COMPARISON OF FOUR PANORAMIC DENTAL RADIOGRAPHIC SYSTEMS FOR TOOTH ANGULATION MEASUREMENT ACCURACY UNDER DIFFERENT TOLERENCES

Stacee Dumas Burson · Allan George Farman · Byung-Cheol Kang

CONTENT

Ⅰ. INTRODUCTION

Panoramic dental radiographs are commonly utilized by orthodontist to aid in diagnosing, treatment planning, and evaluating outcomes for orthodontic treatment.[1-3] The panoramic dental radiograph provides an overall scan of the maxillary and mandibular arches, aiding the orthodontist in the assessment of abnormal tooth eruption patterns, dental impactions, congenitally missing teeth, supernumerary teeth, premature dental shedding, prolonged primary tooth retention, abnormal dental resorption, dental ankylosis, fractures, space inadequacy, cysts and neoplasms.[1-7] Moreover many orthodontists utilize the panoramic radiograph to evaluate tooth angulations.[3,8]

In the literature, one can find those who support the panoramic radiograph as being an accurate means of determining root angulation (Graber[2],1967 ; Mayoral[3], 1982 ; Hauck[8], 1970 ; Tronje, et al,[9] 1981), and those who dispute it's usefulness(Phillip and Hurst,[11] 1978; Lucchesi et al,[12] 1988 ; Samfores and Welander,[13] 1974).

The objective of this study was to evaluated the accuracy of four panoramic radiographic systems in determining tooth angulations in the buccal segment.

Ⅱ. METHODS AND MATERIALS

A dry skull from the Radiology Department of the University of Louisville, School of Dentistry was utilized as the "patient". Stainless steel orthodontic wires to simulate the long axis of teeth(from canine to second molar) were glued on the buccal surface on the teeth.

Four wires were glued parallel to the occlusal plane to be used as reference lines from

which the angulations of the teeth were measured on both sides of the jaws.(Fig.1).

Four panoramic radiographic machines were evaluated : (1) Philips Oralix Pan DC(Orion Corporation Ltd., Helsinki, Finland), (2) GE Panelipse(General Electric Co., Milwaukee,

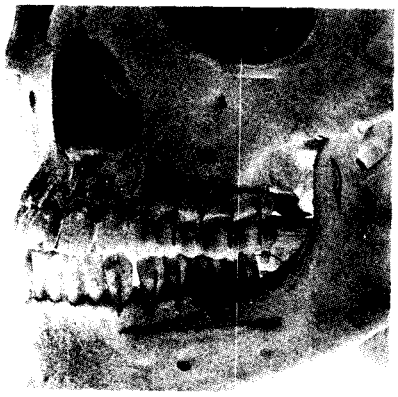

Fig. 1 Orthodontic wires were glued to simulate the long axes of teeth and to make reference lines on the buccal surfaces of the dry skull.

Wisconsin), (3) SS White Panorex 1(SS White Dental Mfg. Co., Holmdel, New Jersey), (4) SS White Panorex 2(SS White Dental Mfg. Co., Holmdel, New Jersey).

On each machine, panoramic radiographs were taken at six different positions: (1) correct position, (2) 5 mm forward position, (3) 5 mm backward position, (4) 10^0 head up position, (5) 10^0 head down position, and (6) 5 mm left position. The skull was stablized in the different positions utilizing standard masking tape. Reference marks were used to reproduce the head positionings from machine to machine.

Kodak X-Omat RP panoramic DF-75 dental film was utilized with the SS White Panorex 1, the SS White Panorex 2, and the GE Panelipse machines. Kodak T-Mat G Panoramic PAN/TMG15 dental film was utilized on the Philips Oralix Pan DC machine.

The settings utilized on each machine were (1) SS White Panorex 1 : 44 kVp, 5 mA, (2) SS White Panorex 2 : 51 kVp, 5 mA (3) GE Panelipse : 85 kVp, 10 mA, (4) Philips Oralix Pan DC : 63 kVp, 6 mA.

Five radiographs were taken per machine in the correct "patient" placement position. In each of the incorrect "patient" placement positions, three radiographs were taken per machine. As the SS White 1 which was unable to accommodate positioning the patient 5mm forward, a total of 77 panoramic radiographs were taken. A Kodak RP-X-OMAT automatic processor(Eastman Kodak, Rochester, New York) was utilized for processing the films.

To ascertain intra-operator error, the angles of the teeth were remeasured for five randomly selected panoramic radiographs. These values were compared to the original measurements.

Inter-operator error was determined by having a second observer measure the teeth angles of the skull and the five random panoramic radiographs. These values were compared to first observer's original measurements. The second observer has similar orthodontic education when compared to the first observer.

The statistical analyses applied to this data included means, standard deviations, coefficients determination(r^2), correlation coefficients (r). The percent accuracy was determined for each set of data at $+/-2^0$, $+/-3^0$, and $+/-5^0$ of error.[9,14] The statistical anaylses were conducted on IBM computer using Quatro Pro

Table 1 Comparison of the the mean radiographic estimates and the actual measurements with the skull correctly positioned

Machines	n	r^2	r	mean diff	SD
Philips Oralix Pan DC	20	0.6	0.77*	1.1	3.3
GE Panelipse	20	0.43	0.65*	−0.6	3.2
SS White Panorex 1	20	0.64	0.80*	−0.05	2.8
SS White Panorex 2	20	0.56	0.75*	0.3	3.9

n : number of teeth
r^2 : coefficient determination
SD : standard deviation
r : correlation coefficient
mean diff : mean difference
* $p < 0.05$

Table 2 Comparison of the the mean radiographic estimates and the actual measurements with the skull positioned 5mm forward

Machines	n	r^2	r	mean diff	SD
Philips Oralix Pan DC	20	0.58	0.76*	0.8	5.3
GE Panelipse	20	0.48	0.69*	−1.7	3.6
SS White Panorex 1	--	---	----	---	---
SS White Panorex 2	20	0.55	0.75*	0.7	4.8

* $p < 0.05$

Table 3 Comparison of the the mean radiographic estimates and the actual measurements with the skull positioned 5mm back

Machines	n	r^2	r	mean diff	SD
Philips Oralix Pan DC	20	0.37	0.61*	1.2	3.4
GE Panelipse	20	0.22	0.47*	−0.4	4
SS White Panorex 1	20	0.58	0.76*	−0.5	2.9
SS White Panorex 2	20	0.53	0.73*	0.3	3.5

* $p < 0.05$

Table 4 Comparison of the the mean radiographic estimates and the actual measurements with the skull positioned with the head up 10

Machines	n	r^2	r	mean diff	SD
Philips Oralix Pan DC	20	0.42	0.65*	2.5	3.1
GE Panelipse	20	0.46	0.68*	0.4	2.9
SS White Panorex 1	20	0.7	0.84*	−0.03	2.4
SS White Panorex 2	20	0.62	0.79*	0.9	2.9

* $p < 0.05$

Table 5 Comparison of the the mean radiographic estimates and the actual measurements with the skull positioned up 10

Machines	n	r^2	r	mean diff	SD
Philips Oralix Pan DC	20	0.47	0.69*	−0.6	4.7
GE Panelipse	20	0.45	0.67*	−3.4	4.3
SS White Panorex 1	20	0.47	0.69*	−1.7	5.9
SS White Panorex 2	20	0.48	0.70*	−0.9	5.3

* $p < 0.05$

Table 6 Comparison of the the mean radiographic estimates and the actual measurements with the jaw 5mm to the left

Machines	n	r^2	r	mean diff	SD
Philips Oralix Pan DC	20	0.7	0.84*	1.4	3.2
GE Panelipse	20	0.56	0.75*	−0.02	2.8
SS White Panorex 1	20	0.55	0.74*	−0.03	3
SS White Panorex 2	20	0.59	0.77*	0.7	3.5

* $p < 0.05$

Table 7 Percentage accuracy for each machine according to the degree of error tolerance and positioning.

Percent accuracy with an error tolerance of +/- 2

machine	#1	#2	#3	#4	#5	#6
Philipse Oralix pan DC	55	30	47	47	43	47
GE Panelipse	49	47	38	63	37	67
SS White Panorex 1	69	--	67	77	37	53
SS White P norex 2	50	37	63	58	47	58

Percent accuracy with an error tolerance of +/- 3

machine	#1	#2	#3	#4	#5	#6
Philipse Oralix pan DC	64	40	70	60	55	63
GE Panelipse	67	58	52	75	52	85
SS White Panorex 1	74	--	73	87	52	75
SS White P norex 2	64	48	75	80	58	67

Percent accuracy with an error tolerance of +/- 5

machine	#1	#2	#3	#4	#5	#6
Philipse Oralix pan DC	85	62	90	87	72	92
GE Panelipse	89	80	80	93	63	93
SS White Panorex 1	89	--	92	95	65	90
SS White P norex 2	81	68	83	88	72	82

#1 : correctly positioned　　#2 : 5 mm forward
#3 : 5 mm back　　#4 : chin up 10^0
#5 : chin down 10^0　　#6 : 5 mm to left

software package. The formulae for these analyses were taken from a standard statistics textbook.[15)]

Coefficients of determination were used to compare the measurements from the different machines to the skull measurements and to evaluate intra-and inter-operator error.

Ⅲ. RESULTS

For each of the patient positions, the mean radiographic estimates using each machine were correlated to the actual measurements, and the mean differences between the mean radiographic estimates and the actual measurments were determined. These results are summerized in Tables 1 through 6.

Statistically, it was shown that all the machines studied showed significant correlation between the mean radiographic measurements and the skull measurements regardless of patient positioning($p<0.05$).

Table 7 summerized the percent accuracy of each machine at the different patient positionings according to the degree of error accepted.

Accuracy with correct skull positioning.

Degree of error tolerance $+/-2^0$

If an error of $+/-2^0$ is clinically acceptable for the discrepancy between the radiographic estimates and the actual measurements of tooth angulation, the SS White Panorex 1 was accurate 69% of the time, the Philips Oralix Pan DC was accurate 55% of the time, the SS White Panorex 2 was accurate 50% of the time, and the GE Panelipse was accurate 49% of the time.

Degree of error tolerence $+/-3^0$

If an error of $+/-3^0$ is clinically acceptable for the discrepancy between the radiographic estimates and the actual measurements of tooth angulation, the SS White Panorex 1 was accurate 74% of the time, the GE Panelipse was accurate 67% of the time, and the Philips Oralix Pan DC and the SS White Panorex 2 were accurate 64% of the time.

Degree of error $+/-5^0$

If orthodontists can accept an error of $+/-5^0$, the accuracy is increased to 89% for the SS White Panorex 1 and the GE Panelipse, 85% for the Philips Oralix Pan DC, and 81% for the SS White Panorex 2.

Accuracy with skull positioned incorrectly

Looking at Table 7, the percent accuracy of the machines decreases with incorrect patient positioning, except with positioning the skull up 10^0 or laterally displaced.

Accuracy of individual tooth angulations with skull positioned correctly

Table 8 summerize the percent accuracy of each machine with the patient correctly positioned in determing the angulations of the individual teeth according to the degree of error accepted($+/-2^0$, 3^0, or 5^0). An error tolerance $+/-2^0$ provided accuracy less than 70% of the time, irrespective of the site.

Using an error tolerance of $+/-3^0$, with the SS White Panorex 1, the maxillary right first and second molars, maxillary right canine, maxillary left first premolar, and mandibular right second molar angulations had 0% to 20% accuracy. The remaining teeth angulations were accurate at least 80% of the time. With the GE Panelipse, the maxillary right first and second molars, maxillary right second premolar, maxillary right canine, maxillary left second premolar, mandibular right second premolar, mandibular left canine, and mandibular left first premolar angulations were accuratly estimated less than, or equal to, 60% of the time. The remaining teeth angulations were accurate at least 80% of the time. With the Philips Oralix Pan DC, the maxillary right first and second molars, maxillary right first premolar, maxillary right canine, maxillary left first premolar, mandibular right canine, mandibular right first premolar, and mandibular left first molar angulations were accuratly estimated less than, or equal to, 60% of the time.

The remaining teeth angulations were accurate at least 80% of the time. With the SS

Table 8. Summary of the percentage accuracy of each machine looking at the individual measurements of the teeth with an error tolerance of +/- 2(a), +/- 3(b), and +/- 5(c) with correct positioning.

	(a)				(b)				(c)			
Tooth	A	B	C	D	A	B	C	D	A	B	C	D
#17	20	60	0	0	20	60	0	0	100	100	80	40
#16	0	0	0	0	0	20	0	0	0	100	20	20
#15	60	20	100	100	100	20	100	100	100	80	100	100
#14	60	80	100	100	60	100	100	100	100	100	100	100
#13	0	0	0	0	0	0	0	0	0	0	40	0
#27	100	40	100	60	100	80	100	100	100	100	100	100
#26	100	60	80	20	100	80	100	60	100	100	100	60
#25	60	0	100	100	100	20	100	100	100	80	100	100
#24	60	60	0	0	60	80	20	0	100	100	100	80
#23	80	60	100	100	100	100	100	100	100	100	100	100
#37	60	60	100	100	80	100	100	80	100	100	100	100
#36	60	100	100	20	60	100	100	40	100	100	100	100
#35	60	40	100	40	60	100	100	80	100	100	100	100
#34	100	0	60	100	100	0	80	100	100	40	100	100
#33	80	40	100	100	100	40	100	100	100	100	100	100
#47	0	60	0	0	0	100	0	0	40	100	40	0
#46	60	80	80	20	80	80	100	80	100	100	100	100
#45	100	40	100	100	100	60	100	100	100	80	100	100
#44	0	100	60	0	0	100	80	40	60	100	100	80
#43	40	80	100	60	60	100	100	100	100	100	100	100
mean	55	49	69	50	64	67	74	64	85	89	89	81

A : Philips Oralix Pan DC B : GE Panelipse
C : SS White Panorex 1 D : SS White Panorex 2

White Panorex 2, the maxillary right first and second molars, maxillary right canine, maxillary left first premolar, maxillary left first molar, mandibular right first premolar, mandibular right second molar, and mandibular left first molar angulations were accuratly estimated less than, or equal to, 60 % of the time.

The remaining teeth angulations were accurate at least 80% of the time.

If one were to tolerate an error of +/-5^0, naturally the accuracy of the individual tooth measurements increases. With the SS White Panorex 1. the maxillary right first molar, maxillary right canine, and mandibular right second molar were the only estimated accurately less than, or equal to, 60% of the time. With the GE Panelipse, the maxillary right canine, and the mandibular left first premolar angulations were the only measurements providing this degree of accuracy less than, or equal to, 60% of the time.

With the Philips Oralix Pan DC, the maxillary right first moalr, maxillary right canine, mandibular right first premolar, and mandibular right second molar angulations were accurately estimated less than, or equal to, 60% of the time. With the SS White Panorex 2, the maxillary right first and second molars, maxillary right canine, and mandibular right second molar angulations were accuately estimated less than, or equal to, 60 % of the time.

Intra-and Inter-operator Error

Intra-operator error measuremtns was insignificant(r^2=0.87, r=0.93, p<0.001 ; r^2=0.95, r=0.98, p<0.001). Inter-operator error was also insignificant (r^2=0.79, r=0.89, p<0.001 ; r^2=0.85, r=0.92, p<0.001).

Ⅳ. DISCUSSION

The tolerance of error varies greatly with the mesio-distal inclination and with displacement of the object toward the film or toward the rotation center. The tolerance is also different in different parts of the film and in different panoramic machines.. Furthermore, the length of an inclined object will have a certain effect on the linear distortion and this will have a minor effect on the angular distortion.[9,16] The angle distortion is most marked when the mesio-distal inclination in the object is 45^0 and decreases successively when the angle is increased or decreased.[9] Obviously , there is no angle distortion when the mesio-distal inclination is 0^0 or 90^0. Toward the rotational center of the beam, the angle to the vertical plane in the image increases with the distance from the central plane of the layer. The angle of the beam to the horizontal plane affects the angle distortion and the tolerance limits decrease when the angle of the beam increases.

Thus, the tolerance limits against angle distortion are greater in the lower jaw than in the upper jaw.[9,14] We always have to consider that the panoramic radiograph can never be free from problems of magnification and geometric distortion.[6,9,10,13,14,16-23]

It is very difficult to determine the acceptable range of tooth angulation error on panoramic radiograph. Tronje et al[9] suggested that angular measurements in the panoramic radiograph might be performed provided an error of +/-$5^0$was accepted.

But for orthodontic treatment, what are the acceptable ranges of teeth parallelism? For the maxilla, from -5^0 to $+5^0$ has been consider- ed good parallelism.[3] From $+6^0$ to $+10^0$ has been considered acceptable parallelism; 11^0 and over considered poor parallelism; and less than -6^0 was classified as overtreatment. A wider range was given for the mandible, and thus from 0^0 to 18^0 was considered good, and acceptalble parallelism.[3] An error on the order of +/- 5^0 degrees is usually within acceptable limits for measurements in clinical practice provided these measurements are performed in properly exposed panoramic radiographs.[3,9,10,14] If this degree of inaccuracy is tolerated, all of the panoramic machines were essentially within acceptable limits, even when the "patient" was badly positioned. Consequently, one can assume that the panoramic dental radiography does provide a resonable accurate assessment of tooth angulations with the buccal segments.

Ⅴ. CONCULUSION

If on believe the +/-3^0 is within the realm of acceptable error, the most accurate machine would be the SS White Panorex 1, But the percent accuracy is only 74 %. If, on the other hand, one believes that an error of +/- 5^0 is good enough to base clinical decisions, the the GE Panelipse and the SS White Panorex 1 are both accurate 89 % of the time.

When looking at the individual tooth measurements, the teeth most commonly looked at on panoramic radiographs for correct angulations are the canines, first premolars, and second molars. The maxillary right canine was consistantly inaccurate on all the machines.

If one errs in positioning the patient in the different machines, this study shows it best to err with the patient positioned with the head up 10^0 or positioned with the head 5 mm to the left(right).

The orthodontist must be aware of the distortion inherent in a panoramic radiograph and be familiar with variations between systems and the impact of error in methodology. If he feels that +/- 5^0 is a clinically acceptable degree of error[3,9,14] and is confident that the patient was positioned correctly, then it is his decision as to whether or not to utilize the panoramic radiograph to evaluate root angulations.

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-ABSTRACT-

COMPARISON OF FOUR PANORAMIC DENTAL RADIOGRAPHIC SYSTEMS FOR TOOTH ANGULATION MEASUREMENT ACCURACY UNDER DIFFERENT TOLERENCES

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Panoramic radiographs of a dry skull were used to evaluate the accuracy of four panoramic dental X-ray systems in determining tooth angulations in the buccal segments. The four machines evaluated were the Philips Oralix Pan DC, the GE panelipse, the SS White panorex 1, and the SS White Panorex 2. Panoramic radiographs were taken at six different patient positions for each machine to evaluate the effects of patient positioning on determining tooth angulations in the buccal segments. All of the machines studied showed a significant correlation between the mean radiographic estimates and the actual measurements regardless of positioning($p<0.05$). With correct placement of the skull, the results were analyzed for an error tolerance of $+/- 3^0$ between the actual measurements and the radiographic estimates for tooth angulation. The SS White Panorex 1 was accurate 74% of the time, the GE Panelipse was accurate 67% of the time, the Philips Oralix Pan DC and the SS White Panorex 2 were accurate 64% of the time. When an error tolerance of $+/- 5^0$ was permitted, the accuracy was 89% for the SS White Panorex 1 and the GE Panelipse, 85% for the Philips Oralix Pan DC, and 81% for the SS White Panorex 2.

Key words : panoramic dental radiographic system, measurement accuracy

-국문초록-

치아장축 각도 측정 정확도에 대한 4종 파노라마 방사선 촬영기의 비교

스테이시 듀마스 버슨, 알렌 조지 화만, 강 병 철

이 연구의 목적은 Philips Oralix Pan DC, GE Panelipse, SS White Panorex 1, SS White Panorex 2 의 4종의 X-선기기로 촬영한 파노라마 방사선사진상에서 치아장축 각도측정시 오차 허용도에 따른 정확도를 비교평가하는 것이다. 파노라마 방사선사진 촬영기에서 건조두개골을 (1)정확한 촬영위치, (2) 전방 5 mm이동, (3) 후방 5mm이동, (4) 전방 10^0 기울인 위치, (5) 두개골을 후방 10^0 기울인 위치 (6) 두개골을 좌측으로 5 mm 이동 시킨위치 등 촬영 위치를 6가지로 변화시켜서 임의로 정한 평면 기준선과 협측의 치아장축과의 각도를 측정하여 건조두개골에서의 실측치와 비교하였다. 그 결과는 다음과 같았다.

1. 치아장축의 각도 측정결과는 파노라마 X-선 촬영기의 종류 및 촬영위치에 관계없이 건조두개골에서의 측정치와 방사선사진상의 측정치의 유의성있는 상관관계를 갖었다.($p<0.05$)
2. 건조두개골에서의 치아장축 각도 측정치를 기준으로 정확한 촬영위치에서 촬영한 파노라마 방사선사진상의 오차 허용도를 +/- 3^0로 하였을때, SS White Panorex 1 은 측정치의 74%, GE Panelipse 는 측정치의 67%, Philips Oralix Pan DC 와 SS White Panorex 2 는 측정치의 64%가 이 오차의 범위내에 있었다.
3. 건조두개골에서의 치아장축 각도 측정치를 기준으로 정확한 촬영위치에서 촬영한 파노라마 방사선사진상에서의 오차 허용도를 +/- 5^0로 하였을때, SS White Panorex 1 과 GE Panelipse는 측정치의 89%, Philips Oralix Pan DC 는 측정치의 85%, SS White Panorex 2 는 측정치의 81% 가 이 오차의 범위내에 있었다.