant component only touches at the periphery, a radiographic anomaly known as the "peripheral eggshell effect" may result. This may lead to the false impression that the components do not match or have failed. This would be an incorrect assumption.

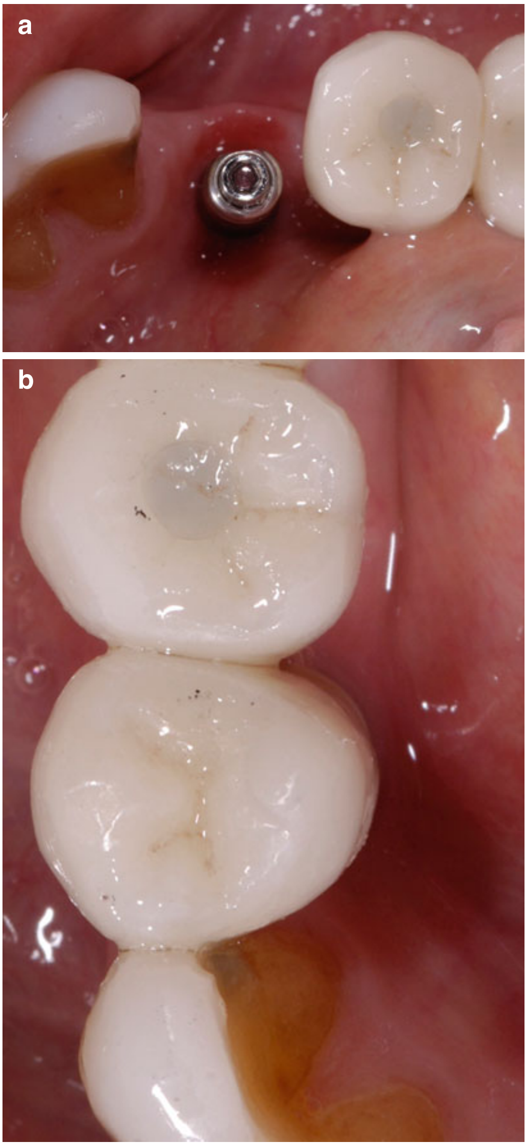

Fig. 10.8 (**a**) It is important to access the implant with respect to radiographic techniques. This implant is angled toward the midline, which must be taken into account when making radiographs. (**b**) Now restored, the underlying implant's orientation can only be guessed at

Fig. 10.9 Understanding the radiographic properties of the implant system, it appears as if this Zimmer AdVent implant abutment only seats onto the implant body mesially and distally. This is a radiographic artifact—the so-called peripheral eggshell effect (PESE)

The Value of Orthogonal Radiography with Implants: Connection and Health

For determining implant component fit, there are ways to provide for orthogonal radiographs to be made. To ensure a perpendicular relationship between the X-ray beam and the implant components, all existing paralleling devices usually attach directly to the implant body at the time of making radiographs. This is a limiting factor because the implant restoration would have to be deconstructed for access to the implant itself; therefore, radiographic assessments can generally only be done on screw-retained restorations or implant bars where the implant access channel is not permanently blocked (Fig. 10.11). In addition, by having to deconstruct the implant prosthesis, the paralleling devices may disrupt the peri-implant tissues and affect their overall health, thus limiting the capacity to monitor crestal bone loss. So, in reality, component misfit can only be evaluated.

By indexing the implant fixture to the adjacent dentition or anatomical landmark, the authors developed a novel X-ray paralleling device, the Precision Implant X-ray Relator and Locator (PIXRL), that can be attached to commercially available film holders. The PIXRL is first positioned perpendicularly to the implant fixture using implant drivers or implant placement drivers; it then allows for registration record to be made between the adjacent teeth or anatomical landmark and the positioned PIXRL jig. The sequence is described in greater detail with the provided illustrations (Fig. 10.12a–e). Because the occlusal relationship is indexed with the adja-

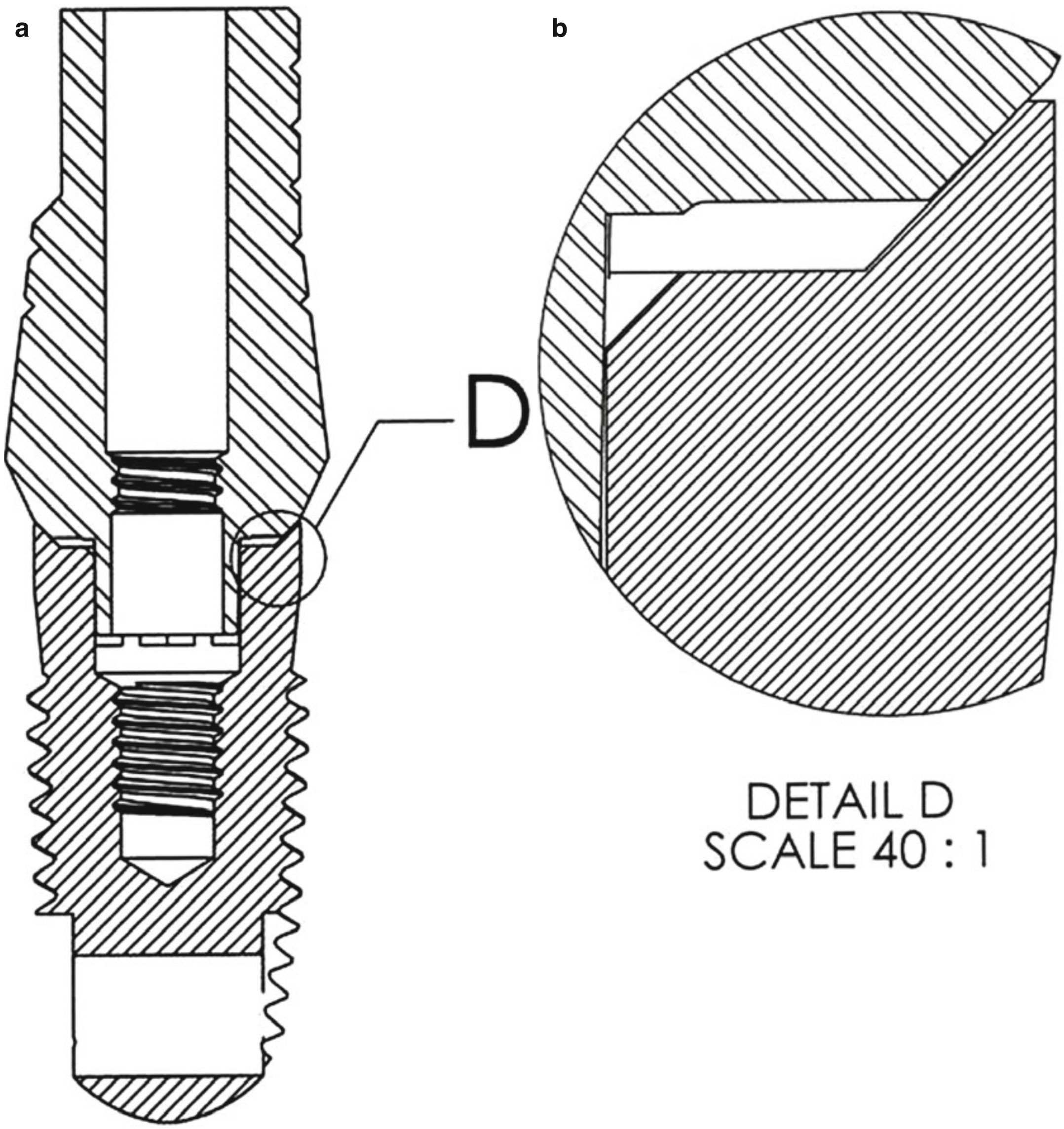

Fig. 10.10 (**a**) The PESE results from the margin of the abutment contacting the lip of the implant only. (**b**) Enlarged image. This must be understood; failure would result in potential misdiagnosis of the components not fitting together correctly (Reprinted with permission by Dentistry Today Wahdwani (2012). Intraoral Radiography and Dental Implant Restoration. Dent Today August 2013; Vol. 31; 8:70])

cent teeth, accurate radiographs can be made consistently without the removal of implant prosthesis thereafter; the evaluation of CCJ occurs at the abutment level.

A study was conducted at the University of California, San Francisco, to compare whether misfit at the AFJ can be more accurately and confidently assessed using radiographs made with the PIXRL X-ray paralleling device in a clinically simulated model. A microgap ranging from 0, 50, to 100 μm was introduced at the AFJ of a provisional implant crown in a manikin-typodont

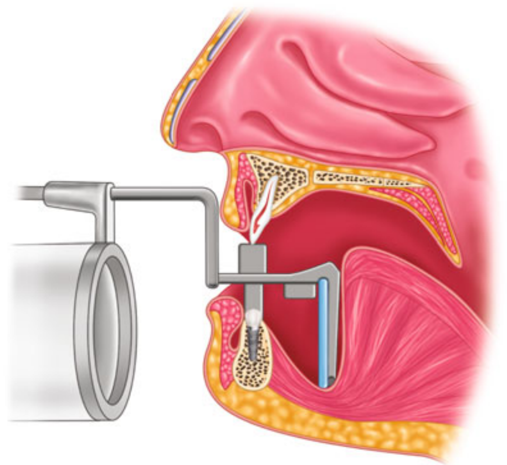

Fig. 10.11 Example of existing devices that allow true orthogonal standard X-rays to be made. All must attach to the implant body (fixture) directly at each and during X-ray exposure (Reprinted from Cox and Pharoah (1986). Copyright © 1986, with permission from Elsevier)

assembly (Fig. 10.13a–c). In 50 and 100 μm misfit conditions where PIXRL was used, clinicians were able to detect prosthetic misfit with 77.8 and 100 % accuracy, respectively. Without the use of PIXRL, clinicians were able to detect only 16.1 % of the misfit in 50 μm gap and 92.6 % of the misfit in 100 μm gap. The sample of radiographs made under each misfit condition (0 um, 50 um, 100 um) is provided (Fig. 10.14a–f). Consistent with previous findings, the study effectively demonstrated that paralleling devices are critical in helping clinicians obtain diagnostic radiographs for implant assessment. How the device provides orthogonal radiographs is demonstrated in Fig. 10.15a, b.

Limitation with Radiography and Professional Responsibility

Adopting the use of a paralleling device in making clinical radiographs provides an opportunity for clinicians to monitor changes in bone architecture or prosthetic misfit around an implant accurately and consistently over time. Anatomical limitations (i.e., missing teeth, the palatal vault contour, shallow lingual sulcus, presence of tori, or unfavorable mandibular arch form) and patient factors (i.e., prominent gag reflex or psychological issues) may restrict the use of such devices. The application of the device in various clinical situations must also be considered.

The accuracy of an intraoral radiograph inevitably reduces the number of X-ray images to be remade in a clinical situation; if the clinician can be more certain about the diagnostic quality of a radiograph, there would be less need for exposing patients to additional radiation. Claus and colleagues have recently correlated dental X-rays to an increased risk of meningioma in a population-based case–control study. Despite the shortcomings in its study design, the subsequent negative publicity generated reminded the entire dental community of the significance of minimizing the patient's radiation exposure when possible.

Intraoral radiography, although considered somewhat basic, has certain advantages over more sophisticated radiographic examinations from cone beam computer tomography and panoramic radiography, as listed below.

Cone Beam CT

1. 'Sunburst' effect due to x-ray scattering from metallic components may make detecting misfit challenging
2. Limited resolution (local cone beam has highest resolution at 70um)
3. Expensive

Panoral Radiograph

1. High false negative rate in detecting small gaps due to inherent limitations such as magnification, distortion, negative vertical angulation of projection, and patient movement
2. Limited resolution

A protocol should be developed by the clinician to determine when radiographs should be made. This is especially important during the initial pick-up impression, seating of the final

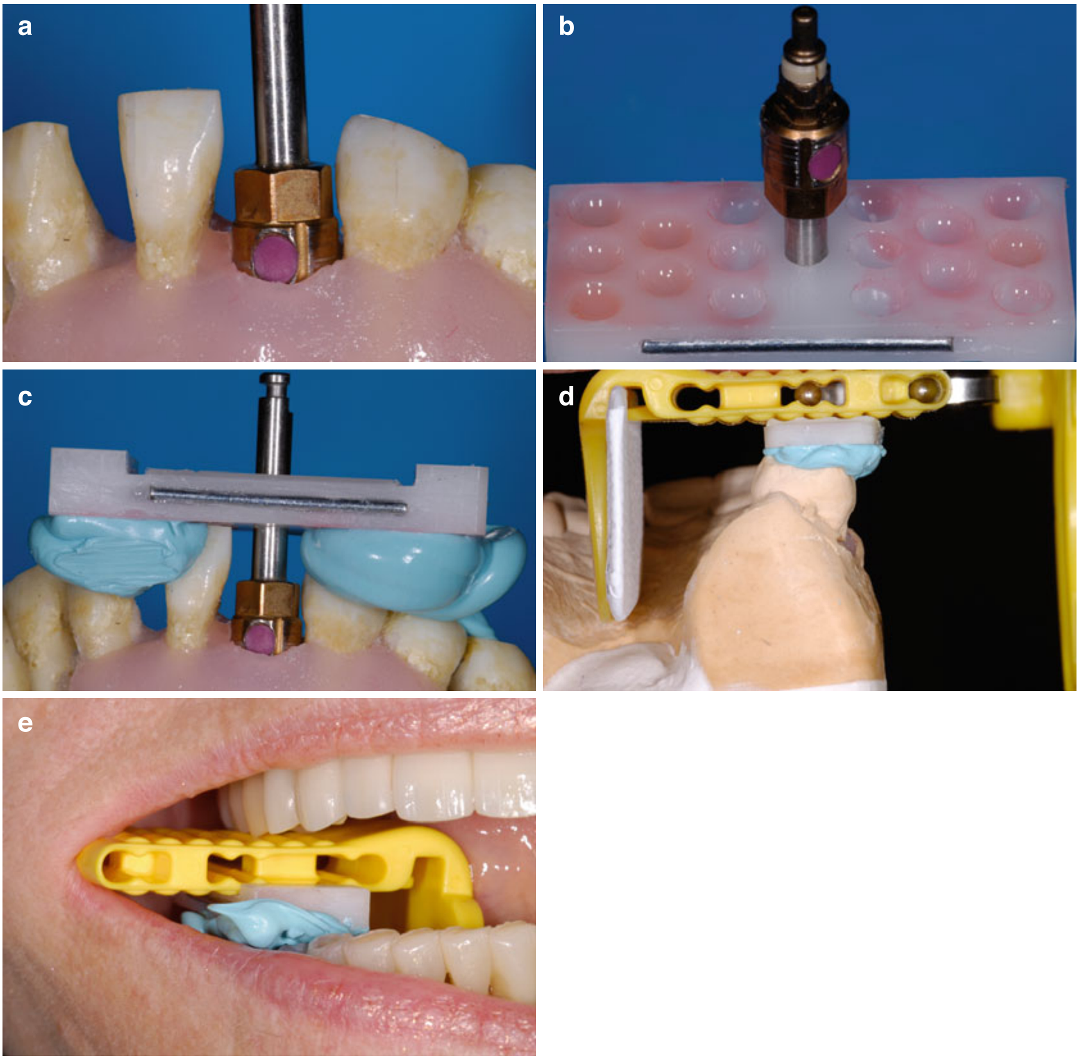

Fig. 10.12 Fabrication and clinical application of the X-ray paralleling device are critical in helping operators obtain diagnostic radiographs for implant assessment. (**a**) Access to implant fixture obtained intraorally or from implant master cast; implant placement driver is attached to the fixture. (**b**) Connect the paralleling PIXRL device to shank of implant placement driver; adhesive is applied on undersurface of the jig. (**c**) Orient PIXRL jig assembly to implant placement driver and make occlusal registration record against adjacent teeth. (**d**) Attach radiographic film holder to PIXRL jig; use occlusal registration record to maintain orientation of film holder and radiographic film. (**e**) Adopt conventional parallel-cone technique to make radiographs intraorally with device (film holder paralleling arm was attached for actual clinical use; it was only removed here for better visualization of PIXRL assembly)

abutment, completion of the restoration, and any other clinical situations when the component fit cannot be directly verified by sight or feel. When a restoration is to be cemented onto an implant abutment and where a connection is not accessible, for example, when it lies beneath the peri-implant tissues, it would be prudent to radiograph the components before final cementation to confirm they match as intended. This is to confirm that the abutment is correctly

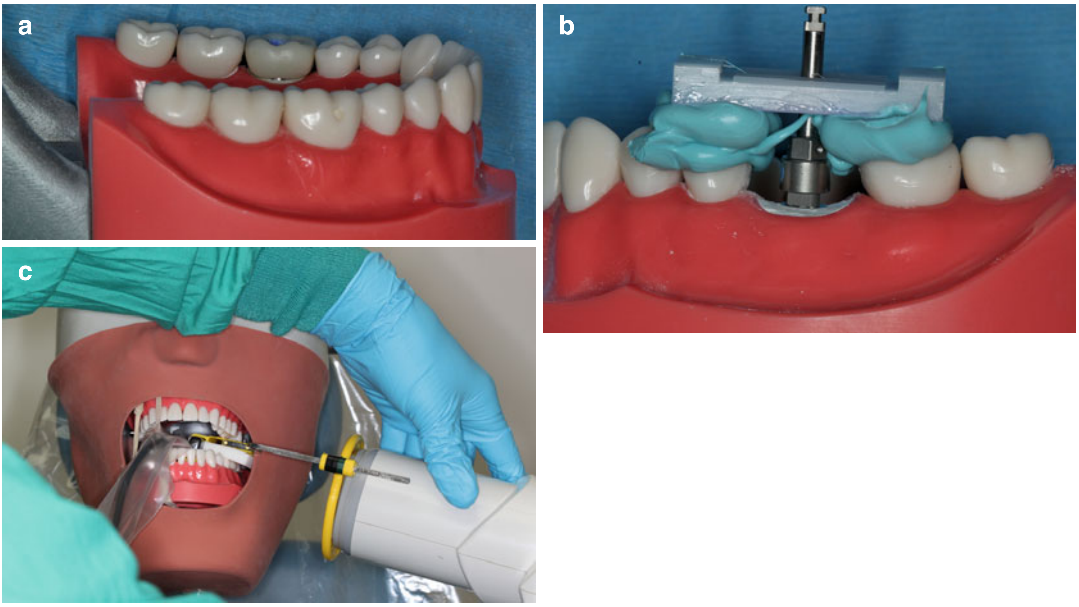

Fig. 10.13 The simulated clinical study. (**a**) The implant crown was fabricated with proper anatomy and occlusion by building composite on the modified UCLA abutment. (**b**) The PIXRL jig is indexed to the implant fixture and the adjacent dentition using an implant placement driver and a vinyl polysiloxane bite registration material. (**c**) The assistants were asked to position X-ray film holding assembly and the X-ray tube in a routine manner. They were free to use cotton roll, gauze, or cotton pad as they saw necessary

located onto the implant, as well as to confirm that the crown seats onto the abutment itself. Failure to do so may fail to detect errors as a result of fabrication, or components not seating (Fig. 10.16).

Cemented Implant Restorations

There is increasing evidence that residual excess cement may lead to peri-implant disease. It is the responsibility of the implant-restoring dentist to ensure and check that no excess cement invades and remains in the peri-implant tissues. One way of confirming that excess has been removed is by the use of IOR. However, there is no standard for the radiopacity required of implant cements, which is problematic. An in vitro study and case studies have reported on the ability to detect commonly used implant cements radiographically. The results indicated that many cements would not be easily found, and some not at all, at any given thickness, as shown earlier in Fig. 10.14a–c. While there is no ideal implant cement, the onus must be on the restoring clinician to choose one that can be readily seen radiographically and to understand the characteristics of the cement extrusion patterns that may present with IOR. When a radiopaque cement is used, a radiograph may be used to determine if residual excess cement exists (see Fig. 10.15a).

Implant Health and Follow-Up

Much has been written about the success of dental implants, with radiographic evaluation used for

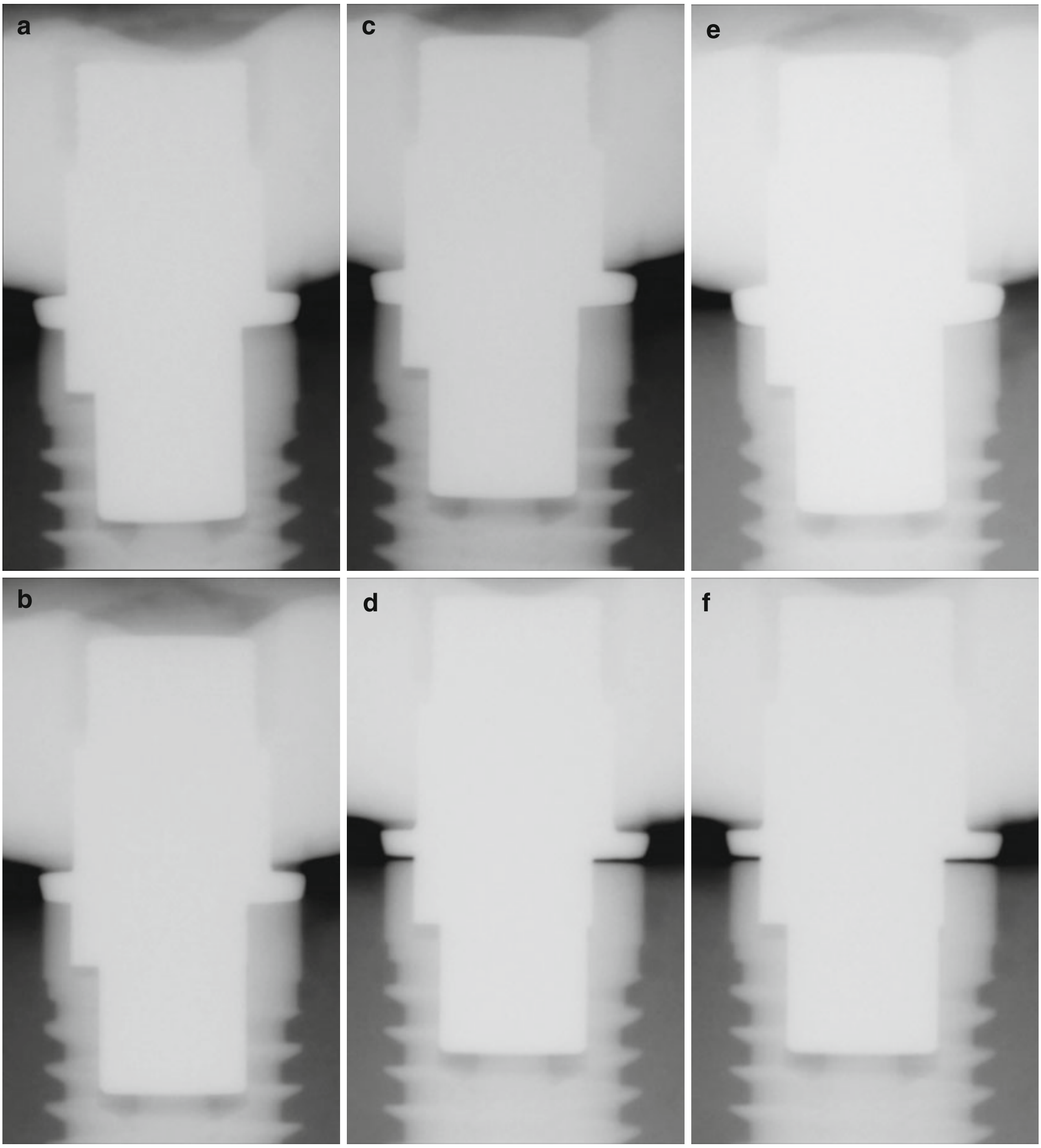

Fig. 10.14 Examples of radiographs with different gap dimension, from 0 to 100 μm, typical of those produced in the study with and without the PIXRL device. (**a**) 0 μm without PIXRL; (**b**) 0 μm with PIXRL; (**c**) 50 μm without PIXRL; (**d**) 50 μm with PIXRL; (**e**) 100 μm without PIXRL; (**f**) 100 μm with PIXRL

measurements. The early criteria for implant success included values related to acceptable bone loss and time. IOR has been used as a tool to evaluate hard tissue health, but again, there are limitations with this method of assessment. Mineral loss from bone is not consistently or easily quantified and varies from site to site. The difference lies in the initial mineral content, the alveolar content, and the amount of cortical bone in the area evaluated. Early studies suggested that mineral loss needed to exceed 7 % of the mass before it may be detected on a film radiograph in the maxilla, but mineral loss in the mandible may have to be as great as 30 % before it is readily detected. More

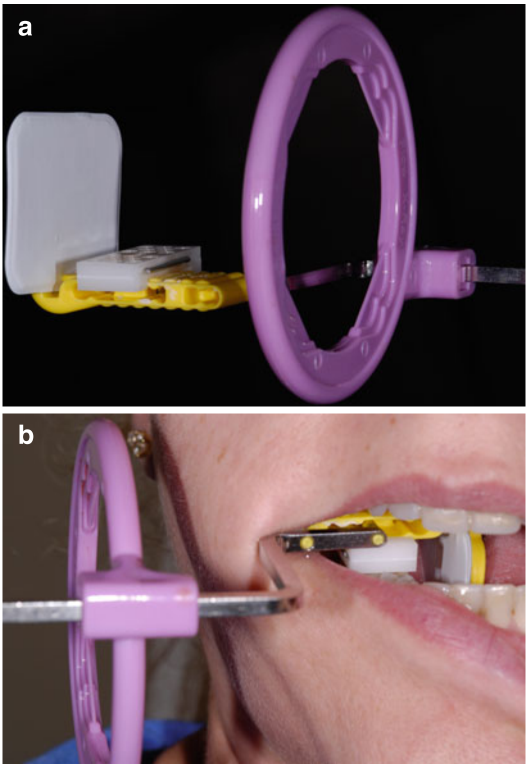

Fig. 10.15 (**a**, **b**) How the PIXRL attaches to a paralleling device. Once the PIXRL is indexed to the implant, consistent standardized radiographs are possible to monitor bone health as well as confirm connection of the abutment

recent studies have reported on mineral loss as a result of osteoporosis and have suggested that detectable mineral changes may be as little as 1.2 % with photo-stimulable phosphor systems.

Frequently, studies compare marginal bone loss measurements; however this may be problematic. Marginal bone height adjacent to implants is highly susceptible to angulation effects relative to X-ray film and implant (see Fig. 10.15a). The ability to obtain consistent perpendicular radiographs that will provide diagnostic relevance is problematic. Devices exist that are directly screwed into the implant body itself that allow the film, X-ray tube, and implant body axis to be related. However, once the implant restoration is placed, this becomes impractical, as removal of the restoration at subsequent visits is both time consuming and may alter the soft tissues and bone levels around the

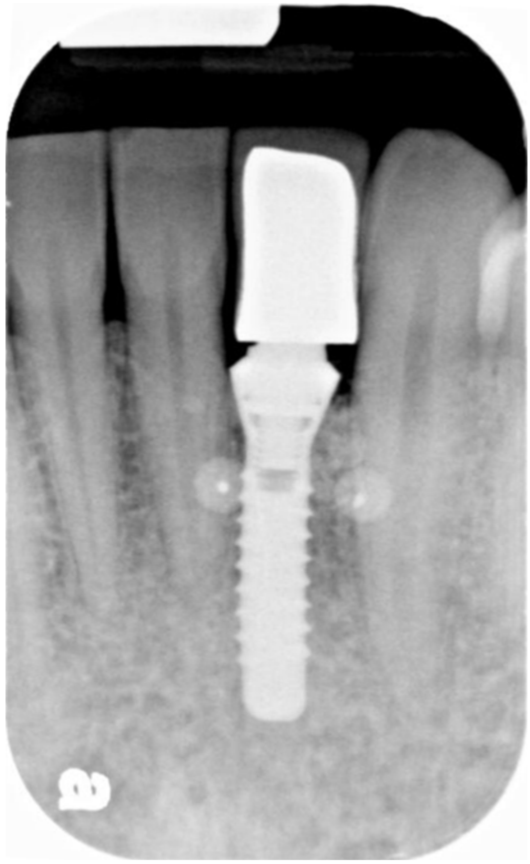

Fig. 10.16 This restoration was cemented onto the abutment. No pre-cementation radiograph was made; the crown did not seat as intended. It is likely the adjacent teeth contacted the restoration prematurely, preventing its placement. The restoring dentist failed to detect this error

implant, as it is known that the disruption caused by removal and replacement of the abutment may lead to loss of the implant supporting tissues. One means of standardizing IOR is to develop more practical devices that align the implant body to the X-ray beam precisely, but do not require the removal of the restoration on subsequent visits.

To date, few protocols have been developed that recommend specific time intervals for radiographic evaluation. However, data from one study suggests a correlation between probing attachment levels and radiographic presentation. It was noted that probing attachment levels obtained with a periodontal probe at 1, 3, and 6 months after loading proved to be a good indicator of peri-implant radiographic status at 2 years. Conversely, radiographically assessed tissue changes observed during the same test periods of 1, 3, and 6 months were good indicators of probing attachment levels expected at 2 years. This relationship between probing and radiographic evaluation may be used to assess examination needs, suggesting that when changes in probing levels occur, radiographic assessment may be advised. For longitudinal research purposes, it is recommended that radiographs be obtained at baseline, 1 year, 3 years, and 5 years, and thereafter every 5 years. How this relates to everyday clinical practice procedures has yet to be ascertained.

Conclusion

The usefulness of intraoral radiography has been described, along with its limitations when considering implant restorations. One major issue is the alignment of the incident X-rays so that they are consistently perpendicular to the implant body, to provide the most reliable information possible. Other limitations include inconsistencies as a result of the inability to verify the nature and extent of bone around an implant, which is subject to variation as a result of type of bone and site. Where implants are concerned, as a diagnostic tool, IOR should be considered as part of a multitude of tests—including probing, mobility, symptoms, and other soft tissue evaluations. It must be emphasized that IOR cannot be relied upon as being the sole diagnostic test.

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