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Dental radiographic diagnostic resolution with minimal exposure

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Abstract

Six test dental radiographic films with varying resolutions and exposure times were evaluated diagnostically by 334 dentists. Each dentist completed a questionnaire relative to observations, dental education, practice profile, film utilization, and opinions on how electronic enhancement of the film affected his diagnostic ability. More than 60% identified 12-20 paired lines per mm of resolution on three of the dental films. Five per cent never take full-mouth radiographs, 45.5% take them every 5 to 10 years, 41.2% every 2 to 4 years, and 8.3% more frequently than every 1 to 2 years. The dentists were asked to rank radiographs from the best to the least diagnostic. Ektaspeed® film was ranked as the best, although it has the third longest exposure. Xeroradiography had the shortest exposure and 72% felt it had the highest resolution. However, this technique was rated only third best, even though it appeared to be the best performing film tested and was rated best by 36%.

The lack of a measurement range for an optimal diagnostic resolution in dental radiographs can result in over-radiation of patients. This possibility exists since improving resolution in dental radiographs often increases radiation exposure. It has been suggested that electronically enhanced radiographs may allow diagnosticians to make adequate diagnoses with reduced radiation exposure for patients.[1-3] Accordingly, the purpose of this study was formulated as follows:

1. To determine the minimal radiographic exposure and optimal diagnostic resolution, in paired lines per mm of anatomic structures on selected dental radiographs, as identified by practicing dentists
2. To determine whether dental radiographs made with minimal radiation exposure can be enhanced electronically to produce optimal diagnostic resolution, as identified by the same dentists.

Possible correlations between these objectives and the characteristic profile of the dentist study population, such as age, educational background, and type of specialty or general practice, will be discussed in a later study.

Literature Review

L.R. Manson-Hing[4] has stated that the quality of a radiographic image is determined by the interplay of several factors: contrast, radiographic mottle, and resolution. He defined resolution as the measurement of a system's ability to produce separate images of objects separated by a small distance, and advocated the use of a standard multi-line test object which has different line pairs in groups of four that vary from 0.25 to 10 line pairs per mm. According to Manson-Hing, "Ten line pairs per mm resolution is approximately the highest that human eyes can see in clinical diagnostic radiographs." In regard to the factor of contrast, Ove Mattsson[5] suggested the step-wedge technique as a means of evaluating the contrasting ability of a radiograph.

Fishel and Tamse[6] discussed several possible factors in incorrect radiographic diagnosis by dentists: (1) lack of knowledge, (2) physical defects in the retinal-optic, nerve-cortex complex, (3) irregular reading, (4) incomplete reading, (5) amount of light falling on the eye, (6) accumulative experience, (7) environmental noise, (8) defective radiographs, and (9) contrast.

Metz[4] outlined a mathematical method of evaluating a diagnostician's accuracy. However, he con-

ceded that the relationship between the physical properties of an image — such as resolution and contrast — and the ability of the clinician to detect and interpret the image features is not well understood. Interferences and such complications as background structure, normal anatomic variations, and observer training must be taken into account.

Gratt et al.[8] concluded that intraoral xerography appears to be a highly accurate, low-radiation, rapid, and convenient alternative to conventional intraoral radiographs. Xeroradiography was shown to have higher resolving power, with a greater latitude of exposure and edge enhancement. Other advantages of the system included reduction of radiation exposure by two-thirds, production of permanent dry images in only 20 sec, and greater economy.

Television first was used in dental research in 1963 with the development of the television microscope for measurement.[6,7] Television also was used to enhance the radiographic characteristics of the region of diagnostic importance by electronically mixing the normal radiographic or positive television image with the separated negative image.[8-10]

Methods and Materials

A mixed dentition, dried mandible with some unusual inverted developing permanent teeth was used in this study. The area of study was imbedded with Mix-D wax[11] to produce a radiolucency equivalent to skin and connective tissues. A 40" constant distance platform (Fig 1) was constructed and the angle of the x-ray head was fixed at a right angle relative to a custom-designed specimen film holder assembly fixed to the platform. The film holder assembly contained a custom-designed radiograph density step wedge[12] and a resolution radiograph paired line test pattern (Fig 2).

X-ray film screen combinations were selected (Table 1) which would create film resolutions lower than the usually available dental x-ray films with both lower and higher exposures. These film screen combinations were cut to fit the occlusal radiograph cassette for exposure. The dental xeroradiograph, in its developmental stage, was available in only one size.[8] Therefore, three exposures were necessary to cover the area. These exposures were made by the xeroradiograph manufacturer to the visual density range of the other test films, since the xeroradiograph is translucent. All radiographs were of the same general density range (Table 1) as measured at the first and last step by a densitometer.[a] Table 1 indicates the estimated paired line per mm resolution obtained by the four investigators at 10x magnification of the various film, screen, and exposure combinations. These resolutions were utilized in obtaining the test radiographs for diagnosis by the dentist population.

All film development was as directed by the manufacturer. Six sets of films were made and coded so that the dentists were not aware of the type of film they were observing. Individual films were bound in glass slides of a uniform size for viewing on a radiograph viewing box. The slides were taped to the box to eliminate extraneous light around each radiograph (Fig 2).

A questionnaire was designed to elicit information relative to details of radiographic diagnosis and the dentist's assessment of the resolution of each of the test films. The dentist was asked to respond with a *Yes, No,* or *Cannot determine* answer as to whether each of the selected anatomic structures could be identified upon viewing the radiographs. The paired lines per mm viewed by the dentist on that film also were recorded. The optimal diagnostic resolution film for a particular dentist was the one which he assessed as having the most paired lines and which also elic-

[a] MacBeth Quanta Log Densitometer Model OP 10.

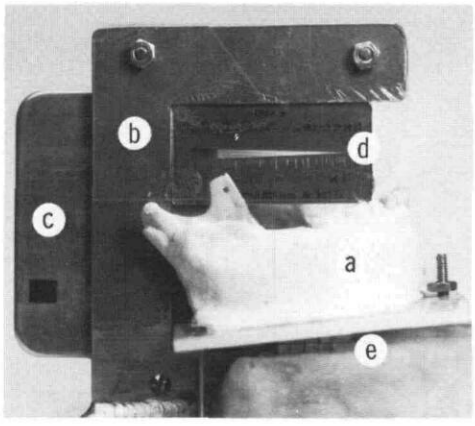

FIG 1. The specimen film holder assembly, consisting of (a) mixed dentition mandible imbedded with Mix-D wax, (b) film holder, (c) occlusal cassette, (d) radiograph resolution paired lines test pattern, and (e) aluminum density step wedge.

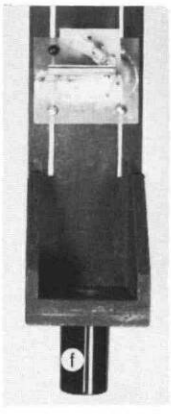

FIG 2. The constant distant platform, which is attached to the x-ray head (f) with the specimen film holder assembly fixed at 40 inches and at right angles to the x-ray head.

Table 1. X-ray Film Screen Combinations

Film	Screens	Speed	Exposure Sec	Exposure KV	Measured Density Range	Estimated Resolution Lines/mm
Ortho-G®	Lanex Regular (double) rare earth	400	.15	70	1.36 - .70	10
Xeroradiograph (dental)	No screen	2X Ekta	1.5	80	Visual Observance (film is translucent)	18
Xomat-RP®	Xomat fine	30	3	80	1.48 - .82	15
Ektaspeed® (dental)	No screen dental Single film	2X Ultra	3	80	1.35 - .70	18
Ortho-M®	Single Lanex fine	40	3.5	80	1.53 - .70	8
Ultraspeed® (dental)	No screen dental Single film	1X	6	80	1.34 - .70	18

ited the most *Yes* answers relative to identifying the anatomic structures. The film with the lowest resolution and the fewest *Yes* answers then was enhanced electronically by the dentist, using enhancement instrumentation designed for this purpose (Fig 4), in an effort to bring its diagnostic quality up to the level of the optimal diagnostic film displayed on a viewer. If it was impossible to increase the film's diagnostic resolution, the next best film was tried, and so on until the dentist found a film which could be enhanced electronically so as to be equal to or better than the optimal diagnostic resolution film. An effort also was made to allow the dentist to enhance a clinical radiograph with a deep carious lesion and determine whether electronic enhancement affected his diagnosis.

To orient the dentists who participated in this project, a videotape was prepared to demonstrate for each participant the method of enumerating the paired lines of resolution they were able to recognize and the operation of the television instrumentation for radiographic enhancement. In addition, two of the investigators were available to answer questions, since most participants had never seen a dental xeroradiograph, identified paired line resolutions, or operated an electronic radiograph enhancement instrument.

Many of the participants volunteered their services at an exhibition booth set up at annual meetings of the Indiana State Dental Association, Indiana State Society of Pediatric Dentists, American Academy of Pediatric Dentistry, Great Lakes Society of Oral and Maxillofacial Surgeons regional meeting, and other district dental society or dental study club meetings.

The 334 dentists participating in this study ranged in age as follows: 25-29 years (18.4%), 30-39 years (44.17%), 40-49 years (18.4%), 50-59 years (12.5%), and older than 60 years of age (6.44%). Types of practice included: general practice (44.61%), oral and maxillofacial surgery (14.67%), orthodontics (5.08%), pediatric dentistry (30.83%), and other specialties (4.57%). Of the total, 9.3% had earned their dental degrees at dental schools in the far West, 15.06% at Eastern schools, and 18.07% at Midwestern schools (56.92% were graduates of Indiana University School of Dentistry). Concerning principal professional activity, 8.63% were full-time faculty members, 69.94% were in full-time private practice, and 21.42% were active in both part-time teaching and private practice.

Results

The data are presented as a percentage of those dentists responding to the individual questions. In some instances the dentists failed to answer certain questions for unknown reasons.

The results indicate that 5% of those surveyed never take full mouth or Panorex® radiographs; 45.5% every 5 to 10 years; 41.2% every 2 to 4 years; and 8.3% more frequently than every 1 to 2 years. Similarly, 13.4% take fewer than one set of bite-wing radiographs each year, 55.8% take one a year, 28.6% take one every six months, and 2.1% more often than that. Most dentists use a radiograph viewing box (92.6%) and an automatic radiograph processor (73.2%).

Table 2 summarizes the data arranged according to radiographic exposure. The ranking of diagnostic quality, with 0 being the least diagnostic film and 5 the best, was determined as follows. In the case of Ortho-G® film, 91.9% ranked the film 0, or least diagnostic, and 5.0% (the next highest percentage to rank this film) ranked it as 1. Therefore, the diagnostic estimated rank was 0. To determine the third, fourth, and fifth ranking, where the highest percentage choosing a particular ranking was less than 50%, the highest percentage and next highest percentage

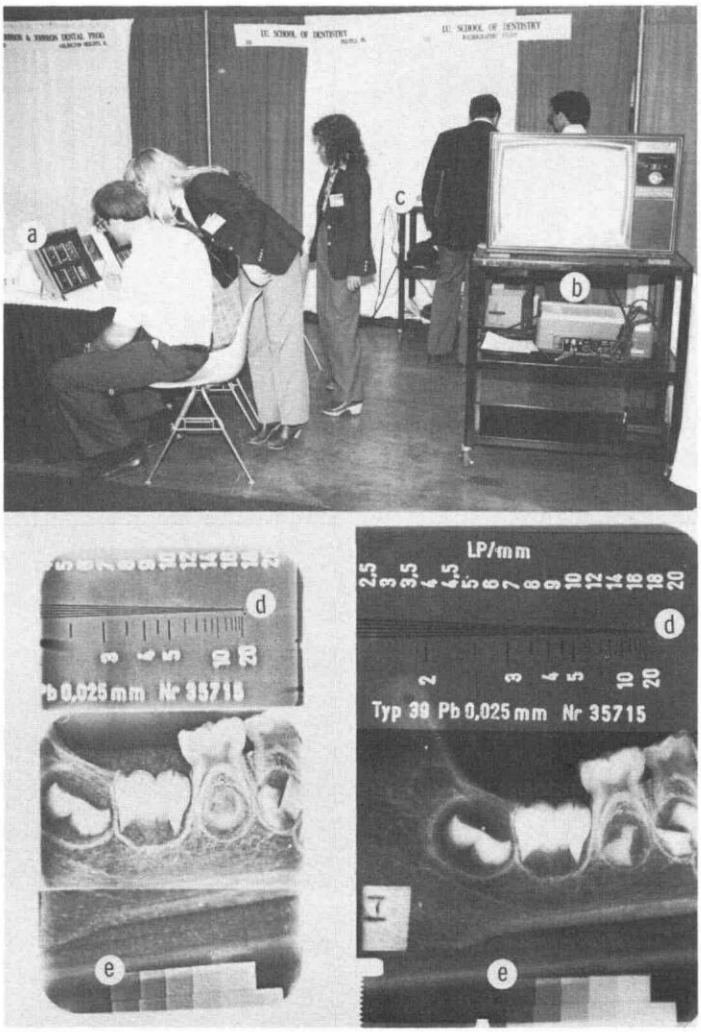

FIG 3. An exhibition booth at a dental society meeting, with three of the investigators (E.C., W.S., and P.Y.) assisting dentists in answering the questionnaire relative to the radiographs taped on (a) the viewing boxes to eliminate extraneous light, (b) the videotape instrumentation for instructing the dentist in the procedures of the questionnaire, and (c) the location of the electronic enhancement instrumentation. Below, the coded Ektaspeed® film (I) and the uncoded xeroradiograph film with the image of the x-ray resolution paired line test pattern at (d) and the density step wedge at (e).

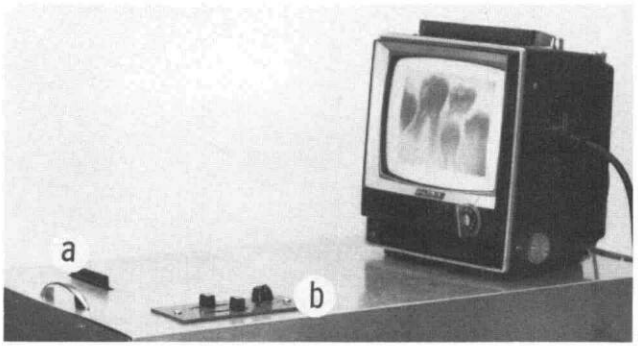

FIG 4. The radiograph electronic enhancement instrumentation, with (a) film holder; (b) variable controls, which the dentists adjusted for enhancing the diagnostic value of the film; and the television monitor on which the dentists viewed the electronically enhanced film.

were totaled with the highest sum ranked 5 (Ektaspeed® 45.5 + 38.9 = 85.4) and succeeding lower percentage totals ranked 4 (Ultraspeed® 71.5) and 3 (xeroradiograph 66.1).

Xeroradiography had a radiographic exposure of 1.5 sec with from one-half to one-fourth of the remaining test film exposures. The maximal estimated 18 paired lines of resolution was identified by 18.6% of the dentists as 16-20 paired lines, and identified by 53.8% as 12-15 paired lines. Identification of the bifurcation of the root canal at the apex as *Yes* had the highest percentage (23.7%) of all the films, 65.9% indicated *No*, and 10.5% indicated *Cannot determine* (the lowest of all the films). The estimated diagnostic ranking was 3, or the third highest ranking.

Ektaspeed, with a radiographic exposure of 3 sec and an estimated maximal 18 paired lines of resolution, was identified by 14.4% with a resolution of 16-20 paired lines and 48.9% with 12-15 paired lines. A total of 72.8% indicated that there was no root canal bifurcation at the apex and ranked the film as the best diagnostic film (5).

Identification of easily recognizable anatomic structures or pathology was not affected significantly by the various films. The limits of the developing follicle were identified by 97%, with 95% agreeing on the height of the interseptal bone. Recognition of the mandibular canal was accomplished by 96%, although only 65.5% identified the canal on the xeroradiograph. This confusion could have been affected by the xeroradiograph having been taken with three films, one of which bordered the mandibular canal. There was no identification of incipient occlusal caries by 85% viewing other test films, although this same conclusion was made by 75% viewing the xeroradiograph. There is evidence of a deep occlusal groove that can be seen on the developing first molar xeroradiograph which cannot be identified on the other films.

The question about "the least diagnostic film that can be enhanced electronically comparable to the best diagnostic film on the viewing box apparently was unclear, since only 62 of 334 answered it, with 49 of them selecting the xeroradiograph. However, on the next question relative to the diagnostic value of the enhanced radiograph (327 of 334 responding), 93.3% indicated that the electronically enhanced radiograph was not improved, 5.2% considered it slightly improved, .9% moderately improved, and only .6% considered the diagnostic value significantly im-

TABLE 2. Data Summary According to Radiographic Exposure

Film Screen	Exposure (sec)	Estimated Resolution	Identified Resolution (paired Lines) 0-3	4-7	8-11	12-15	16-20	Identification Root Canal Bifurcation Yes	No	Cannot Determine	Diagnostic Rank - % Highest	Next	Estimated Diagnostic Rank
Ortho-G Lanex Regular	.15	10	6.9%	46.4%	42.8%	3.3%	0.6%	5.4%	67.1%	27.5%	0-91.9%	1-5.0%	0
Xeroradiography (dental)	1.5	18	.3	4.5	22.8	53.8	18.6	23.7	65.9	10.5	5-.35.9	3-30.2	3
Xomat-R.P. Xomat fine	3	15	.6	23.2	49.4	25.0	1.8	6.6	74	19.5	1-64.4	2-27.2	1
Ektaspeed (dental)	3	18	0	7.5	29.1	48.9	14.4	11.4	72.8	15.9	4-45.5	5-38.9	5
Ortho-M Single Lanex Fine	3.5	8	5.4	35.7	57.7	0.6	0.6	6.6	75.4	18	2-55.9	1-23.1	2
Ultraspeed (dental)	6	18	.3	8.7	30.3	49.8	10.8	12.9	71.9	15.3	4-36.8	3-34.7	4

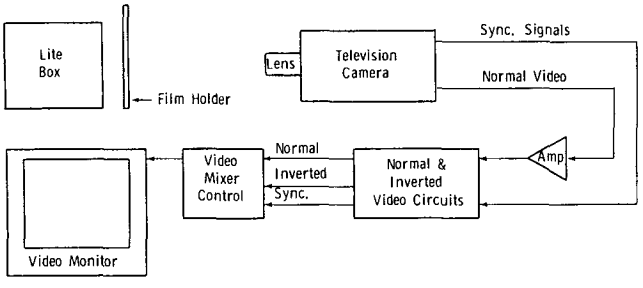

FIG 5. Block diagram of the electronic enhancement instrumentation.

proved. Similarly, with regard to the diagnostic value of the enhanced radiograph demonstrating pathology, 99.1% felt the diagnostic value was not improved and .9% indicated a slight improvement.

The finding that 86.7% take full-mouth or Panorex radiographs each 2 to 10 years and 55.8% take bitewing radiographs annually is in accord with generally accepted radiographic procedures; it is assumed that the scheduling is adapted to each patient's needs. The fact that 92.6% use a radiograph viewing box suggests that their diagnostic approach is discriminating.

Discussion

The ability of the dentists to identify more than the usually accepted 10 paired lines of resolution[8] points to their critical diagnostic ability. In order of estimated diagnostic rank with 18 paired lines of resolution, Ektaspeed had the highest ranking and a total of 63.3% identified 12-20 paired lines of resolution with a 3 sec exposure. Xeroradiography, which was third best in diagnostic ranking, had the highest proportion (72.4%) recognizing 12-20 paired lines with an exposure of 1.5 sec. Ultraspeed, with the second best diagnostic ranking, had the lower percentage (60.6%) recognizing 12-20 paired lines and the highest exposure of 6 sec.

The root canal bifurcation at the apex is extremely difficult to identify with the naked eye, but it can be identified readily by electronic enhancement or handheld magnification at 3-5x. The total percentage of *Yes* and *Cannot determine* responses were made according to the diagnostic ranking of the film as follows: Ektaspeed, 27.3%; Ultraspeed, 28.2%; and xeroradiography, 34.2%. Therefore, xeroradiography appears more diagnostic by this criteria.

The finding that 93.3% indicated that electronic enhancement did not improve the diagnostic value of the radiograph is contrary to previous observations.[1,2,3,12] Since only 62 chose to answer the question on electronic enhancement, one could ask whether they really knew what an enhanced radiograph should be, or whether they could interpret such a radiograph.

Conclusions

The xeroradiograph seems to be the film that produces the best results. It had the lowest radiographic exposure of 1.5 sec, the highest identified resolution of 12-20 lines (72.4%) and the highest total of *Yes* and *Cannot determine* responses relative to root canal bifurcation at the apex (34.4%). However, it had an estimated diagnostic ranking of 3, or the third best of the test films surveyed. The dentists apparently encountered some difficulty in interpreting the xeroradiograph, since most of them had never seen this type of film before.

The diagnosis of electronically enhanced dental radiographs is a skill similar to the diagnosis of unenhanced radiographs, and yet sufficiently different so that one should be trained in the nuances of radiographic enhancement before making clinical diagnosis.

Dentists can identify more than 10 paired lines per mm of resolution in film with 18 paired lines of resolution. More than 60% identified 12-20 paired lines per mm of resolution of these films, indicating their critical diagnostic skills.

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