치의학박사 학위논문

Evaluation of the improving method on the panoramic radiographs for edentulous patients

무치악 환자를 위한 파노라마방사선영상 개선 방법의 평가

2014년 2월

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지도교수 허 민 석

이 논문을 치의학박사학위논문으로 제출함

2013 년 11 월

서울대학교 대학원

치의과학과 구강악안면방사선학 전공

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박종웅의 치의학박사학위논문을 인준함

2013 년 12 월

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Abstract

Evaluation of the improving method on the panoramic radiographs for edentulous patients

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Graduate School, Seoul National University
(Directed by Prof. Min-Suk Heo, DDS, MSD, PhD)

Purpose: The aim of this study was to evaluate the reproducibility of panoramic radiographs, and to assess the image quality of panoramic radiographs taken with a specially designed new bite block for edentulous patients.

Materials and Methods: First, the reproducibility of panoramic radiographs was evaluated using the panoramic radiographs acquired from 30 anterior dentulous patients (dentulous group) and 30 anterior edentulous patients using chin-support devices to take panoramic radiograph (edentulous group), respectively, who had taken 3 or more panoramic radiographs. The widths and angles between the designated landmarks were measured on the panoramic radiographs, and the reproducibility was evaluated using intraclass correlation coefficient (ICC) and the coefficient of variation. Second, the usefulness of the new developed bite block for edentulous patients was evaluated using the panoramic radiographs acquired from

30 edentulous patients who had taken the radiographs with the conventional chin-support device (chin-support group) and 30 edentulous patients with the new bite block (bite block group), respectively. The image quality was compared between the panoramic radiographs taken by the chin support device and the new bite block using an image quality evaluation chart.

Results: In the dentulous group and the edentulous group using the chin-support device, the ICCs of the mandibular ramus and mandibular angle areas were higher than condylar head and zygomatic areas. The mandibular ramus and mandibular angle areas showed statistically lower coefficient of variation means than the condylar head and zygomatic areas in the dentulous group, and the mandibular angle area showed significantly lower coefficient of variation mean than the zygomatic area in the edentulous group. In comparing the two groups, each ICC of the edentulous group were lower than that of the dentulous group, and the coefficient of variation means of the mandibular ramus area, zygomatic area, left condylar inclination and ramus ratio between right and left in the edentulous group were significantly higher than those in the dentulous group. The image evaluation chart mean scores of the bite block group were equal or higher in all items than those of the chin-support group and the mean scores of the bite block group were higher in some items with significant differences compared to those of the chin-support group.

Conclusion: Biting positioning provided better positioning reproducibility and image quality than chin-support positioning in taking panoramic radiograph. Therefore, using the new bite block for anterior edentulous patients can be advantageous.

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Key Word: Reproducibility, Reliability, Panoramic radiography, Image evaluation.

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Contents

List of tables

List of Figures

Ⅰ. Introduction

Panoramic radiograph has been widely used in a variety of cases including screening of roots of teeth, cysts, foreign bodies, and neoplasms.[1-3] Also, it is helpful to find bone resorption and osteopenia of the jaws.[4-6] Furthermore, it is indispensible in installing implants.[7] The prevalence of taking panoramic radiography has been increasing in Korea, but a methodical monitoring system for quality control of the radiographs has been hardly established.[8] While taking the panoramic radiograph, the object should be positioned in the focal trough without any movement. In addition, the narrow image layer at the anterior area can induce the errors on the result image.[9,10] An accurate and stable patients' positioning is essential for the favorable image quality.

Not only the image quality itself but also the reproducibility control of panoramic radiograph is important. Acceptable reproducibility of the radiograph provides the adequate evaluation of disease and post-operative follow-ups. Without proper reproducibility, there will be lack of information and precision, and accuracy of the panoramic radiograph cannot be guaranteed.

Anterior edentulous patients have conventionally taken panoramic radiographs using a chin-support device. The panoramic radiographs of the anterior edentulous patients might show worse reproducibility and image quality than those of the dentulous patients using a conventional standard bite block since the chin-support device might provide less stability in positioning patients. To position the anterior edentulous patients better than using the chin-support device when taking a

panoramic radiograph, a new bite block was developed and used in this study.

The aim of this study was to evaluate the usefulness of the new bite block. To this end, reproducibility of panoramic radiographs using the conventional standard bite block and the chin-support device was evaluated and compared, and the image quality using the chin-support device and the new bite block was compared

Ⅱ. Background

1) Conventional panoramic radiography for edentulous patients

For anterior edentulous patients, the conventional bite block (Fig. 1) and the chin-support device (Fig. 1) which were provided with Orthopantomograph® OP100 (Imaging Instrumentarium, Tuusula, Finland) are available when taking a panoramic radiograph. The chin-support device is more commonly used than the conventional bite block since the vertical height of the bite block is 12 mm, which seems to provide insufficient vertical dimension for anterior edentulous area.

However, panoramic radiographs using the chin-support device has been some problems. Some radiographs showed insufficient inter-maxillary space (Fig. 2), and others lack of reproducibility on the inter-maxillary vertical height (Fig. 3) or anatomical structural dimensions (Fig. 4) especially in the horizontal direction (Fig. 5). Therefore, the chin-support device would not provide appropriate reproducible and accurate positioning in taking panoramic radiograph. However, these problems have received little attention.

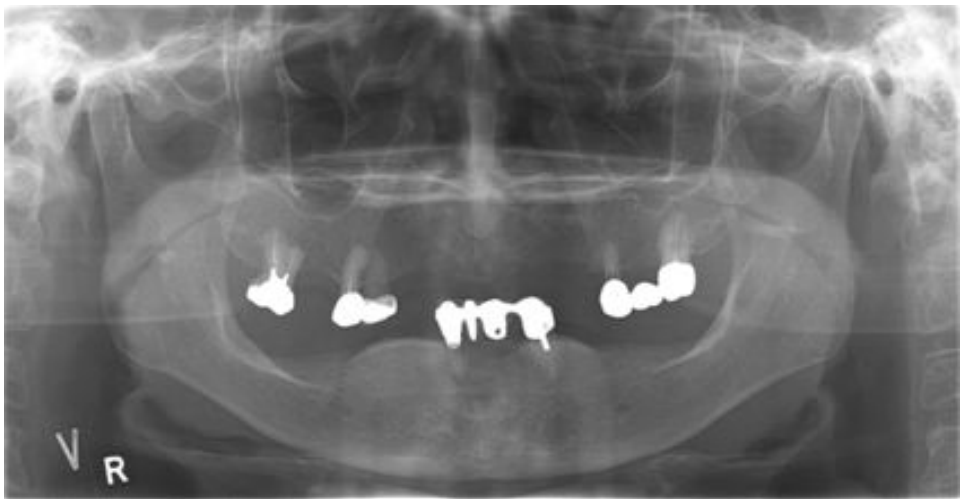
There have been a few studies on the problems of panoramic radiographs. Dhillon et al[11] revealed that most panoramic radiographs had more than one error without distinguishing dentulous and edentulous images. Glass et al[12] stated that 89% of panoramic radiographs for edentulous patients had one or more errors, which were positioning chin too high, positioning too far forward, tongue not raised, chin too

low, head tilted, head turned, too far back, and so on. Batenburg et al[13] showed that without positioning reproducibility, panoramic radiographs were not reliable for diagnosis and evaluation on the edentulous mandible.

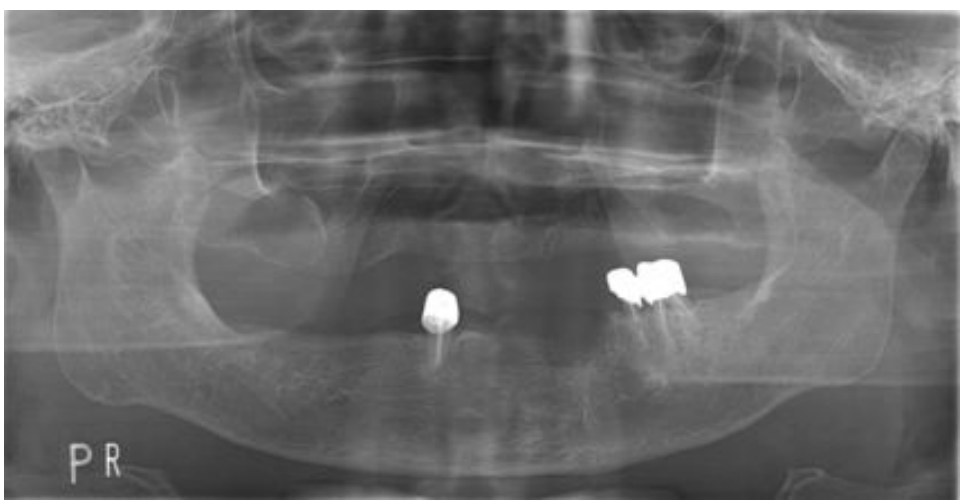
A.

B.

Fig. 1. A. The conventional bite block for anterior edentulous patients. B. The chin-support device for anterior edentulous patients



A.



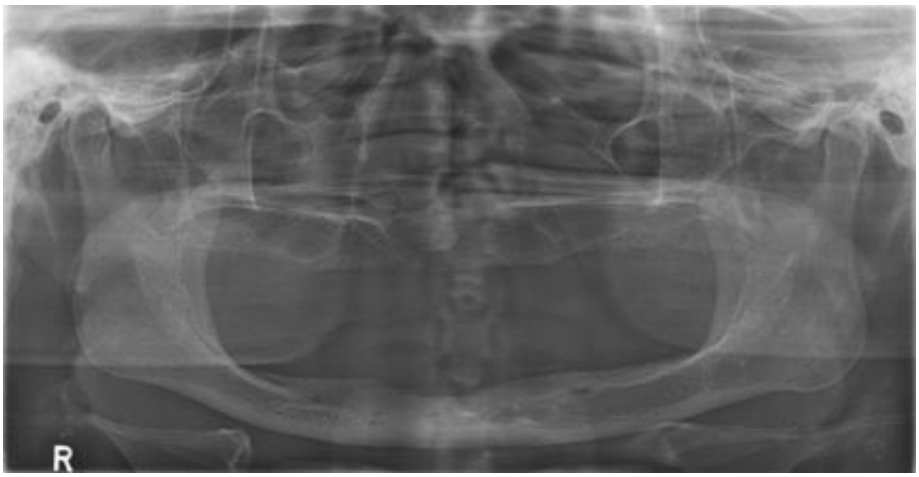
B.

Fig. 2. A and B. The panoramic radiographs acquired from the same anterior edentulous patients using the conventional chin-support device show insufficient inter-maxillary vertical height.

A.

B.

Fig. 3. A and B. The panoramic radiographs acquired from the same anterior edentulous patient using the conventional chin-support device show lack of reproducibility in the inter-maxillary vertical dimension.



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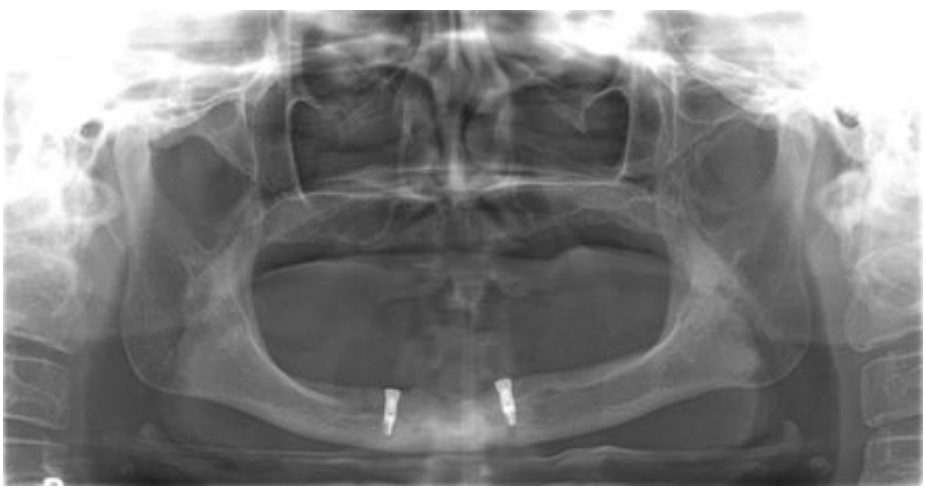
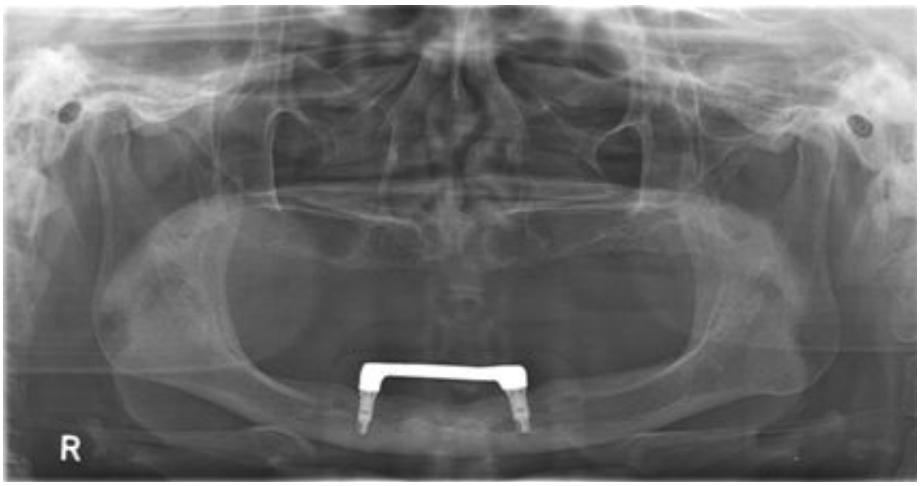
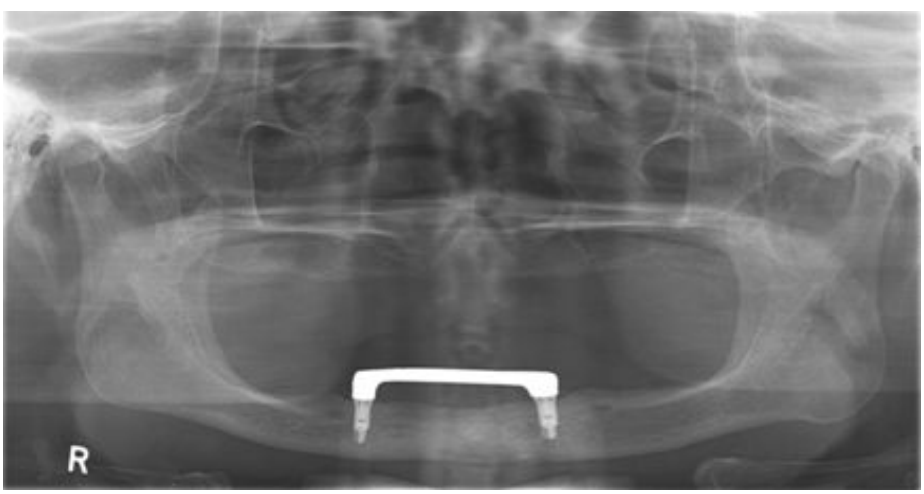


B.

Fig. 4. A and B. The panoramic radiographs acquired from the same anterior edentulous patients using the conventional chin-support device show different overall anatomical structure dimensions.



A.



B.

Fig. 5. A and B. The panoramic radiographs acquired from the same anterior edentulous patients using the conventional chin-support device show horizontal variations.

2) Reproducibility of panoramic radiography

The distortion and measurement stability on panoramic radiographs were evaluated by Tjonje et al,[14] and the vertical measurement might be used in clinical purposes[15] and angular measurements were also satisfactorily accurate for most clinical purposes on panoramic radiographs.[16] Also, Ćatić et al proposed that the linear measurement on the panoramic radiographs was available.[17] Therefore, the linear and angular measurement can be performed on the panoramic radiographs and the measurement can be used for reproducibility evaluation.

The reproducibility of panoramic radiographs could be evaluated more prominently by measuring horizontal linear dimension changes on reproduced panoramic radiographs. In the Larheim et al's study, the vertical length variation in the repeated measurement ranged from 2.4% to 3.1% on the panoramic radiographs,[18] and the measurement of the vertical length was more reliable than that of the horizontal length.[19] Also, the magnification factors of vertical directions were less varied than those of horizontal,[20] and variability of the horizontal magnification factors was high.[19,21] These originated from the changes in the position[19] and a motion factor[19,22,23] which is related with horizontal rotational movement of a panoramic radiograph machine. In other words, when changing the antero-posterior position of the patients, the magnification or reduction in size of the horizontal component would be more prominent than the vertical component on panoramic radiographs because of the motion factor of panoramic machines.[19,22,23] Thus, measuring horizontal length changes would be appropriate to evaluate the

reproducibility of panoramic radiographs.

3) Image quality evaluation

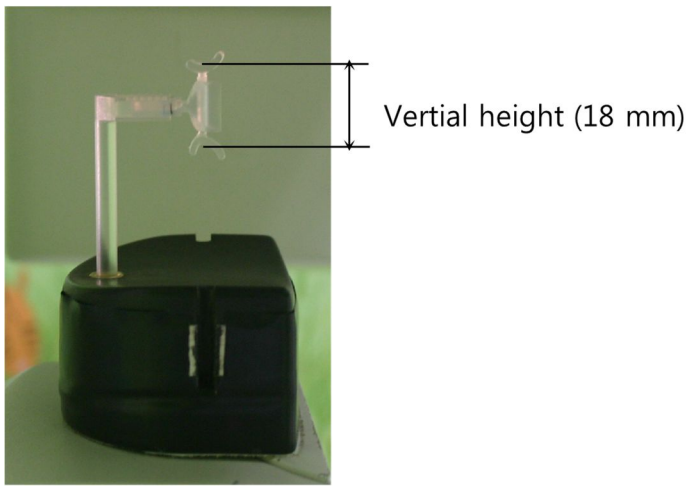
There have been efforts to control the image quality of panoramic radiograph objectively. Choi et al suggested a clinical image quality evaluation chart in 2012[8] and 2013.[8,24] However, their evaluation chart[8] was not available to evaluate panoramic radiographs of edentulous patients. Therefore, the chart was modified to evaluate panoramic radiograph image quality of edentulous patients in this study.

Ⅲ. Preceding work for the present study

A new bite block (Fig. 6) was designed to position anterior edentulous patients in the same manner of anterior dentulous patients who could bite into the notches of a conventional standard bite block (Fig. 6) in taking panoramic radiograph. The new bite block should compensate the area of central incisor teeth, which the anterior edentulous patients didn't have, and the area of resorbed bone. To compensate those areas, statistically measured tooth lengths, facio-lingual inclinations and resorbed anterior alveolar bone lengths were investigated in previous literatures. According to Volchansky and Cleaton-Jones,[25] the mean sizes of teeth were 10.0 mm in maxillary central incisors and 8.4 mm in mandibular central incisors in the age from 20 to 40. Also, the mean facio-lingual inclination of maxillary central incisors was 33.50°, and the value from the mandibular central incisors was 26.44°.[26] The mean angle between occlusal plane and Frankfort horizontal plane was 6.79°.[27] Thus, the angle between maxillary central incisor and vertical plane was 26.71°, and the angle between mandibular central incisor and vertical plane was 19.65°. Also, the amounts of the anterior alveolar bone resorption were 5.90 mm in non-denture wearer and 6.69 mm in denture wearers on the maxillary central incisor area, and 7.07 mm in non-denture wearer and 13.03 mm in denture wearers on the mandibular central incisor area.[28]

Using these values, the vertical dimension and the antero-posterior horizontal distance (horizontal distance) of the new bite block was determined. For the vertical dimension, the vertical vector of the anterior teeth portion was calculated

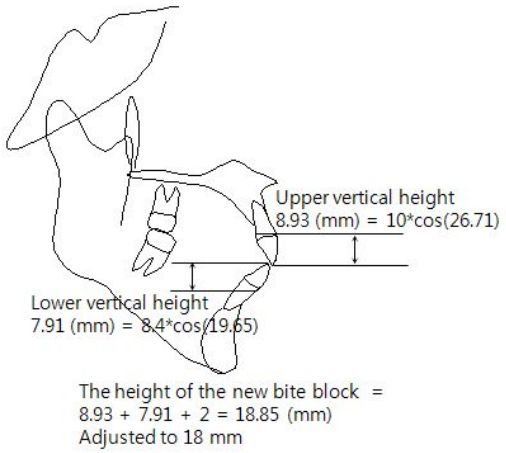
as 16.85 mm, and the thickness of the bite position (notch) of conventional standard bite block for dentulous patient of Orthopantomograph® OP100 (2 mm) was considered. Thus, the vertical height of the new bite block was decided as 18.85 mm, and adjusted to the 18 mm by trial and error procedure (Fig. 7). For the horizontal distance, which is the difference between the lengths from the panoramic radiograph sensor to the standard block's notch and to the biting position of the new bite block, the horizontal vector of the anterior teeth portion was calculated as 4.49 mm, and the horizontal vector of the resorbed bone portion was considered in the range from 2.65 mm to 3.00 mm. The horizontal distance for the new bite block was determined as 5 mm (4.49 mm), and adjusted to the 7 mm by trial and error procedure (Fig. 7). Furthermore, a patent was obtained on the new bite block of edentulous patients in Korea (Registration No. 1299456).



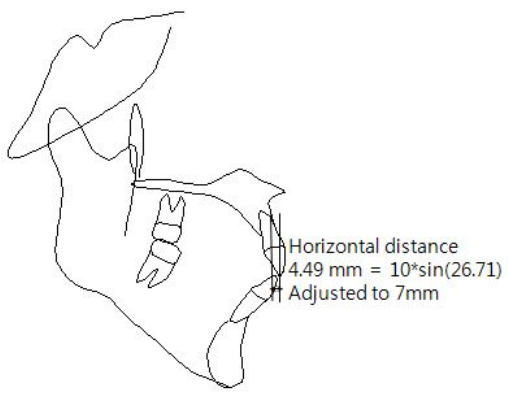
A.

B.

Fig. 6. A. The new bite block for anterior edentulous patients. B. The conventional standard bite block for anterior dentulous patients



A.



B.

Fig. 7. A. A calculation to determine the height of the new bite block. B. A horizontal distance calculation to determine the antero-posterior dimension of the new bite block.

Ⅳ. Materials and Methods

1) Materials

All the panoramic radiographs had been taken by well-trained radiographers using Orthopantomograph® OP100 (Imaging Instrumentarium, Tuusula, Finland), which encompasses overall dental arches and provides proper spatial resolution.[29] Therefore, all the observed areas of the collected panoramic radiographs were assumed to be in the focal trough. Approval for gathering panoramic radiographs was granted from the Institutional Review Board (IRB) of the Seoul National University Dental Hospital, Korea.

2) Reproducibility evaluation

In order to evaluate the reproducibility of panoramic radiographs, the images of 30 anterior dentulous patients (dentulous group) and 30 edentulous patients (edentulous group) were selected, respectively. All of them had 3 or more panoramic radiographs and the dentulous patients took the radiographs using a conventional standard bite block (Fig. 6) and edentulous patients using conventional chin-support device (Fig. 1) in Seoul National University Dental Hospital. Afterward, 3 panoramic radiographs were collected from each of the selected 60 patients. In total, 180 panoramic radiographs were collected, and each group consisted of 90 panoramic radiographs.

In order to evaluate the reproducibility, landmarks were defined, and the widths and angles of the landmarks were measured on separate occasion by one observer who had D.D.S., and was a researcher in Oral maxillofacial radiology field using the function of PACS (PIviewStar, ver5.0.9.81, INFINITT Healthcare, Seoul, Korea) software. The measurement repeated after 1 month. The widths and angles measured in this study are seen in Figure 8 and Table 1. All the measured linear dimensions were horizontal lines.

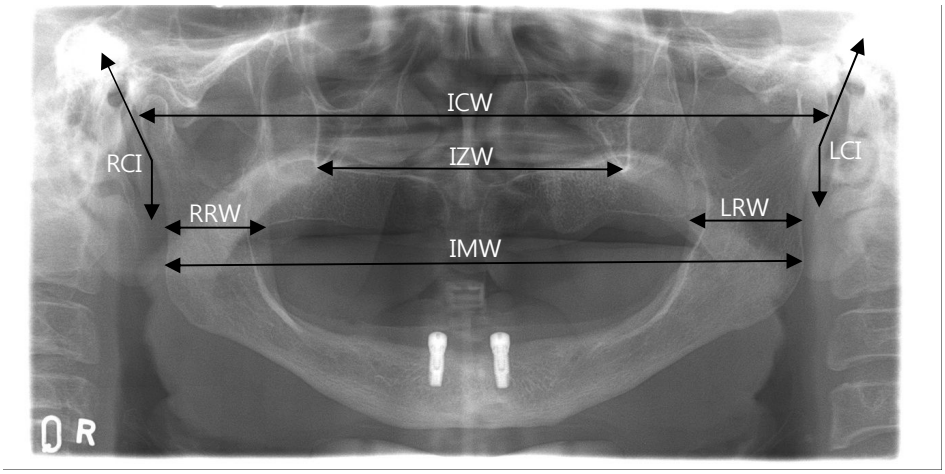


Fig. 8. Reference points, lines, and angles of measuring variables are seen on the radiograph. IMW: Width between the farthest distal mandibular angle points, ICW: Width between the farthest distal condyle head points, IZW: Width between the bottom points of innominate line, RRW: Shortest horizontal length of the right mandibular ramus, LRW: Shortest horizontal length of the left mandibular ramus, RCI: Angle between linear line with distal right condyle neck and vertical line, LCI: Angle between linear line with distal left condyle neck and vertical line.

Table 1. Definition of measuring and calculating parameters assessed in the panoramic radiograph

Parameters	Value description	Explanation
Inter mandibular width (IMW)	Width of inter-mandibular angle	Width between the farthest distal mandibular the angle points
Inter condylar width (ICW)	Width of inter-condyle head	Width between the farthest distal condyle head points
Inter zygomatic width (IZW)	Width of inter-innominate line	Width between the bottom points of the innominate line
Right ramus width (RRW)	Width of right ramus	Shortest horizontal length of the right mandibular ramus
Left ramus width (LRW)	Width of left ramus	Shortest horizontal length of the left mandibular ramus
Right condyle inclination (RCI)	Inclination of right condyle	Angle between the linear line with the distal right condyle neck and vertical line
Left condyle inclination (LCI)	Inclination of left condyle	Angle between the linear line with the distal left condyle neck and vertical line
Ramus Ratio(RR)	Ratio between RRW and LRW	If RRW ≧ LRW, RRW/LRW, Else if RRW < LRW, LRW/RRW
Condyle Ratio(CR)	Ratio between RCI and LCI	If RCI ≧ LCI, RCI/LCI, Else if RCI<LCI, LCI/RCI

The widths and inclinations from the 180 radiographs were measured. Each patient had the 3 sets of measured values from his 3 images of the radiographs. The differences between the values in each patient were used to evaluate the reproducibility. The 3 data sets of the 30 patients in each group were used to calculate intraclass correlation coefficients (ICC) that measures reliability, and the 3 data sets of each patient were used to calculate coefficient of variations (c_v) that

can investigate precision.

The coefficient of variation, which is a normalized measure of dispersion of a probability distribution or frequency distribution should be used for comparison between data sets with different units or widely different means, and could be used to investigate precision. The dispersion of the measured data sets examined by the coefficient of variations would be explained with random errors that closely related the precision. A lower coefficient of variation indicates narrower dispersion and better precision while higher ICC indicates better reliability.

A coefficient of variation mean, which was calculated in the similar way to calculate the inter-assay coefficient of variation and intra-assay coefficient of variation, was the average value of the coefficient of variations in each width and inclination of the 30 patients in each group. Also, a test of significance was performed with the coefficient of variation sets between the measured widths and between the groups.

First, for intra-group assessment, the ICCs were used to evaluate the reliability of each area of the panoramic radiograph image in each of the groups, and the coefficient of variation mean were used to find out which area of the panoramic radiograph image had narrower dispersion and better precision in each of the groups. Second, for inter-group assessment, the ICCs and coefficient of variation mean were used to compare reliability and precision between the groups. Reproducibility was evaluated with the reliability and the precision.

3) Image quality assessment

In order to assess the usefulness of the new bite block for anterior edentulous patients, 30 panoramic radiographs of anterior edentulous patients taken with a conventional chin-support device (Fig. 1) (chin-support group) and 30 panoramic radiographs with the new bite block (Fig. 6) (bite block group) were chosen in Seoul National University Dental Hospital.

The panoramic radiographs of the chin-support group and bite block group were examined using the modified image quality evaluation chart (Table 2) made from the Choi et al's study[8] twice with a 2 week interval. The items related to teeth in the chart of the Choi et al's study[8] were excluded in the modified image quality evaluation chart. Because of the exclusion, the total score of the modified image quality evaluation chart was reduced to 60 from 100 which were originally set in the Choi et al's study[8]. Intra-observer reliability was calculated with intraclass correlation coefficient (ICC).

Score means were the average scores of the 30 patients in each group. The score mean of each evaluation chart item was statistically compared between the groups with the independent *t*-test.

Table 2. Modified image quality evaluation chart for edentulous patients

Item number		items	yes	no
1	1. Coverage area	1. Temporomandibular joint 2. Mandibular angle and inferior border of mandible 3. Inferior border of the orbit : satisfies 1,2,3/ satisfies two of all/satisfies 1 or nothing	6	3 / 0
2	2. Patient positioning or movement	Correct positioning of jaws on image focal trough(layer): adequate/out of image focal trough but diagnosable/ unsuitable for diagnosis	4	2 / 0
3		Occlusal plane: adequate/flat/inverted V or V shape	6	3 / 0
4		Right-left symmetry: symmetric/The discrepancy is less than 1/2 of the width in M-D of mandibular ramus/over than 1/2 of the width in M-D of mandibular ramus	4	2 / 0
5		Blurring of anterior region due to overlapping of spinal column: not present/present but doesn't interfere with diagnosis/unsuitable for diagnosis	4	2 / 0
6		Patient movement- Continuity of anatomic structures: Continuity/step sign under 2 mm/step sign over 2 mm	4	2 / 0
7	3. Density, contrast and resolution or sharpness of image	Distinguishable the alveolar crest in alveolar bone: almost distinguishable/indistinguishable in 2/6 of the region/ indistinguishable in 4/6 of the region	4	2 / 0
8		Distinguishable the trabecular pattern in alveolar bone: almost distinguishable/indistinguishable in 2/6 of the region/ indistinguishable in 4/6 of the region	4	2 / 0
9		Overall image contrast: adequate/partially inadequate/almost inadequate	6	3 / 0
10		Overall image density: homogeneous/partially inhomogeneous/almost heterogeneous	6	3 / 0
11		Overall image sharpness or resolution: clear/partially blurred/ almost not clear	6	3 / 0
12		Noise: not present/present	2	0
	Total score		56	

4) Statistical analysis

ICCs for measuring reliability of panoramic radiographs and intra-observer reliability were calculated with two-way mixed model, absolute agreement type, corresponding 95% confidence interval and single measure values.[30] In accordance with Landis and Koch study,[31] the following ICC interpretation scale was used: poor to fair (below 0.4), moderate (0.41–0.60), substantial (0.61–0.80), and excellent (0.81–1). Also, the statistical significant differences in the coefficient of variation means of the measured widths between the anatomic areas were measured using *Kruscal-Wallis* test, and *post-hoc* test for multiple comparisons of the areas was performed by using *Games-Howell* test. Because of non-equal variances between the compared areas, the *Kruscal-Wallis* test and *Games-Howell* test were selected. Student's *t*-test was carried out to determine whether there were statistically significant differences between two groups in the coefficient of variation means of each anatomic area and in the score means of the modified image quality evaluation chart (Table 2). A P value of $< .05$ was considered statistically significant. All the statistical analysis was performed using the SPSS (IBM SPSS Statistics, ver.21, IBM, Armonk, NY, USA).

Ⅴ. Results

1) Reproducibility evaluation

In the dentulous group, the ramus showed the highest ICCs. IMW showed the second highest value followed by the LCI. Among all the measured values, RRW, LRW, IMW, and LCI were in the range of the excellent score of ICC (>0.8). The ICC of IZW was the lowest while ICW then RCI were the next lower values. RCI, ICW, and IZW showed the ICCs in the substantial range (>0.6, <0.8) (Fig. 9).

With the 30 dentulous patients' data, the coefficient of variation means were calculated for the each item in Table 1 (Fig. 10). In the dentulous group, RRW and LRW showed the lowest and the second lowest coefficient of variation means, followed by IMW. On the contrary, the coefficient of variation mean of IZW was the highest and that of ICW followed. All the inclination measurements were not analyzed for this intra-group comparison. The coefficient of variation sets of each horizontal widths in the dentulous group showed statistically different variances from one another as determined by *Levene Statistic* ($p = 0.002$). There was at least one statistically significant difference between the coefficient of variation means of the horizontal widths in the dentulous group as determined by *Kruscal-Wallis* test ($p = 0.000$). A *Games-Howell* post-hoc test revealed that the coefficient of variation means of IMW, RRW and LRW were statistically significantly lower compared to the coefficient of variation means of ICW and IZW (Table 3) in the dentulous group.

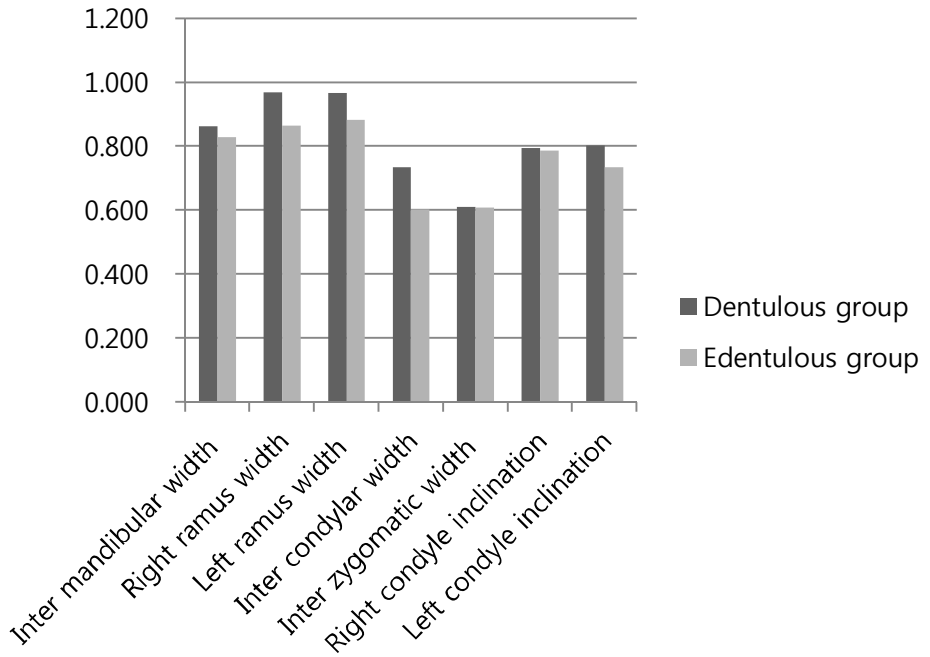


Fig. 9. Intraclass correlation coefficients of widths and angles to show reliability on reproduced panoramic radiographs in the dentulous group and the edentulous group. (Higher is better)

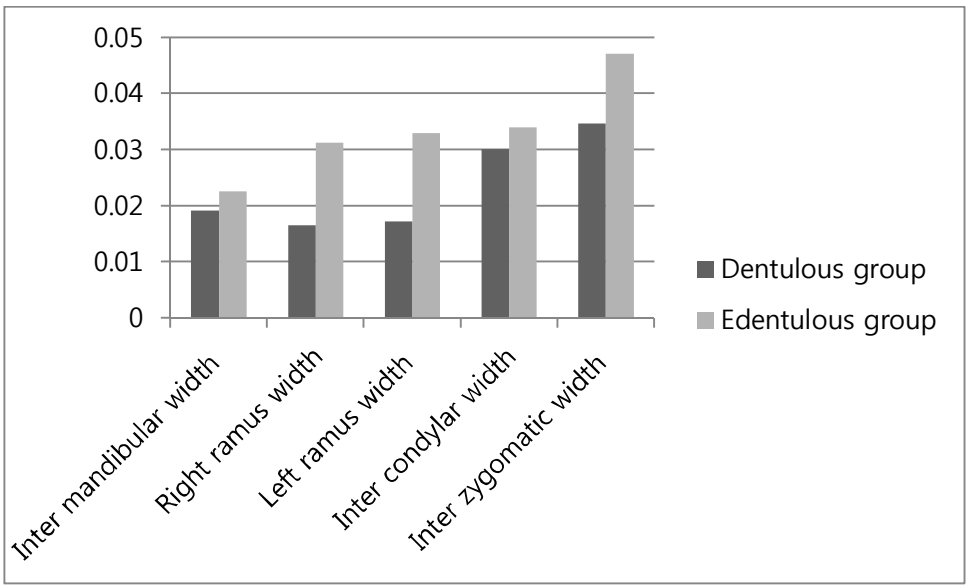


Fig. 10. Coefficient of variation means of widths to show precision on reproduced panoramic radiographs in the dentulous and edentulous group. All the areas (IMW, RRW, LRW, ICW and IZW) of the dentulous group showed relatively lower coefficient of variation means, which indicate higher precision, than those of the edentulous group. (Lower is better)

Table 3. Multiple comparisons of coefficient of variation means to compare precision between anatomical areas in the dentulous group: *Games-Howell* test

(I) Parts			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Games-Howell	Inter mandibular width	Right ramus width	.00257	.00324	.931	-.0066	.0117
		Left ramus width	.00193	.00285	.960	-.0061	.0100
		Inter condylar width	-.01102*	.00355	.024*	-.0210	-.0010
		Inter zygomatic width	-.01549*	.00478	.018*	-.0291	-.0019
	Right ramus width	Inter mandibular width	-.00257	.00324	.931	-.0117	.0066
		Left ramus width	-.00064	.00291	.999	-.0089	.0076
		Inter condylar width	-.01360*	.00360	.003*	-.0237	-.0035
		Inter zygomatic width	-.01807*	.00481	.004*	-.0317	-.0044
	Left ramus width	Inter mandibular width	-.00193	.00285	.960	-.0100	.0061
		Right ramus width	.00064	.00291	.999	-.0076	.0089
		Inter condylar width	-.01296*	.00325	.002*	-.0221	-.0038
		Inter zygomatic width	-.01743*	.00456	.004*	-.0305	-.0044
	Inter condylar width	Inter mandibular width	.01102*	.00355	.024	.0010	.0210
		Right ramus width	.01360*	.00360	.003*	.0035	.0237
		Left ramus width	.01296*	.00325	.002*	.0038	.0221
		Inter zygomatic width	-.00447	.00502	.899	-.0187	.0097
	Inter zygomatic width	Inter mandibular width	.01549*	.00478	.018	.0019	.0291
		Right ramus width	.01807*	.00481	.004*	.0044	.0317
		Left ramus width	.01743*	.00456	.004*	.0044	.0305
		Inter condylar width	.00447	.00502	.899	-.0097	.0187

*. The mean difference is significant at the 0.05 level.

In the edentulous group, the ramus showed the highest ICCs. IMW showed the second highest value. Among all the measured values, RRW, LRW, and IMW were in the range of the excellent score of ICC (>0.8). The ICC of IZW was the lowest while ICW then LCI and RCI had the next lower values. LCI, RCI, ICW, and IZW showed the ICCs in the substantial range (>0.6, <0.8) (Fig. 9).

With the 30 edentulous patients' data, the coefficient of variation means were also calculated in the same way as the dentulous group (Fig. 10). In the edentulous group, IMW showed the lowest coefficient of variation mean followed by RRW and LRW. Contrarily, the coefficient of variation mean of IZW was the highest and that of ICW followed. All the inclination measurements were not analyzed for this intra-group comparison, either. The coefficient of variation sets of each horizontal widths in the edentulous group showed statically different variances from one another as determined by *Levene Statistic* (p = 0.002). There was at least one statistically significant difference between the coefficient of variation means of the horizontal widths in the edentulous group (*Kruscal-Wallis* test p = 0.022). A *Games-Howell* post-hoc test revealed that the coefficient of variation mean of IMW was statistically significantly lower compared to the coefficient of variation mean of IZW (Table 4) in the edentulous group.

Table 4. Multiple comparisons of coefficient of variation means to compare precision between anatomical areas in the edentulous group: *Games-Howell* test

(I) Part			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Games-Howell	Inter mandibular width	Right ramus width	-.00860	.00539	.507	-.0238	.0066
		Left ramus width	-.01039	.00637	.485	-.0285	.0077
		Inter condylar width	-.01133	.00521	.206	-.0261	.0034
		Inter zygomatic width	-.02455*	.00658	.005*	-.0433	-.0058
	Right ramus width	Inter mandibular width	.00860	.00539	.507	-.0066	.0238
		Left ramus width	-.00179	.00718	.999	-.0220	.0185
		Inter condylar width	-.00273	.00618	.992	-.0201	.0147
		Inter zygomatic width	-.01595	.00738	.210	-.0368	.0049
	Left ramus width	Inter mandibular width	.01039	.00637	.485	-.0077	.0285
		Right ramus width	.00179	.00718	.999	-.0185	.0220
		Inter condylar width	-.00094	.00705	1.000	-.0208	.0190
		Inter zygomatic width	-.01416	.00812	.416	-.0370	.0087
	Inter condylar width	Inter mandibular width	.01133	.00521	.206	-.0034	.0261
		Right ramus width	.00273	.00618	.992	-.0147	.0201
		Left ramus width	.00094	.00705	1.000	-.0190	.0208
		Inter zygomatic width	-.01322	.00725	.371	-.0337	.0073
	Inter zygomatic width	Inter mandibular width	.02455*	.00658	.005*	.0058	.0433
		Right ramus width	.01595	.00738	.210	-.0049	.0368
		Left ramus width	.01416	.00812	.416	-.0087	.0370
		Inter condylar width	.01322	.00725	.371	-.0073	.0337

*. The mean difference is significant at the 0.05 level.

In comparing the dentulous and edentulous groups, the edentulous group showed lower ICCs than the dentulous group in each item (Fig. 9). The coefficient of variation means of each item in the edentulous group were higher than those of each item in the dentulous group (Figs. 10 and 11). There were statistically significant differences of coefficient of variation means between the dentulous and edentulous group in the right ramus width, left ramus width, inter zygomatic width, left condyle inclination and ramus ratio (<0.05) (Table 5).

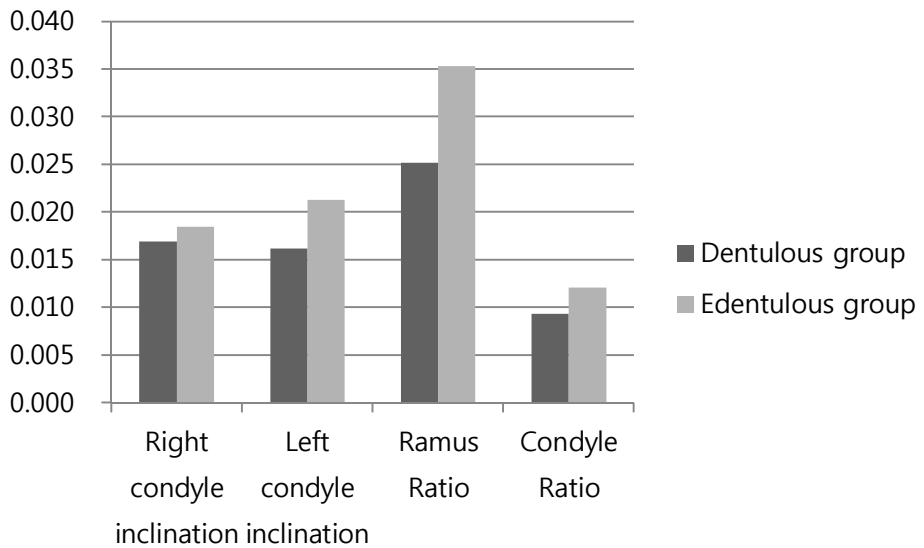


Fig. 11. Coefficient of variation means of Right condyle inclination, Left condyle inclination, Ratio between the RRW and the LRW (Ramus Ratio) and Ratio between the RCI and the LCI (Condyle Ratio) on reproduced panoramic radiographs in the dentulous and edentulous group, which shows the precision of condyle inclination, and ratio between right and left side or the precision of rotation on the vertical axis. RRW: Right ramus width, LRW: Left ramus width, RCI: Right condyle inclination, LCI: Left condyle inclination. (Lower is better)

Table 5. Comparing precision between the dentulous and edentulous group by statistically significant differences of coefficient of variation means between the groups

Variables	coefficient of variation mean of dentulous group	coefficient of variation mean of edentulous group	*p* value (1-tailed)
Inter mandibular width	0.019119	0.022596	0.179157
Right ramus width	0.016545	0.031194	0.002902*
Left ramus width	0.017185	0.032985	0.005497*
Inter condylar width	0.03014	0.033927	0.229247
Inter zygomatic width	0.034614	0.047144	0.044182*
Right condyle inclination	0.016934	0.01849	0.241683
Left condyle inclination	0.016168	0.021298	0.040462*
Ramus Ratio	0.025215	0.035351	0.033688*
Condyle Ratio	0.009355	0.012082	0.077501

*: indicating significant difference (p <0.05)

2) Image quality assessment

Intraclass correlation coefficient (ICC) values for the intra-observer reliability of the modified image quality evaluation chart scores (Table 2) ranged from 0.829 to 1. Therefore, intra-observer reliability of the scores could be considered acceptable.

The panoramic radiographs of the bite block group showed the equal or higher score means in all items of the modified image quality evaluation chart than those of the chin-support group (Table 6). The bite block group showed statistically significantly higher score means than the chin-support group in the items of the 3^{th}, 5^{th}, 7^{th}, 8^{th}, 9^{th}, 10^{th} and 11^{th} in the chart (Table 7).

Table 6. The score means of panoramic radiographs taken with the chin-support device (chin-support group) and the new bite block (bite block group) in each item of the modified image quality evaluation chart

Item number	Chin-support	New bite block
1	4.8	5.3
2	3.8	4.0
3	3.5	5.2
4	3.3	3.6
5	1.6	2.3
6	4.0	4.0
7	2.1	2.6
8	2.1	3.1
9	5.7	6.0
10	5.4	6.0
11	5.6	6.0
12	2.0	2.0
Sum	47.8	54.2

Table 7. Items of the modified image quality evaluation chart showing statistically significant differences between score means of the chin-support group and those of the bite block group

Item number	Item	*p* value (1-tailed)
3	Occlusal plane: adequate/flat/inverted V or V shape	.000*
5	Blurring of anterior region due to overlapping of spinal column: not present/present but don't interfere with diagnosis/unsuitable for diagnosis	.004*
7	Distinguishable the alveolar crest in alveolar bone: almost distinguishable/indistinguishable in 2/6 of the region/indistinguishable in 4/6 of the region	.036*
8	Distinguishable the trabecular pattern in alveolar bone: almost distinguishable/indistinguishable in 2/6 of the region/indistinguishable in 4/6 of the region	.000*
9	Overall image contrast: adequate/partially inadequate/almost inadequate	.042*
10	Overall image density: homogeneous/partially inhomogeneous/almost heterogeneous	.028*
11	Overall image sharpness or resolution: clear/partially blurred/almost not clear	.022*

*: indicating significant difference (p <0.05)

Ⅵ. Discussion

In the panoramic radiographs of the dentulous patients taken with the conventional standard bite block, the mandibular ramus showed the best reliability, followed by the mandibular angle area. On the other hand, the zygomatic arch area showed the worst reliability, and the condylar head area showed the second worst reliability. These results showed good agreement with the result of precision measured from the coefficient of variation means. The mandibular ramus area, which was the closest area to the conventional standard bite block in the position of exposure among the horizontal widths showed the narrowest dispersion, and mandibular angle area showed the second narrowest dispersion. The condylar head revealed the second widest dispersion and the zygomatic arch area had the widest dispersion. In this dentulous group, the closer an anatomic area was to the conventional standard bite block, the better precision the area showed. Also, the mandibular areas except the condylar head showed significantly better precision than the maxillary areas represented by IZW and the condylar head area according to the coefficient of variations' statistical analysis.

The reliability and precision of the edentulous patients using the chin-support device showed the similar order to those of the dentulous patients. In the panoramic radiographs of the edentulous patients, mandibular ramus demonstrated the best reliability, followed by mandibular angle area. The condylar head showed the second worst reliability, zygomatic arch area revealed the worst. These results relatively agreed with the results of the precision evaluation from the coefficient of

variation means. The mandibular angle area which was the closest to the chin-support device in the position of exposure among the horizontal widths showed the narrowest dispersion, and mandibular ramus area showed the second narrowest dispersion. The condylar head area revealed the second widest dispersion and the zygomatic arch area had the widest dispersion. In the edentulous group, the closer an anatomic area was to the chin-support device, the better precision the area revealed. Also, the mandibular angle area showed a statistically significantly better precision than zygomatic areas. This result could originate from the fairly poor coefficient of variation values of the ramus area in the edentulous group, compared to the dentulous group (Table 5).

The reliability and precision varied from area to area on the panoramic radiographs in the dentulous and edentulous group. The reliability and precision could be related with the positioning instability[19] and motion factor[9,17] of the moment taking panoramic radiographs. Mandibular areas except the condylar head area showed the better reliability and precision than the maxillary and condylar head area. These results might originate from the instability of the maxillary area in positioning when taking panoramic radiographs. In positioning of the patients, their chin would be positioned on the chin rest, which could provide fine stability relatively, and almost fixed positions could be guaranteed near the conventional standard bite block especially in the dentulous group. However the head area would be allowed to show somewhat movement because of unstability of the head rest on the panoramic radiograph machine. The importance of the ideal head position has been emphasized in Pfeiffer et al's study, which showed the relationship between the head positions and horizontal measurements in the

panoramic radiographs.[32] Also, Hardy et al showed the effect of the head position on the inclinations in the panoramic radiographs.[33] Moreover, as any anatomic areas locate farther from the most stable reference point which was the biting point of the conventional standard bite block or the center point of chin-supporting, precision of the areas on the reproducing panoramic radiographs became worse since farther distances from the reference point would make the areas more unstable and allow more random errors consequently than closer ones. Thus, if the reference point was located in the middle of a panoramic radiograph image, overall distances from the point to each of the areas could be minimized, and the random errors could be minimized accordingly.

The present study also revealed that the panoramic radiographs of the dentulous group showed better reliability (higher ICC) and precision (lower coefficient of variation) in each area on the images than those of the edentulous group. Especially, the ramus areas of the dentulous group showed statistically better precision than those of the edentulous group ($p<0.01$). The ramus areas were in the almost same horizontal level as the dental arch, which was one of the most important areas on the panoramic radiograph. Also, the zygomatic area of the dentulous group showed statistically significantly better precision than that of the edentulous group ($p<0.05$). Moreover, reliability and precision of the ramus area in dentulous group were better than those of the chin area in edentulous group, which meant that the conventional standard bite block could provide that the more stable reference point than the chin-support device.

The reliability of condylar inclination of the dentulous group was better than that of the edentulous group. The dispersion of condylar inclination data sets in the

dentulous panoramic radiographs were narrower than that in the edentulous panoramic radiographs, and the left condylar inclination in the dentulous group showed statistically better precision than that in the edentulous group ($p<0.05$). These results might originate from the differences in the inter-maxillary stability and in the distance from the fixed reference point between the dentulous and edentulous group.

The ramus width ratios between the right and left side and the condylar inclination ratios between the right and left side were calculated to measure the patients' variability of rotation in the vertical axis or variability of the ratio between the right and left side (Table 1). The dispersion of the ratios were also narrower in the dentulous panoramic radiographs than those in the edentulous, and the ratio between right and left ramus in the dentulous group showed statistically better precision than that in the edentulous group ($p<0.05$).

Therefore, the conventional standard bite block provided better reproducibility, which was represented by reliability and precision than the chin-support device. In accordance with the result, the new bite block was supposed to provide better reproducibility than the chin-support device since the new bite block might provide more stable positioning and could locate the reference point more close to the middle of the radiograph than the chin-support device.

The edentulous group using the new bite block revealed the higher image quality evaluation scores in the evaluation items of an occlusal plane, overlapping of spinal column, alveolar bone distinguishability, trabecular pattern distinguishability, image contrast, image density, and image sharpness than that using the chin-support device ($p<0.05$). According to these results, the image quality of panoramic

radiograph using the new bite block could be regarded as better clinically than that using the chin-support device, which might originate from the assumption that the new bite block could provide better positioning accuracy and stability to both of the jaws than the chin-support device, and reduce patient's movements while taking panorama radiographs.

Further study would be required to evaluate the reproducibility of the panoramic radiographs acquired from the anterior edentulous patients using the new bite block. Also, evaluation of this new bite block with other panoramic radiographic machines which have different rotational systems or different focal troughs is desirable.

Ⅶ. Conclusion

The conventional standard bite block of dentulous patients provided better positioning reproducibility to the panoramic radiographs than the chin-support device of anterior edentulous patients due to the positioning stability and the adequate stable reference point, which was relatively in the middle of a panoramic radiograph image. Accordingly, it could be inferred that the new bite block for anterior edentulous patients might provide better reproducibility than the chin-support device. The new bite block showed the better image quality in panoramic radiographs than the chin-support device since it would provide more accurate and stable positioning during taking the radiographs. Therefore, using the new bite block could be more advantageous to anterior edentulous patients in terms of positioning reproducibility and image quality than using the conventional chin-support device.

References

1. Kogon S, Bohay R, Stephens R. A survey of the radiographic practices of general dentists for edentulous patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995; 80: 365-8.
2. Spyropoulos ND, Patsakas AJ, Angelopoulos AP. Findings from radiographs of the jaws of edentulous patients. Oral Surg Oral Med Oral Pathol 1981; 52: 455-9.
3. Swenson HM, Hudson JR. Roentgenographic examination of edentulous patients. J Prosthet Dent 1967; 18: 304-7.
4. Ortman LF, Hausmann E, Dunford RG. Skeletal osteopenia and residual ridge resorption. J Prosthet Dent 1989; 61: 321-5.
5. Soikkonen K, Ainamo A, Xie Q. Height of the residual ridge and radiographic appearance of bony structure in the jaws of clinically edentulous elderly people. J Oral Rehabil 1996; 23: 470-5.
6. Wical KE, Swoope CC. Studies of residual ridge resorption. I. Use of panoramic radiographs for evaluation and classification of mandibular resorption. J Prosthet Dent 1974; 32: 7-12.
7. Kaffe I, Ardekian L, Gelerenter I, Taicher S. Location of the mandibular foramen in panoramic radiographs. Oral Surg Oral Med Oral Pathol 1994; 78: 662-9.
8. Choi BR, Choi DH, Huh KH, Yi WJ, Heo MS, Choi SC, et al. Clinical image quality evaluation for panoramic radiography in Korean dental clinics. Imaging Sci Dent 2012; 42: 183-90.
9. Welander U. A mathematical model of narrow beam rotation methods. Acta Radiol Diagn (Stockh) 1974; 15: 305-17.
10. Millar JK. Dental pantomography. The orthopantomograph: a method of patient positioning. Radiography 1979; 45: 197-9.
11. Dhillon M, Raju SM, Verma S, Tomar D, Mohan RS, Lakhanpal M, et al. Positioning errors and quality assessment in panoramic radiography. Imaging Sci

Dent 2012; 42: 207-12.

12. Glass BJ, Seals RR, Jr., Williams EO. Common errors in panoramic radiography of edentulous patients. J Prosthodont 1994; 3: 68-73.

13. Batenburg RH, Stellingsma K, Raghoebar GM, Vissink A. Bone height measurements on panoramic radiographs: the effect of shape and position of edentulous mandibles. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997; 84: 430-5.

14. Tronje G, Welander U, McDavid WD, Morris CR. Image distortion in rotational panoramic radiography. I. General considerations. Acta Radiol Diagn (Stockh) 1981; 22: 295-9.

15. Tronje G, Eliasson S, Julin P, Welander U. Image distortion in rotational panoramic radiography. II. Vertical distances. Acta Radiol Diagn (Stockh) 1981; 22: 449-55.

16. Tronje G, Welander U, McDavid WD, Morris CR. Image distortion in rotational panoramic radiography. III. Inclined objects. Acta Radiol Diagn (Stockh) 1981; 22: 585-92.

17. Catić A, Celebić A, Valentić-Peruzović M, Catović A, Jerolimov V, Muretić I. Evaluation of the precision of dimensional measurements of the mandible on panoramic radiographs. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998; 86: 242-8.

18. Larheim TA, Svanaes DB, Johannessen S. Reproducibility of radiographs with the orthopantomograph 5: tooth-length assessment. Oral Surg Oral Med Oral Pathol 1984; 58: 736-41.

19. Larheim TA, Svanaes DB. Reproducibility of rotational panoramic radiography: mandibular linear dimensions and angles. Am J Orthod Dentofacial Orthop 1986; 90: 45-51.

20. Sämfors KA, Welander U. Angle distortion in narrow beam rotation radiography. Acta Radiol Diagn (Stockh) 1974; 15: 570-6.

21. Zach GA, Langland OE, Sippy FH. The use of orthopantomograph in longitudinal studies. Angle Orthod 1969; 39: 42-50.

22. Richardson JE, Langland OE, Sippy FH. A cephalostat for the

orthopantomograph. Oral Surg Oral Med Oral Pathol 1969; 27: 643-6.

23. McDavid WD, Tronje G, Welander U, Morris CR. Effects of errors in film speed and beam alignment on the image layer in rotational panoramic radiography. Oral Surg Oral Med Oral Pathol 1981; 52: 561-4.

24. Choi DH, Choi BR, Choi JW, Huh KH, Yi WJ, Heo MS, et al. Reference line-pair values of panoramic radiographs using an arch-form phantom stand to assess clinical image quality. Imaging Sci Dent 2013; 43: 7-15.

25. Volchansky A, Cleaton-Jones P. Clinical crown height (length)--a review of published measurements. J Clin Periodontol 2001; 28: 1085-90.

26. Tong H, Kwon D, Shi J, Sakai N, Enciso R, Sameshima GT. Mesiodistal angulation and faciolingual inclination of each whole tooth in 3-dimensional space in patients with near-normal occlusion. Am J Orthod Dentofacial Orthop 2012; 141: 604-17.

27. Sato M, Motoyoshi M, Hirabayashi M, Hosoi K, Mitsui N, Shimizu N. Inclination of the occlusal plane is associated with the direction of the masticatory movement path. Eur J Orthod 2007; 29: 21-5.

28. Canger EM, Celenk P. Radiographic evaluation of alveolar ridge heights of dentate and edentulous patients. Gerodontology 2012; 29: 17-23.

29. Scarfe WC, Eraso FE, Farman AG. Characteristics of the Orthopantomograph OP 100. Dentomaxillofac Radiol 1998; 27: 51-7.

30. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979; 86: 420-8.

31. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33: 159-74.

32. Pfeiffer P, Bewersdorf S, Schmage P. The effect of changes in head position on enlargement of structures during panoramic radiography. Int J Oral Maxillofac Implants 2012; 27: 55-63.

33. Hardy TC, Suri L, Stark P. Influence of patient head positioning on measured axial tooth inclination in panoramic radiography. J Orthod 2009; 36: 103-10.

요약(국문초록)

무치악 환자를 위한 파노라마방사선영상 개선 방법의 평가

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1. 목 적

본 연구의 목적은 파노라마방사선촬영 시 환자의 위치 재현성을 평가하고, 새롭게 디자인된 무치악 환자용 교합제를 이용하여 촬영한 파노라마방사선영상의 화질을 평가하는 것이다.

2. 재료 및 방법

재현성 검사를 위해 유치악 그룹은 파노라마방사선사진을 3 회 이상 촬영한 유치악 환자 30 명으로 구성되었고, 무치악 그룹은 파노라마방사선사진을 3 회 이상 촬영한 30 명의 전치부 무치악 환자로 구성되었다. 본 연구에서 채택한 해부학적 구조물 사이의 길이와 각도를 파노라마방사선영상에서 측정하였으며, 급내상관계수 및 변동계수를 구하여 재현성 (reproducibility)을 평가하였다. 새로 개발한 무치악

교합제를 이용하여 촬영한 파노라마방사선영상의 화질을 평가하기 위하여, 기존의 턱받침 기구로 파노라마방사선영상을 1 회 이상 촬영한 30 명 환자의 턱받침 그룹과, 새로운 무치악 환자용 교합제를 이용하여 1 회 이상 촬영한 30 명 환자의 교합제 그룹으로 구성하였다. 턱받침 기구와 무치악 환자용 교합제를 이용하여 촬영한 파노라마방사선영상의 화질은 영상화질평가표를 이용하여 평가하였다.

3. 결 과

급내상관계수에 따르면 유치악 그룹과 무치악 환자 그룹에서 신뢰도가 하악지, 하악각에서 하악과두, 관골 부분보다 더 좋게 나타났다. 유치악 그룹에서는 하악지 부분과 하악각 부분이 하악과두 부분과 관골부분보다 변동계수의 평균이 통계적으로 유의하게 작은 값을 보였으며 무치악 그룹에서는 하악각 부분이 관골 부분보다 유의하게 작은 변동계수의 평균값을 보였다. 위 두 그룹을 비교하면 무치악 그룹의 모든 급내상관계수가 유치악 그룹보다 낮게 나타났고 무치악 그룹의 하악지 부분, 관골 부분, 왼쪽 과두 경사각 그리고 좌우 하악지 비율에서 유치악 보다 유의하게 높은 변동계수의 평균값을 보였다. 교합제 그룹의 영상 화질 평가표 평균 점수들은 모든 항목에서 턱받침 그룹보다 더 높은 점수를 보였으며 특정 항목에서는 통계적으로 유의하게 높게 나타났다($p<0.05$).

4. 결 론

전치부 무치악 환자의 파노라마방사선촬영 시 새로 고안한 교합제를 이용하여 촬영한 영상이 기존의 턱받침을 이용하여 촬영한 영상보다

재현성과 임상적 화질이 모두 우수하였다. 따라서 전치부 무치악 환자용 교합제는 파노라마방사선촬영 시 유용하게 사용될 수 있다.

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주요어 : 재현성, 신뢰도, 파노라마방사선영상, 영상평가

학 번 : 2011-30657