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Comparison of the diagnostic potential of direct digital and conventional intraoral radiography in the evaluation of peri-implant conditions

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Abstract: The aims of this study were to examine whether viewers agreed on details seen in direct (real time) digital and conventional film radiographs of implants, and whether there were differences in agreement between the systems. Intra-oral radiographs of implants were exposed both as direct digital and conventional film radiographs. Fifty pairs of radiographs with similar projection and exposure were selected, showing 59 implants. Ten viewers assessed the radiographs separately and noted eight different details. The viewers showed very high agreement in their assessments of radiographs of each technique separately, and there were no statistically significant differences. However, there was a tendency to stronger agreement in the direct digital radiographs in four assessed points out of eight. The patients' experience of having radiographs exposed with the two methods was also studied by questionnaire. The patients' opinions on the two techniques did not differ statistically. This study shows that digital radiography has at least equal diagnostic yield compared to film radiography.

Endosseous titanium implant therapy in the jaws is a routine procedure today. There are many systems based on the same principle and the method has been proven safe and reliable (Adell et al. 1990; Albrektsson & Sennerby 1991). Because of the routine nature of the implant method, the number of specialist consultations and follow-ups in each individual case has decreased. In uncomplicated cases, controls are no longer conducted as a joint venture with surgeon, prosthodontist and radiologist, but are performed by the surgeon and the prosthodontist separately. This means that their examinations must not be only clinical but also radiographic. Radiography is essential for the detection of misfits of components and non-integration. (Del Balso et al. 1994). The accuracy of diagnosis is, however, not agreed upon. Zarb & Schmitt (1990) were of the opinion that radiographic techniques result in poor diagnostic accuracy. Recent studies by specialists in oral radiology have demonstrated the reliability of radiographic examinations with small inter- and intraobserver variations in such variables as bone level and fixture integration (Sundén et al. 1995; Sewerin et al. 1997; Gröndahl et al. 1998).

Digital imaging techniques have been used for several years, and the advantages, e.g. radiation doses, time saved, the elimination of darkroom procedures, the pedagogical approach vis-à-vis the patient and opportunities for tele-consultations with radiologists are well known to be cost-effective and reliable. These clinical gains make considerable resources free for other purposes. An advantage of digital techniques that is not shared by conventional radiography is that images are not static, but may be manipulated by image processing to improve diagnosis (van der Stelt 1993; Wenzel 1993; Wenzel & Hintze 1993; van Overveld 1995).

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In spite of these facts, there is, to our knowledge, only a single congress abstract (Knutsen et al. 2000), and no peer-reviewed study, comparing the diagnostic yield of conventional and digital radiography as regards endosseous implant treatment.

Aims

The aims of the present study were to compare direct, sometimes known as real time, digital radiography to conventional film radiography in evaluating implant treatment, and to investigate the patients' experience of the two radiographic techniques.

Material and methods

Patients

Patients were randomly selected from those who came for routine diagnostic radiography of implants of all locations. As only the Brånemark System™ (Nobel Biocare, Gothenburg, Sweden) implants are used in the Department of Oral and Maxillofacial surgery in Västerås, no further winnowing was necessary.

The patient material consisted of a total of 30 patients, 23 women and seven men. Their ages ranged from 16 to 86 years, and all decades were represented.

The questionnaire

All patients were asked to give their written consent, and filled in a questionnaire form.

The patients were asked to mark two different Visual Analogue Scales (VAS), for digital and conventional radiographs, respectively, concerning 'discomfort' and 'pain'. The extremes of the scales were 'no discomfort/pain' and 'extremely uncomfortable/painful'. Patients were also given the opportunity to make a written comment. The radiographer kept notes of any difficulties during the examinations.

Radiographic examination

All radiographs were exposed with the same X-ray unit; a Philips Oralix 65S (Dentsply Inc., York, PA, USA) operated at 65 kVp. Paralleling technique was employed and the focus-to-film distance was approximately 25 cm. Exposure times for direct digital radiographs were 0.10–0.16 s, for conventional film radiographs the exposure times were from 0.32 to 0.64 s.

For conventional radiographs, E-speed film was used (Ektaspeed™, Eastman Kodak Co., Rochester, NY, USA). All conventional radiographs were developed in an automatic development machine, Dürr Dental XR 24 (Dürr Dental, Bietigheim-Bissingen, Germany), where all solutions were changed every 8 weeks, and were continuously replenished.

Direct digital radiographs were exposed with the Sens-A-Ray™ system (Regam Medical Systems International AB, Sundsvall, Sweden), which uses charge coupled device (CCD) technique without optics or scintillator.

In order to compare the diagnostic yield of film and direct digital imaging systems, two sets of radiographs were exposed according to the same clinical protocol. Care was taken to make the radiographic projections in films and the direct digital radiographs as similar as possible. Figures 1 and 2. However, no more than two retakes were attempted in any examination. Most radiographs were exposed by a dental nurse with extensive training and experience in radiographic work.

Radiographic evaluation

Ten dentists assessed each implant radiograph. All were working in the field of oral radiology; five were specialists and five were postgraduate students.

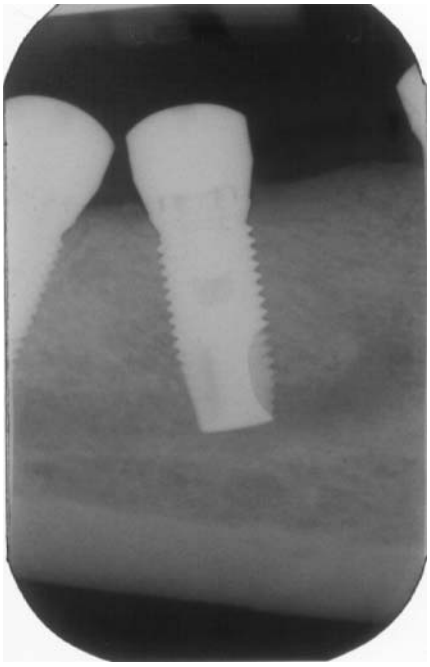

Fig. 1. Example of conventional film radiograph.

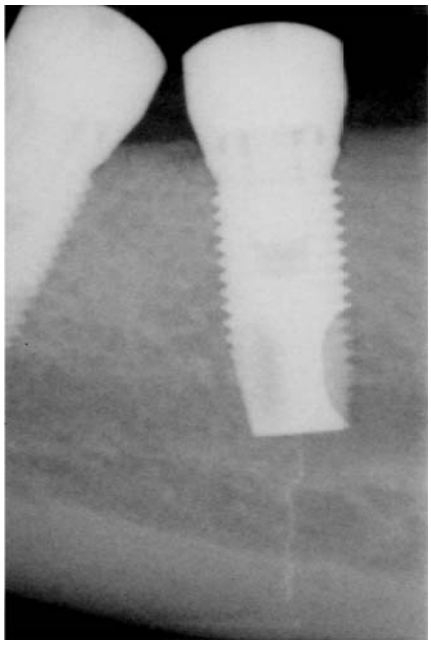

Fig. 2. Example of direct digital radiograph.

All radiographs were presented with the apical part of the implant pointing downwards. Implants next to teeth with fillings were avoided. This was done to avoid that viewers unintentionally memorised certain cases.

Conventional film radiographs were examined in a darkened room with the aid of a light box and a viewer that screened off extraneous light and with two times magnification. Direct digital radiographs were presented on a monitor with brightness and contrast pre-set by the authors. Viewers were invited to utilise the following digital image processing options: changes of brightness and contrast; inverting grey scale; edge enhancement; line profiles of grey level variations; histograms and pseudo-colouring. However, no record was kept of options used, or even if any were used at all.

The following variables were examined: presence of gap between the implant and abutment, yes or no; number of threads above the bony crest, left and right – because all radiographs were presented with their apical part down, the terms mesial and distal were not used; any misfit of the internal screw, yes or no; any presence of a radiolucent zone between the implant and surrounding bone, when present its location and extension was recorded and whether or not the radiographs were regarded as adequate for the above assessments.

Viewers were asked to give additional comments on each radiograph when appropriate.

Statistical methods

Fifty-nine implants were considered the statistical units in an agreement study. Ten viewers examined the implants in conventional films and direct digital radiographs. The agreement within each method was calculated by the *kappa* coefficient of agreement (K) and by the total proportion of agreement [P(A)]. The *kappa* coefficient is the ratio of the proportion of times that viewers agree, corrected for chance agreement, to the maximum proportion of times that viewers could agree, corrected for chance agreement.

$$K = \frac{P(A) - P(E)}{1 - P(E)} \quad (1)$$

where P(A) is the proportion of times that the viewers agree and P(E) is the proportion of times that we would expect the viewers to agree by chance. The extent of agreement among the viewers concerning each implant is the proportion of the number of pairs for which there is agreement to the possible pairs of assignments. To obtain the total proportion of agreement, P (A), the average of these proportions across all implants assessed were computed.

In *kappa* statistics, if the agreement among the viewers is neutral, i.e. what would be expected by chance, then K = 0, whereas K = 1 when there is total agreement among the viewers. If the viewers are in total disagreement, then K = −1, if the expected proportion of agreement is 50%, otherwise K lies between −1 and −0.5. *Kappa* is influenced if the observed proportion of agreement varies from the expected proportion of agreement. If the observation is skewed, K will be lower, as it will also be if the possible categories are many. Landis & Koch (1977) suggested that values of K less than 0.20 reflect poor agreement, values of K between 0.21 and 0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good agreement and values of K above 0.81 indicate very good agreement. However, it is misleading to compare values of K from different variables as K depends on the number of categories and also on the proportion of subjects in each category, which results in very different expected frequencies by chance. Thus, lower kappa values must ensue in the categories where there are more than two choices, e.g. number of threads above the bony crest. In order to compare the two methods the proportion of the number of pairs for which there is agreement to the possible pairs of assignments for each implant within each method was calculated. These scores could range from 0, i.e. no agreement among the 10 viewers, to 1, i.e. complete agreement among the viewers. The total proportion scores were then analysed by the Wilcoxon Matched Pairs Test.

The patients' discomfort and pain in connection to the two different examinations were assessed by marking four analogue scales (VAS) with the anchor points 'no discomfort/pain' (0) and 'extremely uncomfortable/painful' (100). To compare the patients' VAS scores for conventional and digital radiography the Friedman analysis of variance by ranks was performed (Siegel & Castellan 1989).

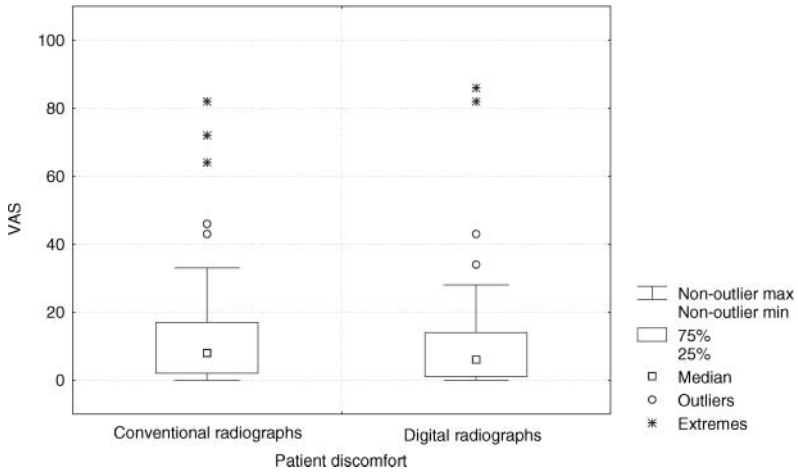

Fig. 3. Patient discomfort.

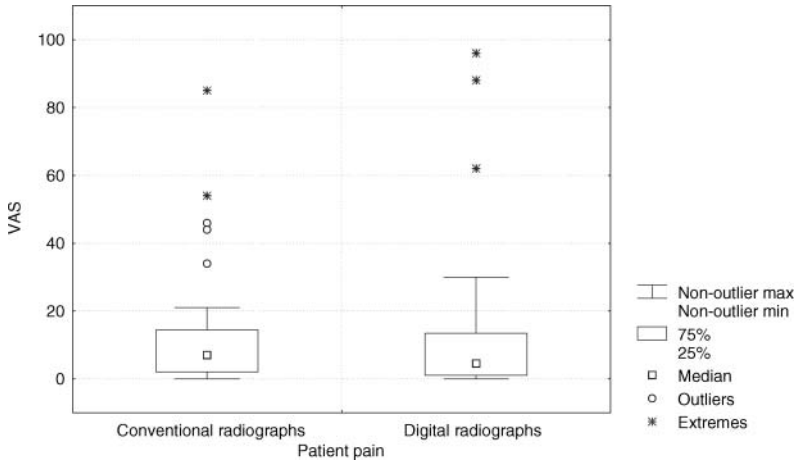

Fig. 4. Patient pain.

Results

Exclusions

In all, 45 patients were asked for consent to make duplicate examinations. Forty-three patients gave their written consent, and two declined. When radiographs were examined for selection, those from five patients had obvious pathological changes and were excluded after conference, as it was felt that these implants would be too easy to remember inadvertently, and thus would influence results of comparisons between film and digital radiographs. Radiographs from eight patients were excluded because the radiographic examinations were unsatisfactory due to varying causes, such as differences in projection. Thirty patients remained and were included in the material, 23 women and seven men. The number of pairs of film and digital radiographs totalled 50, 39 from

women and 11 from men. In all, 59 implants were examined.

Patient evaluation

The results of the patients' evaluation are shown in Figs 3 and 4. Most patients found the experience of the direct digital examination no different from conventional film radiography. Some patients had difficulties, but all of these patients had equal difficulties with both methods. No statistical differences between the methods with respect to VAS discomfort and VAS pain could be demonstrated.

The patients were very interested in the real time digital method, and many were fascinated with at last seeing their own implants, having been unable to decipher what they had been shown in ordinary radiographs. Some comments were: 'Faster, bigger, better. I could see my own teeth!'; 'Ordinary X-rays take more time. With the computer the patient can participate and understand much better. I'm for digital radiography!'; 'Not at all difficult. Very interesting!'; 'Interesting to see my screws. I could see for myself that they were OK.'.

Viewers' evaluation of the different variables

The results are summarised in Table 1. The two radiographic methods were compared with respect to agreement among viewers. The proportion of agreement for each implant within each method was then calculated. A high proportion of agreement was taken to mean a more certain assessment. The total proportion of agreement has been calculated, i.e. it was taken into consideration how many of the viewers agreed on each variable assessed. Thus, only if all viewers had given the same assessment on one variable would 100% have been attained. For instance, the score of 93% in the first column means that out of 590 possible, there was perfect agreement in 555 instances, the score of 96% signifying 572 perfect agreements. The scores for the variables which are not answered dichotomously, e.g. number of threads above the bony crest, are calculated in like fashion, but as the number of possible answers increase, it should be noted that the percentage of agreement decreases. In comparisons between the methods, the proportion scores were analysed by the Wilcoxon Matched Pairs Test. For most of the implants, viewers were in complete agreement, but for some implants they differed. Regarding four of eight variables, the total proportion of agreement for the digital method was somewhat higher than for the conventional method. The total proportion of agreement was slightly higher in one variable of eight for the conventional method (number of threads above the bony crest right). Note, however, that the kappa value is still better for the direct digital technique, because more viewers were uncertain in their assessment for this variable

Table 1. **Agreement between viewers**

	Total proportion of agreement P(A)	Kappa co-efficient	*P*-value	Wilcoxon matched Pairs Test *P*-value[a]
Presence of gap between the implant and abutment – yes or no				
Conventional radiographs	93%	0.28	0.101	
Digital radiographs	96%	0.60	< 0.001	0.187
Number of threads above the bony crest left				
Conventional radiographs	83%	0.30	0.002	
Digital radiographs	87%	0.53	< 0.001	0.227
Number of threads above the bony crest right				
Conventional radiographs	87%	0.38	< 0.001	
Digital radiographs	81%	0.46	< 0.001	0.079
Any presence of a radiolucent				
zone between the implant and surrounding bone left side				
Conventional radiographs	93%	0.33	0.055	
Digital radiographs	94%	0.30	0.088	0.862
Any presence of a radiolucentone between the implant and surrounding bone right side				
Conventional radiographs	92%	0.14	0.424	
Digital radiographs	96%	0.55	0.002	0.052
Location of end of radiolucent bone if present, left side				
Conventional radiographs	93%	0.25	0.161	
Digital radiographs	93%	0.21	0.241	0.952
Location of end of radiolucent bone if present, right side				
Conventional radiographs	92%	0.13	0.474	
Digital radiographs	95%	0.43	0.016	0.179
Whether the properties of theadiographs were sufficient to make the above assessments				
Conventional radiographs	95%	0.18	0.389	
Digital radiographs	94%	0.19	0.342	0.877

[a]Comparisons between conventional and direct digital methods concerning the proportion of agreement for each implant.

in the conventional radiographs. However, no statistically significant differences between the methods could be demonstrated concerning the total proportion of agreement for the different variables.

Some viewers deemed that they could not assess a few of the implants in the radiographs. However, in some cases when there were two implants in one radiograph, one was assessable and the other not. Thus, eight or nine viewers out of 10 deemed most implants assessable. Accordingly, only 22 digital and 20 conventional implant images out of 590 of each were deemed not diagnostic.

Discussion

The results of this study indicate that there are no differences in clinical yield between conventional film and direct (real time) digital radiography. This study pertains to CCD technique, but the results should be applicable to all kinds of digital systems, providing, of course, that technical properties such as resolution and contrast are on par. Indirect digital techniques, i.e. those using storage phosphor, have of course all the same advantages except for not being real time. If this is taken into consideration together with all the advantages of digital techniques, including the low dose to the patient, there are apparent reasons that all examinations be made with direct, or indirect, digital techniques.

The fact that the patients found the direct digital examination just as convenient as conventional film radiography adds to these reasons.

There are technical differences between the two methods. We have opted to study the interpretation of the information obtained by the two techniques and not technical properties. The statistical method used only compares agreement, as we wanted an approach without preconceived opinions on diagnoses, which are of course subjective. The highest *kappa* value in this study is 0.60, which would denote only moderate agreement. However, it should be noted that *kappa* values in studies on agreement among radiologists seldom reach high values, as shown by Boyd et al. (1982). Also, as several viewers pointed out, a diagnosis cannot be made from one radiograph. Further studies with matched sets of two or more radiographs using two or more different techniques could elucidate the differences in diagnostic potential.

One of the problems with all digital radiography is that it is difficult to set the exposure time, as exposure steps have up to now been adapted to the less sensitive films. Several viewers found certain direct digital radiographs slightly overexposed. Digital image processing may, however, compensate for this.

All viewers were more experienced in assessing conventional film radiographs. In spite of this there were no differences in the results between the two methods. All statistical results showed viewers to be equally certain when using both modes of radiography. However, there was a tendency to more consistent evaluations in digital radiographs.

Today, digital techniques are becoming common in oral radiography, and are successively replacing film techniques. The quality and technical properties of digital radiographs have been assessed by several authors (e.g. Welander et al. 1993, 1994; van Overveld 1995; Welander et al. 1995; Kullendorff et al. 1996a; Mörner et al. 1998). Digital techniques allow for multiple copying of each radiograph and the use of the Internet for rapid communications. They are environment friendly, and allow image processing while maintaining the original. Digital techniques are cost effective in the long perspective.

A number of studies have been performed to evaluate digital radiography as a tool in diagnosis. The results all show that digital techniques have properties and qualities equal or better than film radiography, even though many have been *in vitro* studies (Furkart et al. 1992; Gulobow et al. 1994; Hedrick et al. 1994; Hintze et al. 1994; Yokotoa et al. 1994; Stassinakis et al. 1995; Wenzel et al. 1996), and/or have focused on such dental problems as caries (Hintze et al. 1994; Razmus 1994; Wenzel et al. 1996), periodontal disease (Razmus 1994), periapical lesions (Furkart et al. 1992; Razmus 1994; Yokotoa et al. 1994; Stassinakis et al. 1995; Kullendorff et al. 1996a, 1996b, 1997), and endodontics (Hedrick et al. 1994).

There is no therefore no further question of whether or not oral radiology should become digital.

Ethical approval

This study was approved by the ethics committee at Uppsala University, Sweden, Dnr 97368.

Acknowledgements: Specialist dental nurse Eleonor Jepsen in Västerås exposed most of the radiographs. The Sens-A-Ray™ equipment, lent by the Department of Oral Radiology in Huddinge University Hospital, Karolinska Institutet, was installed by, and in a computer personally lent by, Göran Mörner, Computer systems developer, ADCORE, Stockholm, Sweden. The statistics were developed and analysed by Elisabeth Berg, B.Sc., Department of Statistics, Karolinska Institutet.

Résumé

Les buts de l'étude présente ont été d'examiner les variations inter observateurs envers les détails aperçus dans les radiographies d'implants prises soit de manière conventionnelle, soit de manière digitale et d'observer les différences entre ces deux systèmes. Des radiographies intrabuccales des implants ont été exposées tant de manière conventionnelle que de manière digitale. Cinquante paires de radiographies avec une projection et une exposition semblables ont été sélectionnnées, celles-ci montraient 59 implants. Dix observateurs ont évalué les radiographies séparément et notés huit détails différents. Les observateurs montraient un accord important dans l'estimation des radiographies de chaque technique séparément, et il n'y a eu aucune différence significative. Cependant, il y avait une tendance vers un accord plus important envers la radiographie digitale directe sur quatre des huits points. L'expérience radiographique des patients soumis aux deux techniques a aussi été étudié par questionnaire. L'opinion des patients n'était pas différente pour les deux techniques. Cette étude montre que la radiographie digitale apporte au moins un diagnostic égal à celui du film radiographique.

Zusammenfassung

In dieser Studie sollte untersucht werden, ob Betrachter auf direkten (echtzeit) digitalen und konventionellen Röntgenbildern von Implantaten übereinstimmende Details sehen und ob Unterschiede in der Uebereinstimmung zwischen den Systemen bestehen. Intraorale Röntgenbilder von Implantaten wurden sowohl als direkte digitale als auch als konventionelle Röntgenbilder aufgenommen. Fünfzig Paare von Röntgenbildern mit ähnlicher Projektion und Exposition wurden ausgewählt. Darauf waren 59 Implantate zu sehen. Zehn Betrachter werteten die Röntgenbilder einzeln aus und notierten acht verschiedene Einzelheiten. Die Betrachter zeigten eine sehr hohe Uebereinstimmung bei der Auswertung der Röntgenbilder jeder einzelnen Technik und es bestanden keine statistisch signifikanten Unterschiede. Es bestand jedoch eine Tendenz zur besseren Uebereinstimmung bei vier von acht ausgewerteten Punkten bei den direkten digitalen Röntgenbildern. Die Erfahrungen der Patienten, bei welchen Röntgenaufnahmen mit beiden Techniken aufgenommen wurden, wurde mittels Fragebogen ausgewertet. Es bestanden keine statistisch signifikanten Unterschiede in der Meinung der Patienten über beide Techniken. Diese Studie zeigt, dass die digitale Ra-

diographie zumindest die gleiche diagnostische Aussagekraft wie die konventionelle Filmradiographie hat.

Resumen

Las intenciones del presente estudio fueron examinar si los observadores coincidían en los detalles observados en radiografías digitales en directo (tiempo real) o en película convencional de implantes, y si hubieron diferencias entre las coincidencias entre los sistemas. Se sacaron radiografías intraorales de implantes tanto como radiografías digitales en directo como en película convencional. Se seleccionaron cincuenta pares de radiografías con similar proyección y exposición mostrando 59 implantes. Diez observadores valoraron las radiografías separadamente y anotaron ocho detalles diferentes. Los observadores mostraron una coincidencia muy grande en sus valoraciones de las radiografías de cada técnica separadamente, y no hubo diferencias estadísticamente significativas. De todos modos, hubo una tendencia hacia una coincidencia mas fuerte en las radiografías directas digitales en cuatro de ocho puntos valorados. La experiencia de los pacientes acerca de exponerse a radiografías por los dos métodos se estudió también con un cuestionario. La opinión de los pacientes sobre las dos técnicas no se diferenció estadísticamente. Este estudio muestra que la radiografía digital tiene por lo menos los mismos resultados diagnósticos comparada con la película radiográfica.

要旨

本研究では、インプラントの直接の（リアルタイム）デジタル・レントゲンと従来のフィルム・レントゲンにおいて見られる詳細について読影者の見解が一致するどうか、システム間で一致度に差異があるかどうかを調べた。インプラントの口腔内レントゲン像を、直接デジタル・レントゲン像および従来のフィルム・レントゲン像として示した。５９本のインプラントを示す、類似の投射と暴露条件の５０対のレントゲン像を選んだ。１０人の読影者が個別にレントゲン像を評価し、８つの異なる詳細項目を記録した。読影者はテクニック毎の各レントゲン像の評価においては非常に高い一致度を示し、統計的な有意差はなかった。しかし、評価した８項目のうち４項目においては直接デジタル・レントゲン像の方が一致度が高い傾向があった。

２つのレントゲン撮影方法を経験した患者の経験もアンケートによって調べた。２つのテクニックに対する患者の意見に統計的な差はなかった。本研究は、フィルム・レントゲンに比べてデジタル・レントゲンは少なくとも同等の診断上の成果をあげることを示している。

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