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The influence of malocclusion on the diagnostic value of the orthopantomogram in the maxillary labial segment

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Structured Abstract

Objective – To investigate the effect of malocclusion and incisor inclination on the diagnostic value of the orthopantomogram in the maxillary labial segment.

Setting – The Department of Orthodontics at The Royal London Hospital.

Material and Method – A literature review identified seven key features of an ideal radiograph of the upper labial segment. This provided the 'Gold Standard'. Four previously extracted maxillary incisors were set-up with a complementary acrylic dentition in a dry human skull. The maxillary base was modified to facilitate the movement of the upper jaw to simulate a total of nine malocclusions, based on skeletal I, II with III patterns with varying upper incisor inclination. A lateral cephalogram was taken to quantify the upper incisor inclination. An orthopantomogram (OPG), upper standard occlusal (USO) and four long-cone periapical radiographs (PA) were also taken. Each radiograph was scored against the Gold Standard. In addition, a clinical audit involving 100 new orthodontic patients was carried out to determine whether *in vivo* findings mirrored the *in vitro* results.

Results – The orthopantomogram provides low levels of diagnostic value in the maxillary incisor region. The diagnostic value for the skeletal I skull set-up ranged from 57 per cent for the OPG, 71 per cent for the USO and 86 per cent for the PA view.

Conclusion – The orthopantomogram showed poor diagnostic value in relation to the upper incisor teeth. Long-cone periapicals are recommended as the supplementary view of choice in the maxillary incisor region.

Key words: dental pantomogram; diagnostic value; maxilla

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Introduction

The orthopantomogram (OPG) is recognized as a useful imaging technique. It provides a comprehensive overview of the patient's bony and dental features. However, its potential shortcomings, especially in the upper anterior maxilla, have been reported in the literature. Horizontal and vertical distortions are accepted failings of the OPG(1). This radiographic view also has a well-defined focal trough, and provided the subject matter falls within the parameters of the defined parabolic curve, a clear image is produced. If, however, the subject matter exceeds the defined focal trough, varying levels of distortion can be introduced. These, however, have not been quantified in the literature.

In addition to inherent problems such as radiographic distortion, it is inevitable that patient positioning within the constraints of the defined focal trough will impact on the quality of the images produced(2–4). In a retrospective study of 1000 randomly selected radiographs, Schiff et al. (2)found only 20.3% to be error free and of the identified errors, 98.1% were positional in nature.

The depth of the image layer, typically 4 mm with a panoramic machine, also influences the definition of the radiographic image in the upper labial segment. Schiff et al. (2) identified that a lingual movement of 4 mm can result in 33% horizontal magnification, while a further 10 mm results in 150% magnification of the object in question.

Current literature suggests dental trauma and root resorption are both features likely to affect upper incisor teeth. The 2003 Child dental health survey suggests that 11% of 12 year olds have sustained some form of injury to the upper incisor teeth(5). Increased overjet and lip incompetence are associated risk factors(6–8). A 9 mm overjet increases a patient's risk of trauma by 45% with an overjet of <9 mm being associated with a 23% risk of trauma(9). Root resorption is a documented, unwanted sequelae of orthodontic treatment with much reference in the literature being made to predisposing factors. Levander and Malmgren, who suggested that blunt or pipette-shaped roots are more prone to root resorption, placed strong emphasis on the need to establish root morphology prior to orthodontic treatment(10). This thereby allows clinicians to inform patients of their level of susceptibility to orthodontically induced root resorption prior to embarking on treatment.

Despite the extensive use of the OPG in routine orthodontic clinical practice, no study to date has evaluated the impact that different occlusal traits such as an increased overjet and incisor inclination may have on the diagnostic yield of this radiograph and their significance in clinical practice. This study aimed at examining the diagnostic value of the OPG in a range of malocclusions and to compare the findings with those of the upper standard occlusal and the periapical radiograph.

Materials and methods

During this study, a dichotomous scoring scale was applied. For each condition defined, if a feature was present, a score of one was awarded, and if a feature was not present, a score of zero was awarded. The summated score out of seven measured the diagnostic value of that particular radiograph.

The second aspect of this study involved a prospective clinical audit evaluating the radiographic records of 100 consecutive patients commencing fixed appliance therapy within the Orthodontic department. The purpose of this audit was to establish whether or not the findings of the *in vitro* study were reflected in a clinical setting.

Laboratory study

Four previously extracted maxillary incisor teeth were identified from a store of teeth kept only for educational purposes. These incisor teeth were set-up in a dry human skull together with a complementary acrylic dentition (Fig. 1). Each of the four incisor teeth was modified such that an amalgam marker was placed at the cervical margin and at the root apex. This allowed for accurate

Fig. 1. The dry human skull used in the typodont study.

Fig. 2. Male and female Lego® components allowing maxillary movement.

measurements of root length for each radiograph. The skull used was modified such that male and female Lego® components were embedded in the skull base and the maxillary base. This allowed backward and forward movement of the maxilla to simulate skeletal I, II and III patterns. The mandibular base was fixed (Fig. 2).

For each skull set-up, a dental panoramic radiograph, an upper standard occlusal and four long-cone periapical radiographs were taken. Each radiograph was awarded a score out of seven based on the features of the ideal radiograph present, and this was used as a measure of its diagnostic value. A single operator (MH), under standardized viewing conditions using radiograph magnification, scored each radiograph.

Simulated malocclusions

The skull was adjusted to simulate nine malocclusions in total. In the first instance, the maxilla alone was adjusted to examine the effects that altering skeletal pattern from skeletal I, II and III can have on the diagnostic value of radiographs of the upper anterior region. Then, the inclination of the maxillary incisors was altered to examine the effects that incisor inclination can have on the diagnostic value of radiographic images produced. The skull was also marked with indelible pen to denote landmarks allowing for accurate repositioning within the radiographic machines. All 90 degree lateral cephalogram radiographs were taken using an exposure (AGFA Healthcare, Mortsel, Belgium) of 65 kW and 10 mA. An Agfa cronex 10T film type was used.

The occlusal traits of each malocclusion examined are shown in Table (2). Positioning of the dry skull within the dental panoramic and lateral cephalogram machines was based on the standardized measurements outlined by Owens and Johal(11). These measurements were adjusted for the dental panoramic machine such that for the skeletal I (class I) set-up, the dry skull was accurately positioned within the focal trough and produced a radiograph of satisfactory diagnostic value. This setting then acted as the baseline for all other dental panoramic radiographs. A Siemens Orthophos plus machine was used for this study (Siemens, Bensheim, Germany). Radiographs were taken using an exposure of 60 kW and 10 mA. An Agfa Cronex 10T film type was used.

Audit study

The clinical records of 100 consecutive orthodontic patients due to commence fixed appliance

treatment were examined for the presence of a dental panoramic radiograph, an upper standard occlusal and/or long-cone periapical radiographs. The occlusal traits of each of these patients were also recorded with a record made of skeletal pattern, overjet and upper incisor inclination. Each radiograph was scored against the defined gold standard, in a similar manner to the laboratory-based study. Upper standard occlusal and periapical radiographs were taken using E speed film and an exposure of 0.125 and 0.100, respectively.

Error of method

A pilot study was carried out to review the accuracy of positioning within the radiographic machines. Each radiograph was repeated in relation to a single malocclusion to test for error of the method as reported by Owens and Johal(11). All positioning for radiographs was carried out by a single operator (MH) under the supervision of a senior radiographer.

Measurement error

Repeatability measures for lateral cephalogram radiographs were undertaken by the same operator (MH) 2 weeks after initial tracing. This was assessed by retracing 20% of the radiographic sample for the audit study, under standardized conditions. The radiographs for all nine skull set-ups were re-scored 2 weeks following initial assessment. These measures were introduced to minimize the random error. The Bland Altman test was used to test for levels of repeatability(12).

Results

Measurement error

The scoring system used appeared to generate very good levels of agreement and repeatability. The scores allocated for the OPG, upper standard occlusal and long-cone periapical radiograh on the first and second measurements are shown in Table 1. Scores awarded to the OPG, upper standard occlusal and long-cone periapical radiograph for each of the nine skull set-ups were relatively consistent on both the 1st and 2nd measurements. The difference between the two measurements for the OPG was 0.11. This minimal difference is unlikely to be of clinical significance. For the upper standard occlusal radiograph, the mean difference between the first and second measurements was 0.22, suggesting high levels of agreement. The periapical radiograph demonstrated 100% agreement between the scores obtained on the first and second measurements.

Laboratory-based study

For each malocclusion simulated using the dry skull, the SNA, SNB, ANB and incisor inclination were recorded. The class I set-up had an ANB of 5° (Table 2). This value predetermined the ANB values for skeletal II and skeletal III set-ups.

Table 2 shows that for the skeletal I set-up, the OPG was found to have a diagnostic value of four (57%), from a maximum score of seven, in the upper incisor region. The upper standard occlusal had a diagnostic value of five (71%), and the periapical radiographs were seen to have a highest diagnostic value of six of 7 (86%). With the OPG, diagnostic features negatively affected included the length of the root, the visibility of the apex and the distinctive ability of the periapical area.

For the class II division I malocclusion, the OPG appears to display less diagnostic value when compared to the upper standard occlusal and the periapical radiographs. The OPG had a diagnostic value of three out of a maximum of seven. For this skull set-up, the incisor inclination was the same as the initial skeletal I, class I set-up, suggesting that the underlying skeletal pattern, may also impact on the diagnostic value of the OPG.

Overall for the OPG, levels of diagnostic value ranged from 28.6% for a skeletal II pattern with a class II division 2 incisor relationship, to a maximum of 57.1% for skeletal I pattern with average incisor inclination. The diagnostic value of the upper standard occlusal was found to be consistently higher than that of the OPG although there

Table 1. **The mean, standard deviation and 95% confidence intervals obtained for the orthopantomogram (OPG), upper standard occlusal and long-cone periapical radiograph on the initial (1st) and subsequent (2nd) re-measurement. The differences between the two measurements are also tabulated. Each radiograph was scored out of a total of seven depending on the features of the gold standard present. ($p < 0.05$)**

	Orthopantomogram score			Upper standard occlusal score			Periapical score		
	Mean	Standard deviation	95% Confidence interval	Mean	Standard Deviation	95% Confidence interval	Mean	Standard deviation	95% Confidence interval
1st measurement	2.89	0.60	Lower limit = 2.43 Upper limit = 3.35	4.11	1.36	Lower limit = 3.06 Upper limit = 5.16	5.78	0.44	Lower limit = 5.44 Upper limit = 6.12
2nd measurement	2.78	0.44	Lower limit = 2.4 Upper limit = 3.12	3.89	1.27	Lower limit = 2.91 Upper limit = 4.86	5.78	0.44	Lower limit = 5.44 Upper limit = 6.12
Difference between measurements	0.11	0.33	Lower limit = −0.14 Upper Limit = 0.37	0.22	0.44	Lower limit = −0.12 Upper limit = 0.56			

Table 2. **The nine malocclusions simulated via the typodont skull**

Malocclusion	SNA	SNB	ANB	UI inclination	LI inclination	Overjet (mm)	OPG (%)	USO (%)	PA (%)
Skeletal I	82°	77°	5°	113°	92°	2	4 (57.14)	5 (71.43)	6 (85.71)
Skeletal I Bimaxillary Proclination	82°	76°	6°	120°	101°	4	3 (42.86)	5 (71.43)	6 (85.71)
Skeletal II	88°	76°	12°	113°	92°	9	3 (42.86)	5 (71.43)	6 (85.71)
Skeletal II Proclined Incisors	88°	77°	11°	119°	92°	9	3 (42.86)	3 (42.86)	6 (85.71)
Skeletal II with Proclined Incisors	88°	77°	11°	130°	94°	10	3 (42.86)	5 (71.43)	6 (85.71)
Skeletal II with Retroclined Incisors	88°	76°	12°	105°	92°	7	2 (28.57)	2 (28.57)	5 (71.43)
Skeletal II Retroclined Incisors	88°	77°	11°	100°	90°	5	2 (28.57)	2 (28.57)	5 (71.43)
Skeletal III, Edge to Edge	77°	76°	12°	113°	92°	−1	3 (42.86)	5 (71.43)	6 (85.71)
Skeletal III Proclined Incisors	68°	76°	−8°	130°	81°	−4	3 (42.86)	5 (71.43)	6 (85.71)

was still a degree of magnification and lengthening errors. The long-cone periapical was shown to demonstrate the highest level of diagnostic value for all malocclusions.

Audit results

None of the patients included in the audit study had long-cone periapical radiographs of the

maxillary incisor teeth. In keeping with the findings of the laboratory-based study, the upper standard occlusal scored repeatedly higher in terms of diagnostic value in the maxillary incisor region. Patients presenting with both OPG and upper standard occlusal radiographs were looked at to determine how much the diagnostic value varied between radiographs when looking at the same malocclusion (Table 3). Of the 30 patients presenting with a skeletal I pattern, 21 had an OPG and upper standard occlusal. There were 47 patients presenting with a skeletal II pattern, but of these, only 27 had an OPG and upper standard occlusal radiograph. Of the 23 patients presenting with a skeletal III pattern, 19 had OPG and upper standard occlusal radiographs.

Table 3 shows the proportions of the presence of each characteristic for both the OPG and upper standard occlusal radiograph. The upper standard occlusal radiograph scored higher than the OPG ($p < 0.05$), in terms of sufficient imaging of the apex and the periapical area and also the distinctive ability in the anterior maxilla. The difference in the scores obtained for the OPG and the upper standard occlusal was tested for statistical significance using the Wilcoxon signed ranks test. This test was carried out for skeletal I, II and III subjects (Table 3). There were consistently lower scores in relation to magnification for the upper standard occlusal, compared to the OPG. There were shortening/lengthening errors reported for all groups. The greatest difference between the OPG and the upper standard occlusal related to skeletal II patients. The extent of overlapping and orientation in the horizontal plane appears relatively consistent between the OPG and the upper standard occlusal.

The Wilcoxon signed rank test for skeletal I, II and III patients with both OPG and upper standard occlusal radiographs suggests that the upper standard occlusal scored higher than the OPG in all three skeletal groups ($p < 0.05$).

Table 3. **Diagnostic value scores for patients with skeletal I, II and III discrepancy in the clinical audit study comparing the orthopantomogram (OPG) with the upper standard occlusal (USO) radiograph**

		Radiographic feature							
Skeletal pattern	Reviewed radiograph	Constant contrast & density (%)	No shortening/ lengthening errors (%)	No overlapping of teeth (%)	Sufficient Imaging of Apex & Periapical Regions (%)	Cusps and Incisal Surfaces at Same Horizontal Level (%)	Sufficient distinctive ability in Anterior Maxilla (%)	No obvious magnification (%)	*p* value
Skeletal I	OPG	19 (90.47)	9(42.86)	12(57.14)	6 (28.57)	21 (100)	5 (23.81)	11 (52.38)	0.006
(n = 21)	USO	21 (100)	9 (42.86)	13 (61.90)	17 (80.95)	21 (100)	18 (85.71)	15 (71.43)	
Skeletal II	OPG	26 (96.30)	3 (11.11)	17 (62.96)	3 (11.11)	27 (100)	3 (11.11)	11 (40.74)	0.001
(n = 27)	USO	27 (100)	7 (25.93)	16 (59.26)	19 (70.37)	26 (96.30)	19 (70.37)	19 (70.37)	
Skeletal III	OPG	17 (89.47)	6 (31.58)	14 (73.68)	5 (26.32)	19 (100)	4 (21.05)	10 (52.63)	0.003
(n = 19)	USO	19 (100)	6 (31.58)	16 (84.21)	15 (78.95)	19 (100)	12 (63.16)	13 (68.42)	

Discussion

This study for ethical reasons involved two components. The first was a laboratory-based study

looking at the effect of varying occlusal traits on the diagnostic value of the OPG in the maxillary incisor region. These findings were compared to that of the upper standard occlusal and periapical radiograph for each of the malocclusions under review, relative to a gold standard defined from the work by Pepelassi et al. (13). These authors highlighted seven features of an ideal view in the anterior maxilla, which included constant contrast and density; no shortening or lengthening errors; no overlapping of teeth; sufficient imaging of the apex and periapical region; cusps and incisal surfaces of teeth in the same horizontal level; sufficient distinctive ability in the anterior maxillary region and no obvious magnification.

It must be recognized, however, that perhaps this gold standard is not achievable even with the ideal occlusion in view of inherent problems associated with specific radiographic techniques. The OPG, because of its tomographic nature, has a limited focal trough that is relatively narrow in the incisor region(14). As a result, the apices of the incisor teeth and any associated structures may not be clearly visible or in true focus if they fall outside the dimensions of the defined focal trough.

The inclination of the central beam is also relevant in that the more lingually placed an object is, the higher it will appear relative to a buccally placed object in the same horizontal plane(1). Superimposition of the cervical spine further compromises the quality of the image produced.

Within the field of orthodontics, the OPG is used to aid the diagnosis of malocclusions, plan treatment and assess progress of treatment goals. While identifying selection criteria and specific scenarios dictating the use of the OPG in orthodontics, Isaacson and Thom did not review in any great detail, the failings or shortcomings of the OPG (14). Clinical scenarios, which may merit supplementary radiographs, were not explored in any significant detail.

In this laboratory-based study, the diagnostic value of the OPG was found to be consistently affected by both the underlying skeletal pattern and the inclination of the upper incisor teeth. Its diagnostic value in the maxillary incisor region was found to be lower than that of the upper standard occlusal and the long-cone periapical radiograph when scored relative to the defined gold standard. Features negatively affected included shortening/lengthening errors, diagnostic ability and definition of the root apex.

This study used conventional film as opposed to digital radiographs. Digital images can be altered after they have been produced allowing the user to change certain characteristics of the image. This is called 'image processing' with optimization of contrast and brightness being examples of this which might significantly enhance diagnostic ability in the anterior maxillary region. In addition, other features of digital radiography such as digital subtraction techniques facilitate diagnosis in the upper labial segment, and the advantages of this almost instant radiographic technique, with its easily stored and retrievable images, are multiple. However, this technique is only as good as film in that it is subject to all the failings associated with the process of taking the radiograph itself, being affected by positioning, distortion, magnification, superimposition and artefact(15).

The effect of positioning within the focal trough was clearly evident in this study. Marked magnification was seen for skeletal II and skeletal III setups, with the upper incisor teeth being positioned labially or palatally relative to the focal trough. With the incisors positioned outside the focal trough, the fan-shaped X-ray beam means that teeth appear too narrow and too wide, respectively(16). In addition, the inclination of the incisor teeth may make it impossible to position the upper incisors within the focal trough. This was noted in this study. The more skeletal III and the more proclined the upper anterior teeth, the lower the diagnostic value of the dental panoramic radiograph. With skeletal II, class II division I setups, the imaged teeth appeared relatively narrow and smaller in size. The extent of this increased or decreased as the inclination of the teeth altered with more proclined teeth being more notably affected.

The clinical relevance of these findings

This study would suggest that in instances of excessively proclined or retroclined upper

incisors, or marked skeletal discrepancy, the dental panoramic radiograph is likely to yield low diagnostic value in relation to the maxillary incisors. The upper standard occlusal does provide higher levels of diagnostic value but is subject to lengthening distortion and is difficult to reproduce. The long-cone periapical radiograph was shown in the laboratory-based study to yield the highest level of diagnostic value with positioning aids such as ring holders facilitating accurate repositioning.

Despite the need to observe the ionizing radiation regulations, there is a clear clinical indication for supplementary radiographs. The high prevalence of dental trauma and root resorption in children in the incisor region(5) indicates the importance of a good diagnostic radiograph of the upper incisor teeth. This study would suggest that the OPG radiograph should be supplemented with periapical radiographs when indicated to yield the highest level of diagnostic value in the maxillary incisor region. The upper standard occlusal is frequently used as a supplementary diagnostic view, but it is likely to be subject to problems of elongation and difficulty with image repeatability.

Cone-beam CT is a radiographic technique offering a number of significant advantages over conventional radiographs. Dose reduction and X-ray beam limitation along with fast scan-times result in fewer artefacts meaning that this technique is viewed by many as a panacea in radiological terms. However, intrinsic limitations in the technique mean that in some circumstances, other forms of dental imaging would still be more appropriate. Teeth adjacent to amalgam, carious teeth and teeth with prosthetic restorations are not well imaged by cone-beam technology as a result of beam hardening and streak artefact(17). In addition, with clinical questions relating to lamina dura configuration or bony detail, and especially in the maxillary incisor region where superimposition is a common problem, the periapical image may provide the answer with a fraction of the radiation dose, with both lamina dura and bony detail being superior on periapical radiographs compared to cone-beam CT(18).

Conclusion

The OPG demonstrates poor levels of diagnostic value in the maxillary incisor region in instances of skeletal discrepancy and severe incisor inclination. The upper standard occlusal demonstrates greater diagnostic value, but it is the long-cone periapical radiograph that displays the highest level of diagnostic value in the maxillary incisor region.

Clinical relevance

The dental panoramic tomograph is regarded by many as an indispensable diagnostic tool in orthodontics. The tomographic nature of this radiograph does, however, suggest that patients presenting with malocclusion may undergo varying levels of distortion in the incisor region. No previous study has evaluated this effect. A good diagnostic radiograph of the upper labial segment is imperative to assess the likelihood of root resorption in susceptible individuals prior to the commencement of orthodontic treatment. The study aims to identify the radiograph of highest diagnostic value in the anterior maxilla.

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