0300-5712(95)00055-0

Journal of Dentistry, Vol. 24, No. 3, pp. 185–201, 1996

Printed in Great Britain
0300-5712/96 $15.00 + 0.00

The use of panoramic radiology in dental practice

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ABSTRACT

Objectives: Approximately 1.5 million panoramic radiographs are taken annually in the general dental service in England and Wales. The aim of this review was to assess the clinical role of panoramic radiology in the diagnosis of diseases associated with the teeth and to consider its value in routine screening of patients.
Method: This was carried out by critical review of the literature.
Results: In addition to common problems with radiographic technique and processing, there are limitations in image quality inherent to panoramic radiology. These factors contribute to a reduced diagnostic accuracy for caries diagnosis, demonstration of periodontal bone support and periapical pathology when compared with intraoral radiography. Routine screening is unproductive for large proportions of dentate and edentulous populations, while in those cases where pathology is detected the diagnostic accuracy can be questioned. Furthermore, the 'detection' of asymptomatic anomalies may have no effect on patient management. Attempts to develop and test panoramic radiographic selection criteria are reviewed.
Conclusion: New, high-yield selection criteria for panoramic radiography are proposed as a means of reducing unnecessary examinations, limiting radiation doses and reducing financial costs to patients and health service providers. However, research is indicated to develop further and to test such selection criteria. Copyright © 1996 Elsevier Science Ltd.

KEY WORDS: Panoramic radiography, Dental radiography, Diagnosis

J. Dent. 1996; **24:** 185–201 (Received 10 November 1994; reviewed 16 January 1995; accepted 7 March 1995)

INTRODUCTION

The development of the principles of dental panoramic radiology[1,2] represented a major innovation in dental imaging. Prior to this, dental radiographic examinations were limited to intraoral and oblique lateral projections of the jaws taken using a dental X-ray set. For the first time practitioners were able to produce an image of both jaws and their respective dentitions on a single radiographic film by a quick and relatively simple procedure.

The first aim of this review is to assess the value of panoramic radiology in the diagnosis and management of diseases associated with the teeth and jaws, taking into account the validity, sensitivity and specificity in imaging the diseases with the greatest prevalence. Using this information, the widespread use of panoramic radiology as a method of 'screening' for clinically unexpected ('occult') pathology will be critically examined. Finally, we suggest a number of high-yield selection criteria which may offer the possibility of improved diagnostic yield and reduced radiation dose from panoramic radiology in general dental practice.

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FREQUENCY OF PANORAMIC RADIOGRAPHIC EXAMINATIONS

Dental radiography represents the most frequent diagnostic X-ray examination undertaken in the industrialized countries of the world[3]. In England and Wales, all types of dental radiographic examinations carried out within the National Health Service have shown a regular incremental rise throughout the last two decades[4]. However, the use of panoramic radiology has shown a more marked increase. In 1983, Wall and Kendall[5] remarked upon the rapid rise in the use of panoramic radiology in Great Britain. This rise has continued more or less unabated since then, with the total number of panoramic examinations exceeding 1.5 million within the general dental services of England and Wales in 1991/1992, representing almost 10% of all dental radiographic examinations[4]. These figures obviously underestimate the true scale of use of panoramic radi-

ology as films produced in private practice, in hospitals and within the community dental services are not included. Two studies, separated by several years, recorded levels of panoramic use ranging from 8% of dentists[6] to 22%[7]. It has been estimated recently that there are approximately 3250 panoramic X-ray sets in clinical use in the UK[8].

This increasing use of panoramic radiography has been observed in other countries. In the USA, it was estimated that 23% of all practitioners had access to panoramic equipment in 1982[9], while 25,000 panoramic X-ray units were in routine use in 1986[10]. However, recent data confirm the extensive use of panoramic equipment, with estimates of the proportion of dentists using panoramic radiology ranging from 26% in Texas[11], 41% in Michigan[12], 45.5% in North Carolina[13] to 60% in Virginia and Florida[14].

In continental Europe, published evidence for the availability and use of panoramic radiological equipment is more limited. Havukainen[15] found in 1988 that one quarter of all radiographic film purchased by dentists in Finland was panoramic, with 10.6% of practitioners owning panoramic equipment. In France[16], the proportion of dental radiography made up by panoramic examinations is less than in the UK. However, the number of films taken (1.7 million) exceeds that in the UK, reflecting a much greater use of radiography of all kinds by French dentists. In contrast to the UK and the USA, most of the panoramic exposures in France are carried out by radiologists (46%)[16]. In Australia, it was estimated that, in 1988, 6% of practitioners used panoramic radiography[17].

DOSES AND RISKS FROM PANORAMIC RADIOLOGY

Examination of the clinical value of any radiological technique is incomplete without consideration of the doses and risks associated with its use. In the case of panoramic radiology, the weighted dose equivalent from a panoramic examination was calculated to be 80 μSv[5], corresponding to a lifetime risk of fatal cancer of 1.3×10^{-6}. Other risk estimates have arrived at varying figures: Danford and Gibbs[18] estimated the risk to be between 2 and 7×10^{-6} and Bengtsson[19] 4.2×10^{-6}. Since much of this work was undertaken, several international organizations have suggested that the risk may be greater than previously estimated[3,20,21]. Over the same period of time the design of panoramic machines has changed and rare earth screen/film combinations have become more widely used, resulting in a reduction in radiation doses. Using the most recent tissue weighting factors and risk probability coefficients[20] and assuming the use of rare earth screen/film combinations, White[22] computed the average effective dose for a panoramic examination to be 6.7 μSv; this figure is associated with an estimated risk of fatal malignancy of 0.21×10^{-6}.

Despite these encouraging findings, it should be emphasized that the lower levels of risk are associated with new equipment. Horner and Hirschmann[23] described the various methods of limiting patient dose in panoramic radiography. The facility for field size reduction is associated with a reduction in absorbed dose of 85% and effective dose of 50%, when the temporomandibular joints are excluded from the field[24]. However, it is likely that the higher levels of dose and risk reported by previous researchers[5,18,19] will remain valid as long as older equipment remains in clinical use. For example, certain types of equipment using a circular scanning motion incorporating three centres of rotation produce doses between 3 and 16 times higher than those with an elliptical system, due to the proximity of the rotational centres to the mandible[25] and parotid glands[16,26]. A study carried out in France showed this type of equipment to be the most widely used[16]. Furthermore, a survey of panoramic equipment in the UK[27] found that a higher dose than appropriate was being delivered during use of 70% of this equipment.

Although abdominal lead protection is clearly inappropriate in panoramic radiography, some researchers[28,29] have recommended the use of a lead thyroid collar in younger patients because of the relatively high anatomical position of the gland. However, because the primary beam does not strike the patient from the front during a panoramic examination, a thyroid shield must logically be placed on the back of the neck. This runs the risk of attenuating useful parts of the primary beam and obscuring areas of the mandible on the radiograph. Therefore it would seem reasonable to suggest that no lead protection should be used during panoramic radiography[8].

QUALITY OF THE PANORAMIC IMAGE

Details of the method of image production in panoramic radiology have been well described[30] and are outside the scope of this review. However, there are a number of factors inherent to panoramic radiology, not applicable to intraoral imaging, which reduce its diagnostic quality and which should be considered when examining its diagnostic value. These include the limitations imposed by the film/screen/cassette combination, tomographic blur, superimposed soft tissue and 'ghost' shadows, the overlap of adjacent teeth and variations in magnification.

The transfer of information from the attenuated X-ray beam to intensifying screens, and from screens to the film, is inevitably associated with degradation of that information[31]. This is less of a problem with conventional intraoral film, where the attenuated X-ray beam is directly recorded by the film. Panoramic radiology is a modified form of tomography; all tomographic techniques blur the images of structures above

and below the 'in-focus' layer. The latter ranges from 4.5 to 12 mm in the anterior regions and is two to three times greater in the molar regions[32].

Panoramic images are further degraded, to a variable degree, by shadows of soft tissues and surrounding air. For example, the presence of air between the dorsum of the tongue and the hard palate leads to a band of relative overexposure of the roots of the maxillary teeth and alveolar bone (*Fig. 1*). 'Ghost' images of the spine and mandible further reduce diagnostic quality[30]. There are also variations in the horizontal angle of the slit X-ray beam and the line of the dental arches, resulting in variable amount of overlap of contact points of teeth, particularly in the premolar regions[30] (*Fig. 2A*).

All radiographic images are magnified. In panoramic radiography the degree of magnification ranges from 10 to 30%[30]. However, with panoramic imaging the degree of horizontal magnification varies considerably, depending upon the relationship of the structure to the image layer. Therefore inaccuracies in patient positioning lead to discrepancies between vertical and horizontal magnification of teeth, with consequent distortion of shape (*Fig. 3*).

Diagnostic quality of panoramic radiographs is heavily dependent upon careful attention to technique and processing. Four studies[33-36], have assessed panoramic film quality. Schiff *et al.*[33] evaluated a variety of films taken by dental students, faculty members and technicians in a hospital environment. They found that 80% of radiographs showed some degree of fault; the number of faults being reduced to 53% by using only one technician to position all patients. Similarly, Akesson *et al.*[34], using radiographs produced within a dental hospital for comparison, reported inferior image quality in panoramic radiographs obtained from various external clinics. The remaining two studies[35,36] assessed panoramic radiographs produced by general practitioners. The study in the US[35] examined 500 films and classified 18.2% of films as inadequate; a further 8.8% were of 'marginal' quality. Smith *et al.*[36], who surveyed the quality of 387 radiographs submitted to the Dental Practice Board of England and Wales, found that 26% were of no diagnostic value. In each of these studies, low density or low contrast and incorrect positioning of the patient were cited as frequent causes of inadequate films.

THE ROLE OF RADIOGRAPHY IN DIAGNOSIS

Diagnosis of caries

Radiography remains an important aid to caries diagnosis. Kidd and Pitts[37] in a review of the available literature, concluded that the use of bitewing radiography was essential if much approximal caries is not to be missed. Indeed, a recent survey[38] showed that 68.5% of dentists depended upon radiographs alone for diagnosis. A number of studies have been carried out comparing the diagnostic efficacy of panoramic and intraoral radiographs for approximal caries. Interpretation and correlation of the findings of these studies is complicated by differences in populations examined, caries prevalence, the 'gold standard' for a positive diagnosis, the diagnostic thresholds and the types and numbers of observers. Consequently, although the sensitivity and specificity values may not be comparable between studies, the relative values within a particular study can be

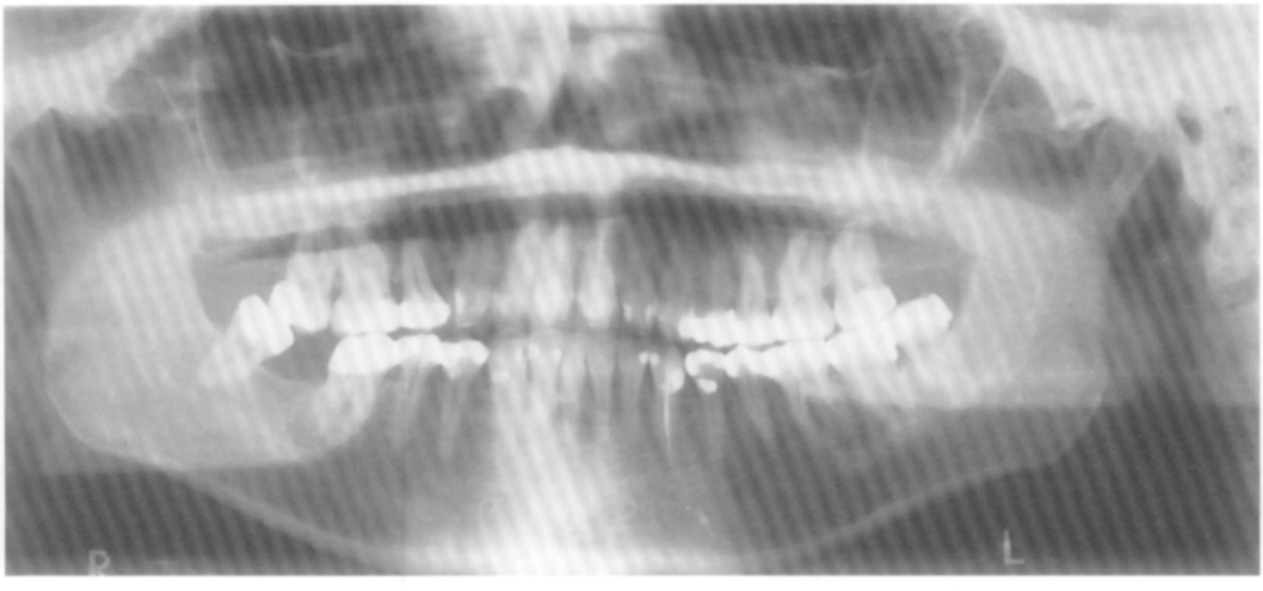

Fig. 1. The presence of air between the dorsum of the tongue and the hard palate producing a band of relative overexposure of the roots of the maxillary teeth and alveolar bone.

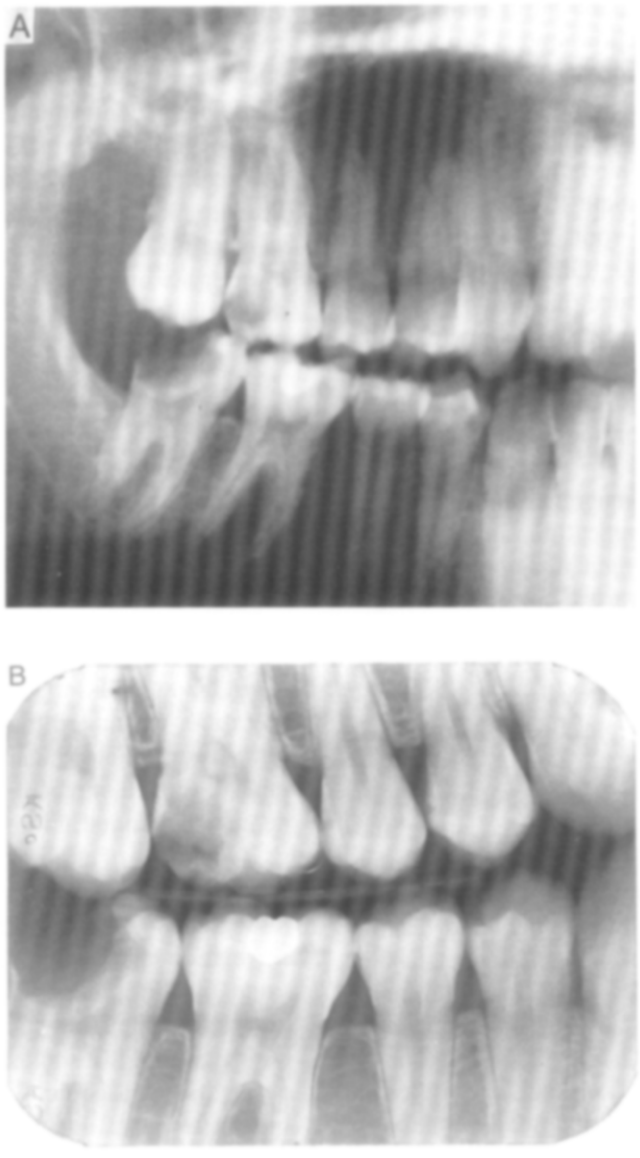

Fig. 2. (A) Part of a dental panoramic radiograph showing overlap of contact points in the premolar region. Additionally, the air shadow of the right commisure overlies the mesial aspect of (45) 'mimicking' approximal caries. (B) Right bitewing radiograph of the same patient showing a number of carious approximal lesions not revealed on the panoramic radiograph and confirming the absence of a lesion on the (45).

used to gain a measure of the relative efficacy of panoramic and intraoral examinations.

The panoramic radiograph has been shown to be inferior to periapical and bitewing radiographs in the detection of approximal caries[39-43]. However, the design of each of the relevant studies can be criticized in some way; for example, the small sample size, the absence of a 'gold standard' for caries diagnosis, differing diagnostic thresholds and the consequent failure to derive figures for sensitivity and specificity.

Douglass *et al.*[10] found that the sensitivities for caries diagnosis using bitewing radiography (59.4) were greater than those for panoramic radiography (22.0). The diagnostic threshold in this study was at the caries into dentine level; it is possible that the difference in sensitivity would have been even greater if the threshold had been set at the level of enamel caries, as a number of studies have shown that the accuracy of panoramic radiology in diagnosis of enamel lesions is particularly low[44-47]. However, some researchers have argued that panoramic radiography is more effective in diagnosing larger lesions extending into dentine[44,45]. Even if it is accepted that panoramic images are adequate for the detection of deeper carious lesions, it is clear that in clinical practice they would need to be supplemented by bitewing films, whereas the latter alone are suitable for the detection of both large and small approximal lesions (Fig. 2A and 2B).

Lesions located in the anterior teeth are poorly demonstrated on panoramic films[10,39,40,42-44,47-49]. Douglass *et al.*[10] demonstrated that approximal caries diagnosis sensitivity varied throughout the mouth, with levels of 30% in the molar regions, dropping to 19% and 8% for the premolar and incisor regions respectively. The findings of Molander *et al.*[47] were confirmatory.

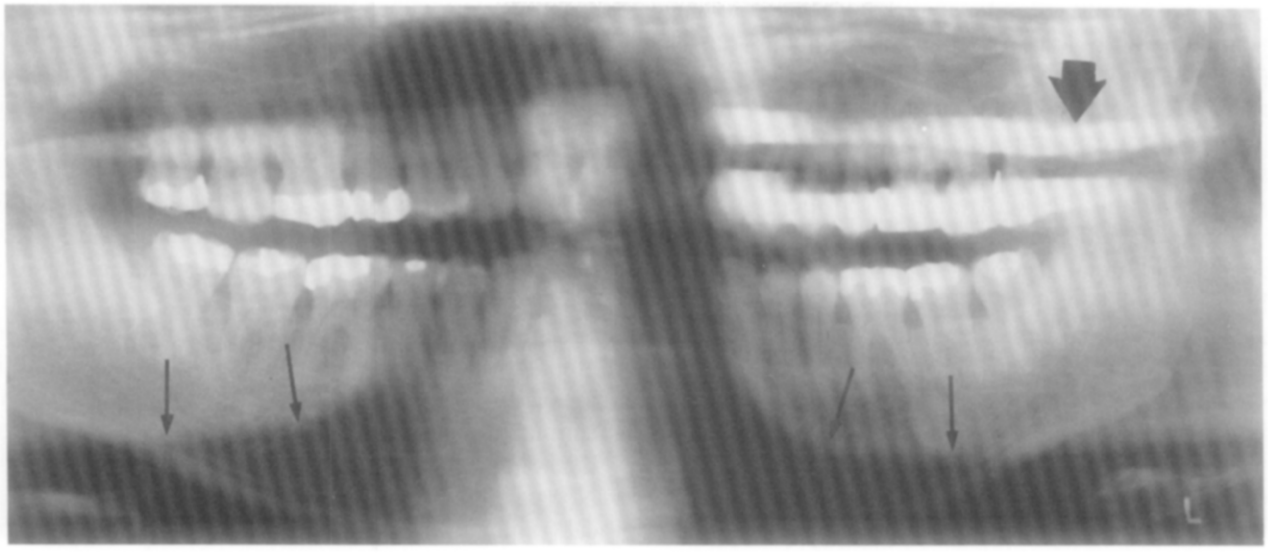

Fig. 3. A dental panoramic radiograph of a patient who was positioned inaccurately, too far back relative to the focal trough. This has resulted in a distorted (widened) image of the anterior teeth. Note also the prominent secondary shadows of the mandible (small arrows) and dental restorations (broad arrows).

The positive predictive value for caries, i.e. the probability that a positive radiological finding is correct, was only 54% overall in the study of Valachovic *et al.*[49], indicating a high level of false-positive diagnoses. Molander *et al.*[47] came to a similar conclusion. It is clear, therefore, that panoramic radiology is not an effective method of approximal caries diagnosis. Nevertheless, there is evidence that dentists use it for this purpose. In a study[7] carried out in one district of the UK, 57% of patients had only a panoramic radiograph taken as part of the examination; in 48% of cases where a panoramic film was taken, the main reason for taking the radiograph was stated by the dentists to be caries diagnosis. This finding indicates a real disparity between practitioners' perceptions of the value of panoramic radiographs and the evidence from the literature and has implications for undergraduate and continuing education of dentists.

Diagnosis of periodontal disease

The diagnosis of active periodontal disease depends on careful clinical examination, while radiography is essentially a method of demonstrating past disease activity in the form of bone loss. Hirschmann[50] identified five aspects of diagnosis and management of periodontal diseases in which radiography plays an important role: the demonstration of bone loss, widening of the periodontal ligament in relation to clinical mobility, identification of the radiological signs of occlusal trauma, imaging of calculus and overhanging restorations and demonstration of the crown–root ratio. Although this list could be expanded, e.g. to include bone sclerosis as a response to periodontal disease, an important distinction must be made between what radiography can demonstrate and the importance of such findings upon management.

The traditional method of choice for imaging periodontal bone loss is the full mouth periapical survey, taken using the paralleling rather than the bisecting angle technique because of the recognized fault with the latter of underestimating bone loss[51]. Bitewing radiographs are also commonly used as a means of examining bone height. However, for reasons of convenience, the perceived advantage of a 'complete' view of the dentition and reduced radiation dose relative to full-mouth surveys, panoramic radiographs are commonly used to demonstrate periodontal bone levels[52]. The slight upward angulation of the beam in panoramic radiography corresponds well with the slight downward angle used in bitewing radiography, suggesting that panoramic radiographs will not suffer from the intrinsic problems of underestimation of bone loss seen on bisecting angle periapicals. Panoramic radiography has also been extensively used in epidemiological studies because of the convenience of their use[46,53–55].

There is some disagreement in the literature as to the efficacy of panoramic radiographs in imaging bone levels. Ainamo and Tammisalo[56] found that measurements of bone height from panoramic radiographs differed from actual measurements on dry skulls less than those obtained from intraoral films. Kaimenyi and Ashley[57] argued that panoramic radiographs are reproducible, possess validity and may be used in investigations of the pattern of bone loss in periodontal disease. However, other studies[10,49] have cast doubt upon these claims, demonstrating that panoramic radiography is not as accurate as intraoral radiography for imaging bone levels, particularly in the anterior parts of the mouth[10]. Akesson *et al.*[58] found that the periodontal

bone image quality of bitewing radiographs was significantly higher than that on panoramic images, particularly in the upper jaw. The overlap of contacts between teeth in the premolar/canine region (*Fig. 2A*) can lead to a proportion of unmeasurable sites[46,53,54,57,58]. This proportion ranges from 15% to 43% of sites[46,53,55,57-59]. The most reliable demonstration of periodontal bone on panoramic radiographs appears to be in the lower premolar and molar regions[10,46,60-62].

In part, the limitations of panoramic radiology for imaging periodontal bone level are due to the same factors that affect caries diagnosis: poorer image sharpness and anatomical superimpositions. In addition, differences in magnification at different sites in the jaws[63], intra- and inter-observer variations[64] in interpretation, particularly in reproducibility of identification of the cemento-enamel junction[54,61,64,] play their roles. Both Grondahl *et al.*[60] and Akesson *et al.*[65] found that panoramic radiography underestimated bone loss in early stages of the disease process and, for this reason, Balis[45] argued that it was an ineffective imaging method for the demonstration of periodontal bone levels in children. It has been suggested[60] that the underestimation of bone was due to the loss of image sharpness with panoramic images compared to intraoral views, while Kaimenyi and Ashley[57] suggested that it may be related to craters or depressions in the alveolar bone undetected on radiography. However, in patients with advanced chronic periodontal disease, a greater extent of bone loss has been associated with panoramic radiography[43,48,60-62]. This paradox is difficult to explain; the suggestion that differences in vertical tube angulation are responsible seems difficult to believe when the beam angles with paralleling technique periapicals and panoramic radiography are very similar. Perhaps the higher inherent contrast of panoramic radiographic film leads to a degree of 'burn-out' of crestal bone.

In many respects, the published clinical studies represent a fruitless exercise because of the lack of any knowledge of the 'true' extent of pathology. This problem is compounded by the difficulties in measurability of some sites, the method of measurement used and a degree of inter-observer variation which may exceed the differences between imaging techniques[62]. Furthermore, the scale of the discrepancies between panoramic and periapical radiographs in imaging periodontal bone loss is small[62] and it can be reasonably argued that panoramic radiographs of good quality are adequate for general clinical use. In a pragmatic approach, Hirschmann[50] recommended that if a panoramic radiograph is used as part of a periodontal assessment it should be supplemented by periapical radiographs of 'dubious' teeth, a view supported by Akesson *et al.*[58] and Molander *et al.*[62]. It is assumed that teeth in this category would include those where the image was of inadequate quality, or where there was any suggestion of irregular bone loss or complicating factors such as angular defects and furcation involvement.

In everyday clinical practice, bitewing radiographs of posterior teeth are usually available, or are required as part of a caries assessment. Posterior bitewing radiographs, taken 'vertically' where clinical loss of attachment exceeds 5 mm, will provide excellent images of the bone levels. In terms of image quality it would seem appropriate to use these films in conjunction with anterior periapical or bitewing views to assess periodontal bone height, rather than expose an additional panoramic radiograph[66].

Clinical mobility and occlusal trauma may be associated with radiological widening of the periodontal ligament. In addition, occlusal trauma may be seen in conjunction with root resorption, hypercementosis, thickening of the lamina dura or root fracture[50,51,67]. No specific studies comparing panoramic and periapical radiography for the visualization of periodontal ligament space and lamina dura appear to have been carried out. However, clinical experience indicates that these features are not always evident on panoramic radiographs in the absence of disease, and that intraoral radiographs are superior. Visualization of calculus and overhanging restorations is possible from the bitewing radiographs which will usually be available; consequently there can be no justification for taking a panoramic radiograph purely for this purpose.

In summary, the role of panoramic radiography in periodontal disease diagnosis and management would appear to be in cases where there is extensive periodontal bone loss and/or other coexisting problems necessitating the taking of a larger radiograph, e.g. symptomatic third molars[66]. The clinician should be prepared to supplement a panoramic film with periapical views where appropriate.

Diagnosis of periapical pathology

Many studies have highlighted a reduced diagnostic accuracy of panoramic radiographs for periapical inflammatory pathology[10,41,42,45-47,68-71]. Most periapical pathological lesions are overlooked in the anterior regions[41,42,46,68,72] presumably reflecting the reduced image quality in these regions due to superimpositions of cervical spine and intraoral air.

However, all the comparative studies need to be viewed with some caution because of the absence of any real 'gold standard' for diagnosis, while some fail to consider sensitivity and specificity. Stephens *et al.*[42], Galal *et al.*[48] and Molander *et al.*[47] simply compared the number of 'lesions' observed on intraoral and panoramic radiographs with no consideration of 'true' or 'false' diagnoses. Ahlqwist *et al.*[46] used intraoral radiographs for the 'true' diagnosis; others[71] have used all radiographs (panoramic and full mouth periapicals), or full-mouth radiographs and clinical data[45], to arrive at a 'gold standard' decision. In a large, carefully conducted study, Balis[45] found that panoramic radiography

had a sensitivity of 79% and a specificity of 92% for periapical pathology. Consensus of a number of observers has been used as a 'gold standard' by some workers[48,71,73], although Rohlin *et al.*[73] highlighted the problems of inter-examiner variation according to the background of different observers. They found that the accuracy of diagnosis using periapical radiographs was superior to that using a panoramic radiograph when oral radiologists were the observers, while there was no difference between the two imaging modalities when the observers were general practitioners or endodontists.

Only a few studies have failed to confirm the superiority of intraoral radiographs; both Muhammed and Manson-Hing[43] and Rohlin *et al.*[71] found no significant difference in diagnostic yield for periapical lesions between panoramic radiographs and full-mouth surveys, while only two other studies, both involving a very small number of examinations, have found panoramic radiography superior[40,74]. Accuracy appears to vary according to the tooth in question[46,71], with panoramic images having a lower sensitivity (86%) for lesions associated with single-rooted teeth than for those related to multi-rooted teeth[46]. It should be noted that Rohlin *et al.*[71] excluded widening of the periodontal ligament from consideration; as lamina dura is less 'well-defined' on panoramics[73], this criterion would presumably favour the accuracy of panoramic radiography by excluding cases where the greater resolution of intraoral film might be advantageous. In addition, they[71] proposed that the higher inherent contrast of panoramic film may increase the number of "small" apical lesions identified. This hypothesis could support the research carried out by Molander *et al.*[47] which found that, of the total periapical lesions identified (by intraoral and panoramic techniques), almost one-third were only recorded on panoramic radiographs and only one-fifth on periapical radiographs. Conversely, this apparent discrepancy may result due to a preponderance of false positive diagnoses with panoramic radiography.

In the upper premolar region interpretation of the periapical region can be particularly difficult. Rohlin *et al.*[71] suggested that this may be due to the deviation of the projection away from orthogonality (*Fig. 2A*). Although this may affect approximal caries diagnosis, it is difficult to see how the degree of overlap of adjacent teeth would be of such a degree as to affect periapical interpretation. Reduced diagnostic efficacy in this region would seem likely to be due to 'burn-out' of the radiograph due to the coincidence of the air in the mouth and the relatively darker part of the film between the cervical spine shadow and the secondary image of the contralateral angle of the mandible (*Fig. 1*).

The substantive problems regarding the reliability of radiographic interpretation of the periapical region are not restricted solely to panoramic radiography. Several papers have highlighted the degree of inconsistency between examiners assessing periapical radiographs for evidence of apical change[75–78]. It has also been demonstrated that the visibility of a bony lesion is dependent upon thickness of overlying cortical bone and the extent of involvement of the latter by the lesion[79]. Whilst accepting these inconsistencies, research has shown that the most reliable and important radiographic features influencing practitioners to differentiate between healthy and diseased teeth are a widening of the periodontal ligament space and a loss of the lamina dura[80]. Unfortunately the technique of panoramic radiography precludes the consistent identification of these structures, thereby limiting its usefulness in identifying those teeth with early apical change.

SCREENING USING PANORAMIC RADIOLOGY

Where a disease is serious, treatable, of high prevalence and where the costs are outweighed by the likely benefits there may be a justification for screening of populations. Within medical radiographic practice, the routine screening of selected population groups, with the exception of mammography[81] and in certain clinical conditions, has been shown to have little value and has been abandoned except where clinical indications demonstrate a need[82]. However, within dental practice, 'routine' radiographic practices still continue[13,14,83,84]. The literature shows that three groups of patients tend to be routinely 'screened' using panoramic radiography: the young patient for orthodontic assessment, the dentate adult patient and the edentulous patient.

The orthodontic patient

The Court Report in 1976 recommended the routine orthodontic screening of all children[85]. Screening of children at 8–10 years has now become an accepted orthodontic practice[86,87]. Several studies have been carried out within this population group which have documented the anomalies and pathology found[88–90], while Rolling[91] assessed the proportion of children with findings of orthodontic significance. One other study[86] has considered both these aspects. In the UK, 25% of orthodontic departments within dental schools recommended orthodontic screening at 9–10 years[92]. Moreover, in one study[86], practitioners routinely used panoramic radiography within this age group because it was considered good practice to screen the 9–10 year old child to "check up on occlusal development". In fact, 65% of panoramic radiographs of children below 15 years of age were taken for orthodontic purposes[92].

In the USA, the lateral cephalostat and panoramic views (or complete intraoral radiographs in place of the latter) comprise the basic films necessary for orthodontic diagnosis and treatment planning[93]. This combination of panoramic and cephalostat films was also re-

commended by more than two-thirds of orthodontic departments within dental schools in the UK[92]. Within American orthodontic practice it has been reported that 70% of children in the primary and mixed dentition stage are assessed using a panoramic film, as are 90% of patients in the permanent dentition stage[94]. The literature records many instances of children below 5 years of age having panoramic radiographs taken[13,90,95], often in combination with bitewing films[95,96].

Several authors have questioned the routine prescription of panoramic radiographs within these younger members of the population[87,90,97,98]. This view is supported by the finding that many of the radiographs taken for orthodontic assessment have little or no influence on diagnosis or treatment planning[93,99]. Although orthodontic and paediatric specialists perform more radiographic examinations[94-96], the diagnostic yield varies considerably according to the type of personnel viewing the resultant radiograph[98].

Missing permanent teeth are the most prevalent dental anomaly of children[100,101]. It has been shown that by using clinical methods alone, all children with incisor and first-molar aplasia could be detected at 10 years of age, thus avoiding radiographic screening in a large proportion of the children previously examined[101].

Recently, a report[102] was produced for the British Orthodontics Society by the British Orthodontics Standards Working Party. This group strongly questioned the indiscriminate taking of radiographs for orthodontic screening, but fell short of listing detailed selection criteria. In their opinion "it would seem generally accepted that usually radiographs are indicated ... if clinical examination leaves reasonable suspicion as to the presence of any abnormality that might affect dento-facial development". Such an approach is a considerable improvement upon routine screening. However, it is of interest to note that in such instances the routine supplementation of panoramic radiographs by upper and lower occlusal views is recommended because of the narrow focal plane in this region. This advice can be criticized: if, for example, a supernumerary tooth is not seen on a panoramic film because it is markedly displaced from the focal plane, it is arguable whether its presence would have an effect upon orthodontic management.

The dentate patient

The majority of these studies are retrospective analyses of screening examinations of US armed-service personnel[103-105], of volunteer dental practitioners attending conventions[106-110] and of patients seeking treatment within a hospital[41,43,111-113]. The studies carried out in Europe have used a university student population[114], hospital patients[52,115] and 35-year-olds within a Norwegian population[69].

Within these cohort groups, the proportion of patients demonstrating abnormalities has ranged from 4.8%[111] to 89.6%[105]. However, the principal findings were impacted teeth (with a prevalence ranging from 1.6%[111] to 76.6%[114]) and periodontal disease (with a prevalence ranging from 1.3%[114] to 84.4%[52]). Caries prevalence was recorded in four studies at levels ranging from 10.8%[108], between 18.3 and 25.9%[110], 46%[114] and 24.6%[52].

In each of the studies, differences in methodology, age distribution of population group and variations in examiner training, variability and bias may have affected the prevalence of pathology seen. Moreover, as has already been discussed, the limited diagnostic accuracy of panoramic radiography for certain types of lesion casts significant doubts on their validity.

In a study by Keith[115], 23% of patients were identified as having unerupted teeth; in 56.2% of these cases, from radiographic examination alone, the author considered that there was a need for treatment. The author went on to conclude that the panoramic survey was justified because 25.8% of patients benefited in terms of a consequent modification to their treatment plan. In the majority of cases the modified treatment was related to removal of impacted third molars. However, the extent of impaction as assessed from any radiograph has been shown to be inaccurate in some cases[116], while it is clear that a decision on the need to remove a tooth cannot be made without clinical information. Moreover, the identification of an impacted tooth rarely leads to a change to the immediate treatment plan[116].

Two studies[52,69] recorded the highest prevalence of periodontal bone loss (64%[69] and 84.4%[52]). However, both pairs of researchers were periodontists, while in one case[52] patients were specifically referred to the authors for periodontal assessment. Studies that involve hospital patients in all probability differ from those of patients attending a general dental practice, and their results should not be extrapolated to the general population. Similarly, it is likely that the nature of the patient attendance for treatment affects the diagnostic yield from panoramic surveys. Keith[115] records 57.4% of the group as being 'casual' patients, of whom 59.3% presented with pain. It could be argued that patients attending for this reason would have more untreated dental pathology; Weems *et al.*[117] have shown that casual patients whose only previous dental care has consisted of extraction produce the highest yield from radiography.

The majority of studies have indiscriminately documented 'pathology', but two[111,113] have determined the actual diagnostic yield obtained from panoramic radiography. Barratt *et al.*[111], reviewing the panoramic radiographs of 1000 patients, discovered pathology that required definitive treatment in only 4.8% of patients. Moreover, none of the pathology discovered was con-

sidered serious and altered the immediate treatment plan in only 12 cases. Similarly, White and Weissmann[113], using panoramic and full mouth periapical surveys of 3059 patients, showed that panoramic radiographs recorded additional noteworthy pathology in only 5.3% of all cases, with only 0.1% of patients requiring subsequent definitive treatment for the condition.

The majority of studies reviewed[43,52,69,103-110,112,114,115] have continued to simply record pathology in a documentary fashion, without reflecting upon the clinical importance of the findings. It is evident that the majority of these studies are long on diagnosis but short on the prescriptive needs of the screened population. Against this background only four studies[52,111,113,118] have questioned the continued use of panoramic radiography in the assessment of the asymptomatic dental patient relative to the risk/benefit relationship. Three of these studies[111,113,118] have concluded that screening by panoramic radiography has a poor risk/benefit, especially in younger age groups[111]. Conversely, Osborne *et al.*[52] condone the continued use of the panoramic radiograph as a screening tool on the basis of cost, time, increased yield relative to area exposed and reduced dose to the patient. However, close examination of their data shows their conclusion to be ill-founded. Most of the 'chance' findings were simple dental pathology (caries, restoration defects and periapical changes) for which the panoramic radiograph has limited diagnostic efficacy. The authors do not consider whether clinical signs or symptoms were present that would have indicated radiography and do not directly assess the proportion of radiological findings that required treatment. They themselves point out that the impacted teeth identified on radiography "had probably never caused symptoms and, certainly, attempts at removal would be likely to result in significant morbidity in patients in this age group". Why then do the authors conclude that panoramic radiography is "a valuable screening technique for clinical practice"?

Some clinicians, perhaps aware of the limitations of panoramic radiology for diagnosis of common dental pathology, justify screening on the basis of detection of cysts or odontogenic tumours. The prevalences and incidence of these lesions vary. However, Shear and Singh[119] reported an annual age-standardized incidence rate for dentigerous cysts ranging from 1.18 to 9.92 per million. If it is assumed that the most common lesion of this type, the radicular cyst, occurs about three to five times as frequently[120] as the dentigerous cyst, the overall incidence rate cannot be such as to justify routine screening of the population. Furthermore, most benign lesions of the jaws will have clinical signs or symptoms which would indicate the need for a radiographic examination.

Many have placed emphasis on the detection of oral malignancy as a means of countenancing the continuation of screening radiography. Zeichner *et al.*[70], using the data provided by 30,000 patient records, found that non-inflammatory lesions were extremely rare, with only one 'occult' lesion recorded. In a recent excellent paper, Stephens *et al.*[121] addressed the incidence, prevalence and relative frequency of oral pathology. If it is assumed that the most prevalent oral malignancy, squamous cell carcinoma of the mucosa, would be detected by clinical examination, the role of panoramic screening would be in the identification of asymptomatic bone neoplasia. The prevalence of primary bone malignancy ranges from 8 to 12 cases per million per year in the whole skeleton, while in the head and neck alone this figure falls to around 2 per million per year. Only a fraction of the latter will affect the jaws and some of these will be symptomatic. It is clear that this prevalence is of the same order as the level of risk of causing malignancy by exposure to X-rays in panoramic radiography, and that the benefits of screening do not justify the risk. Furthermore even if a lesion is present on a radiograph there is no certainty that it will be recognized by the clinician.

In the face of this evidence, some dentists cite medico-legal worries as the reason for screening panoramic radiology: they fear litigation as a consequence of failing to identify a lesion, however low the prevalences of serious non-dental bony pathology. This view cannot be defended as it implies that those dentists who do not have a panoramic X-ray machine and do not carry out panoramic screening are negligent. Furthermore, the medico-legal consequences of carrying out unjustified X-ray exposures, along with those of failing to recognize pathology in the unlikely event of its presence, outweigh such arguments.

The edentulous patient

In the edentulous patient the types of pathology likely to occur may be different from those in the dentate patient, but the problems related to routine screening are still present. Nevertheless, a survey of US and Canadian dental schools in 1988 showed that 79% routinely screened edentulous patients using a panoramic radiograph[122]. This practice also concurs with guidelines produced by the United States 'expert' panel on selection criteria for dental radiography[123].

Many retrospective studies[112,124-138] have considered the yield of pathology from screening panoramic radiographs and the results have been used as a support for routine 'screening' of edentulous patients. Differences in methodology have led to a wide variation in the incidence of abnormalities, ranging from 0.33%[135] to 61%[130] of patients.

The main radiological findings are retained roots, embedded teeth and foreign bodies. Retained root fragments are seen in between 6%[136] and 40%[125] of cases. However, even if retained roots are detected on radiographs, there is often no reason for their removal;

the retention of non-infected roots which are completely submerged has been shown to be an effective method of maintaining alveolar bone[139–141]. Embedded teeth are seen in 0.9%[132] to 10.0%[138] of cases, while foreign bodies are seen in between 0.4%[131] and 10.0%[138], the latter mainly comprising amalgam tattoos. As far as other findings are concerned, many, such as elongated styloid processes and calcified lymph nodes are of no relevance to treatment[127,135].

In one study[142], routine screening was found to be unproductive for 96% of patients at the cost of missing, in only two cases, 33% of those findings that might influence treatment. This view has been endorsed by others who found that routine screening had little[135,136] or no influence[132,134,143] on the surgical or prosthetic treatment of the patient and should be discontinued. Nevertheless, one researcher[144] has attempted to justify the continued use of panoramic screening on the basis that the risk is modified in an ageing edentulous population due to the long latency in which stochastic effects will manifest themselves. This proposal ignores the radiation burden to a healthy but older population group and the cost to the health service provider.

The relative inferiority of panoramic radiology in diagnostic accuracy applies as much to edentulous patients as to others. A comparative study of panoramic screening with periapical and full-mouth screening of edentulous patients recorded a higher incidence of false positives and false negatives using panoramic radiography[128] and, more worryingly, the modality failed to show 25% of pathological lesions found using the periapical survey.

In all the studies undertaken, no definite predictors or factors have emerged which can identify either the type of patient, or the region of the oral cavity, that might benefit from radiological examination[129]. Although some researchers still advocate the prescription of a panoramic film for the edentulous patient[123,134], this should be questioned when in many cases it appears that the radiograph is merely mirroring the clinical diagnostic yield. As previously discussed, the predominant pathologies seen in this group of patients are retained roots[125,136] and unerupted teeth[132,138]. Consequently, radiographic examination determined by patient signs and symptoms should, in the first instance, comprise an intraoral radiograph of the area of interest.

RADIOGRAPHIC SELECTION CRITERIA

A recent joint report[145] has suggested that at least 20% of radiological examinations carried out within the National Health Service in the UK are clinically unhelpful. Similarly in the USA, it has been estimated that the elimination of these non-productive examinations by the use of selection criteria could lead to the reduction of the collective population dose from medical radiography by 30%[146].

Selection criteria are defined as descriptions of clinical conditions observed from patient signs, symptoms and history that identify those patients who are likely to benefit from a particular radiographic examination[147]. It is a basic tenet of radiation protection that all exposures should be clinically justified[20,148] in order that the diagnostic value outweighs the potential hazard.

The principles of selection criteria to determine the appropriateness of a specific radiographic examination are well established in medical radiographic practice[82,149]. In the UK, the use of such guidelines has achieved both a reduction in radiation exposure to the population while reducing costs to the health service provider, and has also achieved a more efficient use of radiographic techniques[150].

In the USA, the use of radiographic selection criteria in dental practice has been recommended for the last 30 years[151–154], but until recently there has been little published work on identifying suitable selection criteria. In 1983, the Department of Health and Human Services decided to address these issues with the establishment of an expert panel to develop selection criteria for dental radiography. The group reviewed previously published data and this culminated in 1987 in the publication of a strategy for the radiological management of patients seeking dental treatment[123]. The panel approached the challenge by categorizing patients according to specific situations, type of visit (new or recall patient), stage of dental development and in the case of dental caries assessment, the presence of risk factors (e.g. poor oral hygiene, etc.). These classifications helped to introduce a sensitivity to variations in patients' radiographic needs.

The guidelines support the continued use of panoramic radiography in certain categories of patients, e.g. young patients in the transitional dentition stage in order to assess growth and development, to evaluate developing third molars in the adolescent, and finally in the edentulous patient. The validity of these specific recommendations has been questioned by Stephens and Kogon[155], who argued that their adoption lends support to the continuation of routine screening within these specific groups.

Valachovic and Lurie[97] and White and Weissmann[113] have both questioned the validity of routine radiography. In a wide-ranging article on dental radiography for children, Valachovic and Lurie[97] suggested a variety of clinical and historical findings which might indicate the need for a radiographic examination. Both[97,113] sets of authors were sceptical of the need for the majority of panoramic radiographs taken in general dental practice, but it remained for others to develop and assess the effectiveness of specific selection criteria. White and Weissmann[113] logically suggested that panoramic radiographs could be justified in those cases where the

extent of the pathological condition exceeded beyond the coverage of a periapical film. However, having made this statement, they went on to contradict themselves by detailing numerous situations where a panoramic film can be justified on other grounds, e.g. "pre- and post-surgical assessments" (although why a small radiograph would not suffice if the pathology was limited in size was not explained). The authors also proposed that a bilateral view is essential in the evaluation of patients with Paget's disease of bone, hyperparathyroidism and fibrous dysplasia in order to permit a comparison of normal trabecular and cortical patterns with areas of pathological change. Although it is quite possible that a patient may have clinical indicators for a large radiograph with these conditions, the authors appear to be falling into the trap of recommending a screening film without a clinical justification.

In 1982, using a retrospective study, Kogon and Stephens[118] examined 54 adult patients who had prior panoramic and posterior bitewing radiographs. Their objectives were to assess the yield from panoramic radiographs and to develop criteria in order to select those patients who might benefit from a particular radiographic examination. Following the development of an eight-point high yield criteria list which encompassed the more common clinical signs and symptoms, the researchers reduced the need for the majority of panoramic films. Overall, they found that in only one case did the panoramic film substantially alter the proposed treatment plan following a history, clinical examination and the use of appropriate intraoral radiographs. 'Missing teeth' was found to be the most useful selection criterion for radiography, reflecting the presence of impacted third molars. However, there was no mention of what proportion of the third molars required treatment, or what proportion was symptomatic. Nevertheless, demonstration of the value of using selection criteria in place of screening was valuable.

A later study[142] generally substantiated the finding that 'missing teeth' was a valuable indicator for panoramic radiography. However, there are doubts about the clinical need for treatment here also. Most patients were examined for 'third molar evaluation'; how many of these patients had symptoms or signs indicating radiography as an aid to treatment? The authors also found that the observation of evidence of endodontic therapy on bitewing radiographs achieved a significant yield by indicating periradicular changes, although again they failed to make clear how 'positive' findings affected treatment. A similar criticism can be levelled at Akerblom *et al.*[156], who also found that radiographic evidence of prior endodontic treatment, in combination with history and examination, was a good indicator to take further (intraoral) radiographs because it led to a high sensitivity for detection of periradicular abnormalities. Once again, it is not evident how many teeth were symptomatic or how radiography changed the management of the patient. Furthermore, the interpretation of the periapical region of endodontically treated teeth without access to previous radiographs for comparison is handicapped.

White et al.[142] assessed the signs and symptoms which prompted clinicians to request a panoramic film in 1424 patients. In the edentulous patient the most valuable selection criterion appeared to be patient gender (female), planned surgery or a history of malignancy. When the panoramic film was ordered as a general screening examination, the diagnostic yield was found to be extremely low and was unlikely to be of any diagnostic value when combined with a full mouth survey. Similar findings have been documented by others[41,113]. Additionally, this study[142] found that the development of a high-yield criteria algorithm permitted the number of panoramic films to be reduced by 83% with the risk of missing only 7% of findings that might influence treatment.

Douglass *et al.*[157] compared clinical and radiographic observations in 602 asymptomatic adult male patients in an attempt to assess the extent to which common oral diseases were identified by panoramic, bitewing and periapical radiography. A clinical algorithm was designed to identify patient types which would benefit from radiography. Gingivitis, plaque and calculus were limited indicators for the prediction of radiographically evident periodontal disease and dental caries. Not surprisingly, the clinical discovery of several carious lesions appeared to be the best predictor of radiographically evident caries, while pocket depth and mobility were important indicators of radiographically evident periodontal disease. In the case of caries diagnosis intraoral radiographs were more sensitive than panoramic radiographs. No consideration was made of periapical pathology.

A number of selection criteria were assessed by Hintze *et al.*[98] to determine the need for panoramic radiography when carrying out an orthodontic assessment (*Table I*). Their adoption permitted the correct identification of 97% of children in need of treatment, while 94% of 'healthy' children were effectively excluded without the need for any radiological examination.

Kogon *et al.*[143] used selection criteria to assess the need for radiographic examinations in a small group of

Table I. Selection criteria of Hintze *et al.*[98] used to determine the need for panoramic radiography when carrying out an orthodontic clinical examination at 11–12 years

	Selection criterion
1	Infra-occlusion of primary molars
2	Clinically missing permanent incisors
3	Unerupted premolars after exfoliation of primary predecessors
4	Unerupted permanent maxillary canines

51 edentulous patients. In only two of these was panoramic radiography indicated on clinical grounds (both had a history of trauma), but neither radiograph was subsequently productive. They therefore questioned the validity of trauma as a selection criterion in the absence of signs and symptoms.

In 1986, 61% of US dental schools used written selection criteria for all radiographic procedures[158]. Paradoxically, a study of the same 69 accredited dental schools in 1988[122] found that only a limited number of schools used radiographic selection criteria for the dentate adult, edentulous adult and child patient, recording levels of 18.8%, 11.6% and 22.4% respectively. Kantor[122] believed that the respondents' replies may have been in some part due to differences in a lack of specificity in the terminology used in the questionnaire, but regardless of this, both studies demonstrate that influential dental teaching institutions do not comply with internationally accepted principles of radiation protection[20,148]. A recent follow-up study[159] has shown only a small improvement in the proportions of schools with a policy of selecting radiographs according to patient needs/selection criteria.

There has been little published work to investigate the acceptance of radiographic selection criteria in general dental practice, and this tends to suggest that other factors are of importance in radiographic prescription. A postal questionnaire of 559 Ontario dentists[160], comprising verbal descriptions of five patients, revealed generally good compliance with US guidelines[123] regarding the correct radiographic views required for the clinical conditions. However, they reported that the majority (54.4%) of respondents relied upon clinical experience to select patients for radiological examination with only 9.4% relying upon published guidelines. Stanek *et al.*[161] found that clinical experience was a major factor in determining the frequency of radiographs. Despite this, a recent study[162] in Pennsylvania has demonstrated that the medical history is the only procedure routinely completed prior to determining the need for radiographs in both new and recall patients, and that a clinical examination is not carried out before radiography.

In the UK, efforts to produce radiographic selection criteria have been made by specialists such as the British Endodontic Society[163], the British Orthodontic Society[102] and also by individual clinicians[164]; only one of these[102] has specifically addressed panoramic radiography. Although such guidelines as exist may be included in undergraduate dental curricula, the degree to which they are adopted in general practice is unknown. Within the auspices of the National Health Service in England and Wales, the Dental Practice Board not only functions as a fund holder and payment body for treatment carried out within general dental practice but also acts as a peer-review body. Using information provided by academic and general practitioners a consensus list of seven specific guidelines (*Table II*) was developed to assist practitioners in the use of panoramic radiography[165].

Table II. Guidelines for the use of panoramic radiology in general dental practice produced by the Dental Practice Board of England and Wales[165]

	Guideline
1	Examination of a patient new to the practice, or for a patient for whom a comprehensive radiographic examination has not previously been undertaken at the practice
2	As an aid of examination/diagnosis when considering the need for orthodontic treatment (this normally applies to patients of 8 or 9 years of age when they can be expected to be into the mixed dentition stage
3	To assist in orthodontic treatment at a later stage of dental treatment
4	Prior to oral surgery, such as the extraction of impacted wisdom teeth or enucleation of a cyst
5	After facial trauma
6	For following up progress of pathology or post-operative bony healing
7	Investigation of temporomandibular joint dysfunction

It is evident that these guidelines allow a multiplicity of possible interpretations. For example, using Guideline 4, is it "acceptable" to expose a panoramic radiograph on a patient following minor trauma to a single incisor tooth, while guideline 5 sanctions the use of a panoramic film to establish whether a single third molar is present even where the other three may be erupted and functional. The use of Guideline 6 would depend upon the interpretation of 'pathology'. More worryingly, it is likely that many dentists may perceive these guidelines as 'selection criteria', legitimizing routine screening of patients (guidelines 1 and 2).

Guideline 7 can also be questioned. Most patients presenting with 'temporomandibular joint dysfunction' are suffering from either myofascial pain–dysfunction or an internal joint derangement[166]. In the former, there are no related bony abnormalities of the joints, while in the latter, bony changes (sclerosis, erosions, osteophytes and flattening) are seen infrequently, usually in association with non-reducing and perforated discs[167]. Even in the minority of patients with a bony abnormality, it is doubtful whether the findings of any plain radiographic examination will influence initial management, particularly in a primary care setting. A prudent approach would be to limit imaging to those patients whose symptoms fail to respond to conservative treatments. However, in these cases the best investigation may be one which permits visualization of the soft tissues of the joint, i.e. magnetic resonance imaging or arthrography.

CONCLUDING COMMENTS

Panoramic radiological examinations are performed on large numbers of patients either as an alternative, or as

a supplement, to intraoral radiography. The criteria used in the decision to take a panoramic radiograph may be specific clinical indicators or an indiscriminate 'screening' procedure for pathology. The many published studies on the diagnostic accuracy, sensitivity and specificity of panoramic radiology compared to intraoral radiographic examinations indicate that it is generally inferior in the imaging of the dental diseases with the greatest prevalence. Despite these problems, it is possible that the relative simplicity of taking a panoramic radiograph and its value for explaining treatments to patients favour its routine use. More worryingly, as Barrett *et al.*[111] pointed out, an overreliance on panoramic radiography may lead to an undermining of thorough clinical examination.

As with all radiological examinations, the use of panoramic radiography should be based upon specific selection criteria which have been shown to result in both a high and significant diagnostic yield, thereby minimizing unnecessary exposures. In times of proliferating expenditure on health services, the application of selection criteria should also result in a net reduction in costs to patients, public health services and third-party payment organizations. However, before this ideal situation can be achieved there must be agreement between clinicians as to what clinical situations necessitate a panoramic radiograph.

One aim of this review was to raise the awareness of dentists about the limitations of panoramic radiology and stimulate further research to develop high-yield selection criteria. From examination of the literature we suggest a number of clinical situations in which panoramic radiology may be justified:

1. Where a bony lesion or unerupted tooth is of a size or position which precludes the demonstration of its full extent on intraoral radiographs[113]. It is implicit in this statement that intraoral films should be used as a 'first choice' method of imaging.
2. Prior to a dental surgical procedure under general anaesthesia. Here it can reasonably be argued that the risks associated with the latter outweigh those associated with exposure to radiation and all efforts should be made to avoid the need for a repeat general anaesthetic procedure.
3. As part of an assessment of periodontal bone support where there is pocketing greater than 5 mm in depth, unless other radiographs such as vertical bitewings are available. The concurrent presence of symptomatic ectopic third molars may influence the selection in favour of a panoramic radiograph[66].
4. Prior to a dental clearance or multiple dental extractions where a clinical decision to remove teeth has already been made, where appropriate intraoral films are unavailable and where only a gross assessment of root morphology is required.
5. As part of an orthodontic assessment where there is a clinical need to know the state of development of the dentition and the presence/absence of teeth. The use of clinical criteria[98] to select patients rather than routine screening of patients is recommended.

This list is not exhaustive and other clinical situations may exist. For example, the increased use of implants necessitates reliable information about bone depth and the position of important dental structures. Many practitioners have used the panoramic radiograph as an appropriate imaging modality to determine available bone depth. However, this assumption must be tempered by the inherent deficiencies within the method of image production, in particular image magnification and the variable degree of clarity of image resolution especially when evaluating the outline and position of the antral floor and inferior dental canal. Furthermore, implantology requires detail about width of bone, information which is most effectively supplied by specialized tomographic and computed tomographic imaging.

There is a particular question about the value of panoramic examinations of new patients. It could be argued that a 'survey' examination is useful for new patients with a history of extensive, multi-quadrant restorative treatment, where there is probably a high chance of detecting unexpected pathology and where panoramic radiographs will show the presence of endodontically treated teeth. In terms of diagnostic quality such a survey would be best achieved using full-mouth periapical radiographs and bitewings, but it is appreciated that this is a time-consuming procedure not commonly carried out in British dental practices. Consequently, we propose that new dentate patients should have a bitewing examination supplemented by periapical radiographs of any teeth which exhibit signs or symptoms of pathology. Such an approach would appear to offer a sensible means of achieving optimal diagnostic quality at the lowest cost while minimizing radiation doses to patients.

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