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Intraoral Radiography and Dental Implant Restoration

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Intraoral Radiography and Dental Implant Restoration

Effective Date: 08/1/2012 Expiration Date: 08/1/2015

LEARNING OBJECTIVES

After participating in this CE activity, the individual will learn:

- The clinical advantages and limitations of intraoral radiography when restoring dental implants.
- Clinical examples of common radiographic effects when imaging dental implants during the restorative phase.

ABOUT THE AUTHORS

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Disclosure: *Dr. Wadhwani reports no disclosures.*

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Disclosure: *Dr. Schuler reports no disclosures.*

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Disclosure: *Dr. Taylor reports no disclosures.*

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INTRODUCTION

The planning stages of implant dentistry often involve sophisticated imaging equipment and techniques, which most dental offices do not presently possess. This is in contrast to the implant restorative phases where intraoral radiography (IOR) is more commonly used as a diagnostic tool. The equipment necessary for IOR is readily available in most dental offices, and when used appropriately it can provide clinically relevant information in a minimally invasive, inexpensive, and immediate manner. It is currently the preferred method for most clinicians when evaluating hard dental tissues, especially bone where implants are involved.

Some of the advantages IOR can offer when evaluating body tissues include: the detection of pathology, visualization of trabecular bone pattern, and highlighting of anatomical aberrations and adjacent tooth angulations that may affect the restoration path of insertion. IOR can also offer useful information with respect to the mechanical alignment and union of the implant components. 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.

Limitations with the use of IOR also 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. The diagnostic yield of any given radiograph may vary, depending upon the pathological process being identified as well as the ability of the clinician evaluating the radiographic image. It has been reported that IOR can yield false negatives; in other words, a disease process or issue may be present but may not be detected, especially in the early pathological and/or bone remodeling phase[1,2] (Figure 1).

IOR, when used with implant therapy, should be considered part of the evaluation process along with other clinical assessment methods. For example, IOR can supplement the clinical implant site examination in which signs of inflammation, recession, probing pocket depth and mobility are also assessed.[3] 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 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 article 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. General limitations of use of IOR as well as specific equipment variations will also be highlighted.

Figure 1.
This implant had a nonhealing stoma, some vertical radiographic bone loss, but no radiolucency noted between the implant and the surrounding native bone.

Figure 2.
Periapical radiograph prior to final restoration with custom-made acrylic healing abutment. The bone quantity and quality, as well as adjacent structures, are evaluated for pathosis, position, angulation, and any anatomical structures that need to be considered.

INTRAORAL RADIOGRAPHY AND EVALUATING THE PERI-IMPLANT TISSUES

Implant dentistry frequently focuses on the bone directly adjacent to the implant. In fact, osseointegration[4,5] is defined as "the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening connective tissue" (Figure 2). However, IOR has limitations in the diagnosis of osseointegration, as direct bone contact cannot be accurately determined. One major limitation of using IOR to assess bone-to-implant contact is the inability to discern bone levels directly facial and lingual to the implant body, as these sites will be obscured by the implant itself.

A study on the accuracy of radiographic diagnosis of peri-implant radiolucencies evaluated implants that were inserted

into bone and radiographed under standardized conditions.[6] An implant with intimate contact to bone was compared to others where an intentional gap was created between the implant and the socket. Ten experienced implant clinicians compared radiographs of these sites and were asked to judge the likelihood that a space was present. The inter-observer agreement was low and the diagnostic accuracy was greatest only when a 0.175 mm space existed. It was concluded that radiographs were an unreliable method for diagnosing peri-implant spaces; however, their value improved with increasing space widths 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.

Another issue when considering bone-to-implant contact is the amount of bone that contacts the implant body. Implants are generally placed into cancellous or alveolar bone. The word alveolar is derived from the Latin *alveolus*, meaning "little cavity." Thus, the bone is not solid, but rather consists of many little cavities within it. This results in the actual bone contact often being limited to only 35% to 40% of the implant surface[7] (Figure 3). The alveolar or marrow spaces are filled with readily displaced nonmineralized material, and their existence is frequently highlighted by endodontic processes (Figure 4).

Other limitations with the use of IOR when evaluating bone tissue in general similarly include the lack of ability to accurately reflect the existence of normal or pathogenic conditions.[1] Studies have reported on the lack of correlation between radiographic findings and some disease processes within the mandible and maxilla, especially when the cancellous bone was involved.[1,2]

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, even 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.[3]

Marginal bone height around implants has been used as a measure for monitoring bone health. Again, *in vitro* studies have reported on potential errors,[8,9] suggesting in clinical cases that 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.[8] 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.

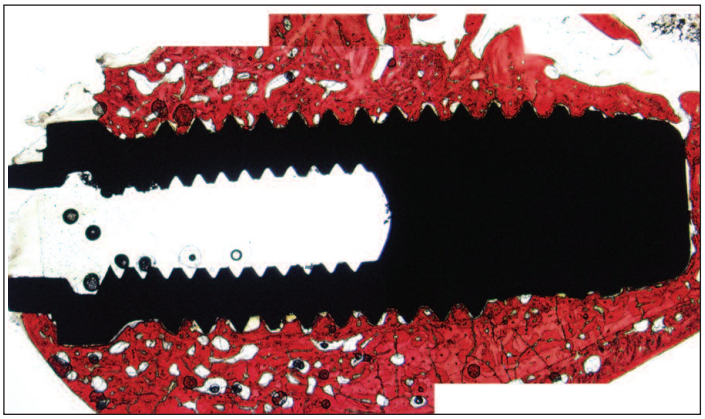


Figure 3. Histological section of an osseointegrated implant. The red part is the bone, the black item is the implant. Notice the tight adaptation of bone to the implant. Thirty-five percent to 40% of the mineralized content is in contact with the implant surface.

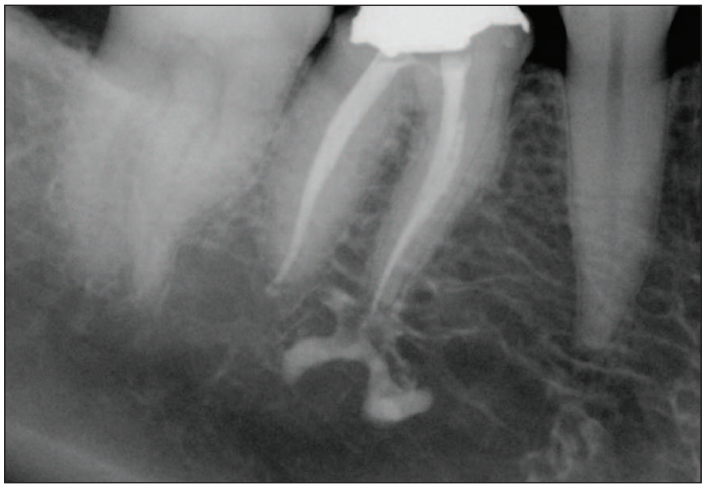


Figure 4. An example of alveolar spaces. The endodontist has used calcium hydroxide as an interim treatment. During the process of placing this into the root canal system, some has been extruded. Note the radiopacity in areas of the alveolar spaces that were previously occupied by marrow space.

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 (Figure 5). IOR can be a useful adjunct to determine the accuracy of fit for a prosthesis.[10,11] 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.[12]

Again, limitations of IOR have been reported. An in vitro study[10] analyzed the possibility of radiography detecting slits or gaps due to incomplete component connection. The authors concluded that in clinical cases, a demonstration of incomplete abutment-implant connection by the use of the recommended radiographic technique is to some extent fortuitous. When evaluating for the fit of implant components, the radiographic image is subject to distortions as a result of angulation effects. Several studies have evaluated these artifacts and how they develop,[11,13] 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 (Figure 6a). However, if the implant has been previously restored, it may be more difficult to determine the orientation without first removing the restoration (Figure 6b). 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.[13] Gaps of 0.1 mm or larger can also be detected with 10° to 15° x-ray beam incidence away from the long axis. However, when the incident beam is greater than 10° to 15° (Figures 7a to 7c), these gaps also become obscured (Figures 8a to 8d). If the goal of treatment is to determine exacting component fit, then clearly the tube angulation must be strictly controlled (Figures 9a and 9b). In the horizontal plane, if the incident x-rays are perpendicular to the long axis of the implant, 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 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; eg, RINN systems (DENTSPLY RINN). However, the holder should be oriented relative to the implant long axis rather than the

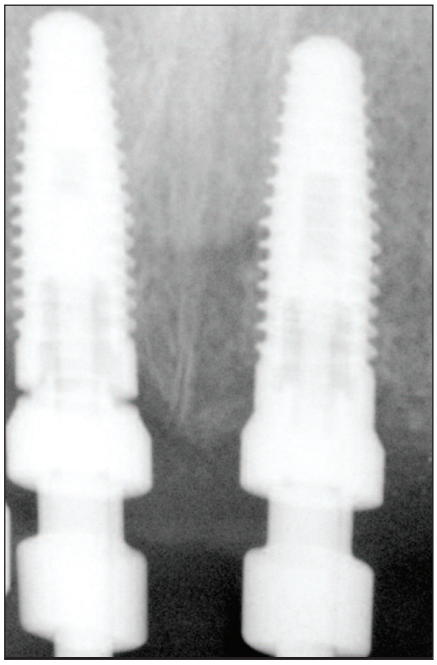


Figure 5. Commencement of the restoration; the first stage usually involves impressioning. The abutment "felt" as though it were fully seated. The radiograph shows the abutment failed to seat correctly.

Figures 6a and 6b. **(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)** Once restored, the implant's orientation must be estimated.

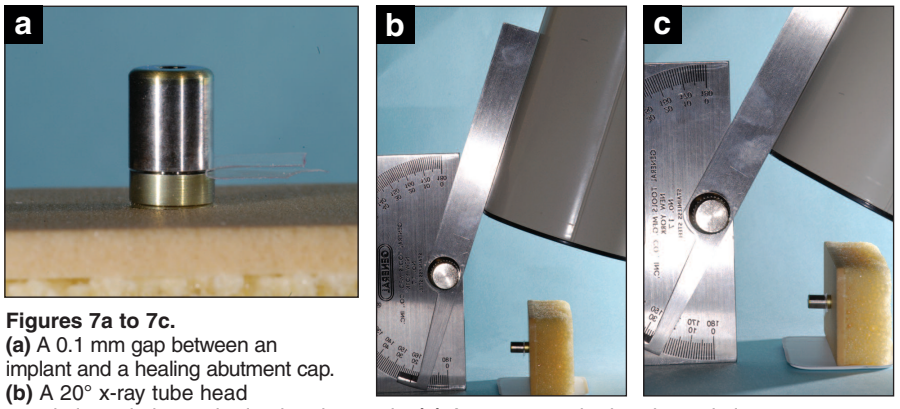
occlusal surfaces, which more commonly occurs and produces information that may be inaccurate.

The fit of splinted restoration on implants or a fixed partial denture may present with particular issues related to nonpassive fit.[12] Laboratory processes along with embedment relaxation effects that occur when metal components are connected with screw joints make multiple implant connection particularly susceptible to nonpassive fit errors. When evaluating seating of such a prosthesis, the individual implant positions must be accounted for with each attachment site (Figures 10a and 10b).

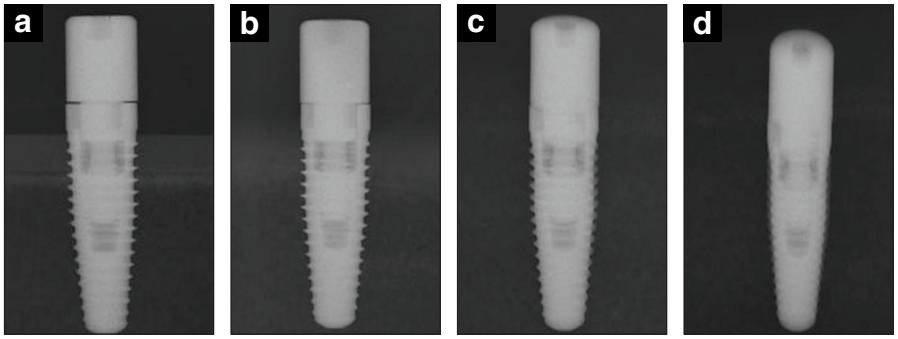
A means of quickly assessing the angulation of the implant angle relative to the radiographic film or sensor is the ability to visualize distinct screw thread patterns on the implant body itself. If the thread pattern is sharp and readily seen, then the x-ray beam will also be more likely to distinguish a gap in the fit of components if it exists (Figures 9a and 9b). Conversely, if the screw thread appears out of focus or diffuse without sharp distinct edges and gaps, then the ability to detect a misfit decreases (Figures 9a to 10b), as the angle of incidence of the x-ray is vertically too great.

Understanding the component structures and how these relate to the radiographic images seen is also vital for diagniosis of component fit (Figure 11). Implant components come with a variety of matching surfaces that can lead to misinterpretation of a radiographic image (Figures 12a and 12b). When an implant component only touches at the periphery, a radiographic anomaly known as the "peripheral eggshell effect" may result.[14] This could lead to the false impression that the components do not match or have failed. This would be an incorrect assumption.

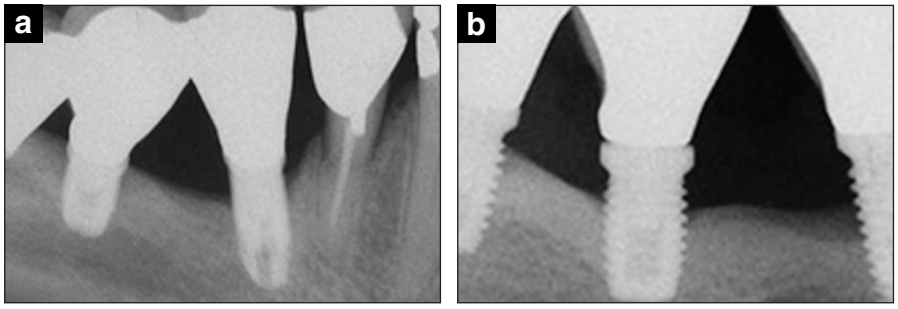
A protocol should be developed by the clinicain to determine when radiographs should be made; for example, when the component fit cannot be directly verified by sight or feel, which would include for the initial pick-up impression, seating of the abutment, and completion of the restoration. When a restoration is to be cemented onto an implant abutment and where a connection is not accessible—for example, it lies beneath the peri-implant tissues—it would be prudent to radiograph the components



Figures 7a to 7c. **(a)** A 0.1 mm gap between an implant and a healing abutment cap. **(b)** A 20° x-ray tube head angulation relative to the implant long axis. **(c)** A 30° x-ray tube head angulation.



Figures 8a to 8d. Radiographs of the 0.1 mm space in **Figure 7a** with different x-ray tube angulations. A = 0°; B = 10°; C = 20°; D = 30°. *Note how the screw thread pattern becomes obscured as the angle increases.*



Figures 9a and 9b. (a) The radiograph tube angulation is greater than 20°; the lack of prosthetic fit is not detectable. **(b)** A film made with a more appropriate tube angulation clearly reveals the problem.

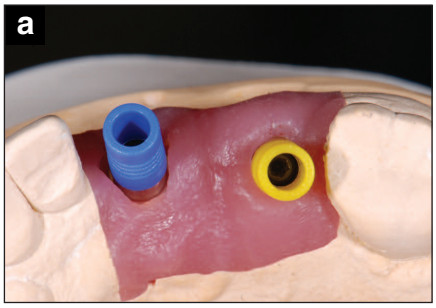
before final cementation to confirm they match as intended. This is to confirm that the abutment is correctly located onto the implant, as well as to confirm that the crown seats onto the abutment itself. Failure to do so may fail to detect errors as a result of fabrication, or components not seating (Figure 13).

CEMENTED IMPLANT RESTORATIONS

There is increasing evidence that residual excess cement may lead to peri-implant disease.[15-17] 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 as well as case studies have reported on the ability to detect commonly used implant cements radiographically.[18,19] The results indicated many cements would not be easily found, and some not at all, at any given thickness (Figures 14a to 14c). 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.[19] When a radiopaque cement is used, a radiograph may be used to determine if residual excess cement exists (Figure 15a).

IMPLANT HEALTH AND FOLLOW-UP

Much has been written about the success of dental implants, with radiographic evaluation used for measurements. The early criteria for implant success included values related to acceptable bone loss and time.[5] IOR has been used as a tool to evaluate hard-tissue health,[18] 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.[20] Early studies suggested that mineral loss needed to exceed 7% of the mass before it could 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 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

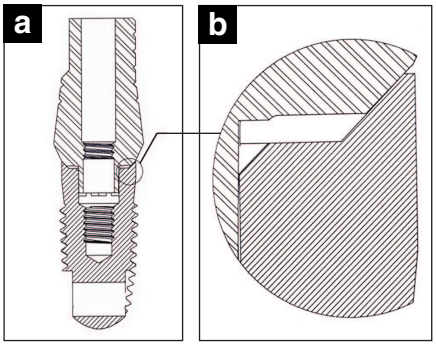


Figures 10a and 10b. **(a)** This cast shows the lack of parallelism of these 2 implants. They are to be restored using a screw-retained 3-unit bridge. **(b)** To assess adequacy of fit, 2 radiographs will be required, each one within 5° of the test implant long axis.

photostimulable phosphor systems.[20]

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 (Figures 15a and 15b). 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,[21-23] that allow the film, x-ray tube, and implant body axis to be

Figure 11. 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).

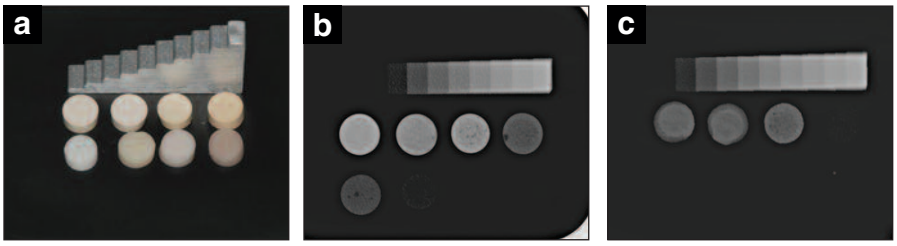


Figures 12a and 12b. Contact of the abutment to implant is on the periphery only, as seen in the enlarged section. In intraoral radiography images, the mesial and distal edges are augmented as a result of the x-ray's incident upon a curve (the PESE). The mid aspect of the implant appears less dense radiographically, giving the false impression of a problem. **(a)** Schematic of the implant abutment connenction. **(b)** Enlarged section of **a**.

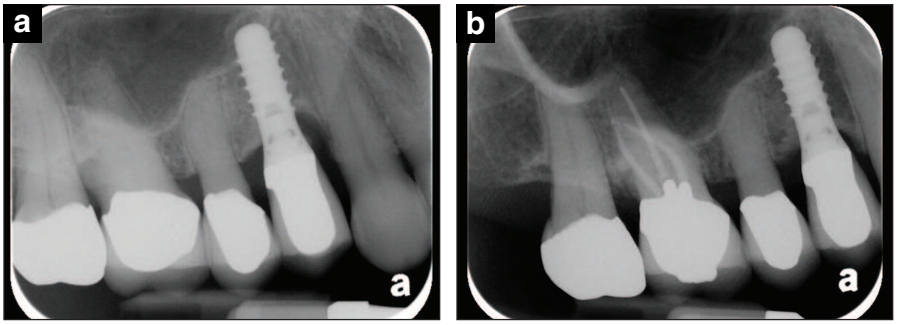
related. However, once the implant restoration is placed, this becomes impractical, as removal of the restoration at subsequent visits is both time consuming and may alter the soft tissues and bone levels around the implant.[23,24] It is known that the disruption caused by removal and replacement of 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.[21] It was noted that probing attachment levels obtained with a periodontal probe at one, 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 one, 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, one year, 3 years, and 5 years, and thereafter every 5 years.[21,23] How this relates to everyday clinical practice procedures has yet to be ascertained.

Figure 13. This restoration was cemented onto the abutment. No precementation 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.



Figures 14a to 14c. (a) Eight cement disks on a Scanex PSP Envelope (Air Techniques) prior to radiographic exposure. **(b)** At a disk thickness of 2 mm, only 6 cement specimens are visible radiographically. **(c)** At one-mm thickness, only 3 of the disks show on the radiographic image plate.



Figures 15a and 15b. Unless consecutive radiographic images are consistent, the ability to obtain useful diagnostic information is reduced. **(a)** Image of an implant with residual excess cement on the mesial aspect. The periodontist removed the cement and debrided the site. **(b)** Four years later it appears as though bone growth has occurred. However, the radiographs are at different angles, and it is likely that a different view is seen. The bone levels may not be any different.

SUMMARY

The usefulness of IOR 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 incon-sistencies 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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POST EXAMINATION QUESTIONS

1. **At which stage of implant therapy are radiographs most useful?**
   a. Planning.
   b. Surgical.
   c. Restorative.
   d. All of the above.

2. **Intraoral radiology (IOR) has been used to measure the health and success of implants. In order to do this the radiographs should:**
   a. Have a baseline record.
   b. Be taken every 3 months.
   c. Be sequential and standardized.
   d. Both a and c.

3. **Regarding osseointegration and IOR:**
   a. IOR is excellent for determining osseointegration.
   b. IOR gives information on bone contact at all sites of the implant.
   c. IOR will detect bone levels directly on the lingual and facial aspects of the implant body.
   d. IOR has limitations as it will not detect bone levels directly on the facial or lingual aspects of the implant body.

4. **Peri-implant radiolucencies next to the body of an implant:**
   a. May not be detected easily, unless a space of 0.175 mm or more exists.
   b. Are clearly visible.
   c. Always show up as a dark line on the radiographic image.
   d. Sometimes show up as a white line on the radiographic image.

5. **Bone-to-implant contact:**
   a. Is the same as osseointegration.
   b. Is usually 35% to 40% of the implant body in cancellous type bone.
   c. There is no bone to implant contact on an implant surface.
   d. Can be fully assessed from a periapical radiograph.

6. **What does the term *alveolar* mean?**
   a. Dense or compact.
   b. Little cavity.
   c. Jawbone.
   d. Same as cortical bone.

7. What is the generally accepted bone-to-implant contact percentage in alveolar bone in a well-integrated implant?

a. 100%.
b. 80% to 99%.
c. 60% to 65%.
d. 35% to 40%.

8. The degree of overestimation of buccal and lingual bone height when monitoring implant health is contributed to by:

a. The implant connection type.
b. The implant surface configuration.
c. The buccolingual position of the implant.
d. The mesial-distal position of the implant.

9. The accuracy with which IOR reflects the existence of disease in the mandible and maxilla is:

a. Always very accurate.
b. More difficult when evaluating cortical bone.
c. More difficult when cancellous bone is involved.
d. Never an issue.

10. Evaluating the fit of implant components with radiography is useful when:

a. The components are radiopaque.
b. The angle of the x-ray tube is perpendicular to the implant body.
c. The connection cannot be clearly visualized clinically, if under the soft tissues.
d. All of the above.

11. It is recommended that the implant site be radiographed prior to restoration:

a. To provide a baseline standard against which subsequent images can be compared.
b. To determine the implant body angle.
c. Only in instances when the connection between components cannot be otherwise determined.
d. To see if the screw threads are clearly visible on the image.

12. A gap between implant components of 0.05 mm can be detected on a radiograph if:

a. The head of the x-ray tube lies to the mesial of the implant by 5°.
b. The head of the x-ray tube is within 5 cm of the implant body.
c. The head of the x-ray tube is within 5° to the long axis of the implant body.
d. The head of the x-ray tube is within 10° to 15° of the long axis of the implant body.

13. A quick way to determine the relative angulation of an implant body to the incident x-rays is:

a. Relate the x-ray tube relative to the occlusal surface—it will always be 90°.
b. Estimate by looking at the restoration long axis.
c. Evaluate how clear and sharp the screw threads of the implant appear on the radiograph.
d. It does not matter—any angle of incidence will be useful.

14. What level of mineral loss in mandibular bone may have to occur before it can be detected on a film radiograph?

a. Up to 30%.
b. All the mineral must be lost.
c. 7%.
d. Less than that detectable in the maxilla.

15. 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.

a. The first statement is true, the second is false.
b. The first statement is false, the second is true.
c. Both statements are true.
d. Both statements are false.

16. Radiography is an adjunct to monitoring implant health and should:

a. Be used with other tests, and not purely relied on by itself.
b. Have an association with probing attachment levels that is useful.
c. Be applied according to a strategy to reduce patient exposure to radiation.
d. All of the above.

Intraoral Radiography and Dental Implant Restoration

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ANSWER FORM: COURSE #: 152

Please check the correct box for each question below.

1.	❑ a	❑ b	❑ c	❑ d	9.	❑ a	❑ b	❑ c	❑ d
2.	❑ a	❑ b	❑ c	❑ d	10.	❑ a	❑ b	❑ c	❑ d
3.	❑ a	❑ b	❑ c	❑ d	11.	❑ a	❑ b	❑ c	❑ d
4.	❑ a	❑ b	❑ c	❑ d	12.	❑ a	❑ b	❑ c	❑ d
5.	❑ a	❑ b	❑ c	❑ d	13.	❑ a	❑ b	❑ c	❑ d
6.	❑ a	❑ b	❑ c	❑ d	14.	❑ a	❑ b	❑ c	❑ d
7.	❑ a	❑ b	❑ c	❑ d	15.	❑ a	❑ b	❑ c	❑ d
8.	❑ a	❑ b	❑ c	❑ d	16.	❑ a	❑ b	❑ c	❑ d

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Please complete the following activity evaluation questions.

Rating Scale: Excellent = 5 and Poor = 0

Course objectives were achieved. _____

Content was useful and benefited your clinical practice. _____

Review questions were clear and relevant to the editorial. _____

Illustrations and photographs were clear and relevant. _____

Written presentation was informative and concise. _____

How much time did you spend reading the activity and completing the test? _____

What aspect of this course was most helpful and why?

What topics interest you for future *Dentistry Today* CE courses?