Dental and Skeletal Changes in the Upper and Lower Jaws after Treatment with Schwarz Appliances Using Cone-Beam Computed Tomography

Kiyoshi Tai*/ Jae Hyun Park**

Objective: *The purpose of this research was to use cone-beam computed tomography (CBCT) images to evaluate dental and skeletal changes in upper and lower jaws after treatment with Schwarz appliances.* ***Materials and Methods:*** *28 patients with Angle Class I molar relationships and crowding were randomly divided into two groups – 14 non-expanded and 14 expanded patients. 3D-Rugle CBCT software was used to measure various reference points before treatment (T0) and during the retention period of approximately 9 months after 6 to 12 month expansion (T1). Cephalometric and cast measurements were used to evaluate treatment in both groups. To test whether there were any significant differences between the control and treatment groups at T0 and T1, the Mann-Whitney U-test was used.* ***Results:*** *The dental arch (including tooth root apices) had expanded in the upper and lower jaws. Alveolar bone expansion of up to 2 mm apical to the cementoenamel junction (CEJ) was detected. The midpalatal sutures were separated in some cases and subsequent expansion was observed at the inner surface of the nasal cavity at the inferior turbinates. However, no significant ($P > 0.05$) difference was observed in the inter-width of the mandibular bodies, zygomatic bones, nasal cavity in the middle turbinate region, condylar heads, or antegonial notches. In mandibular and maxillary cast measurements, arch crowding and arch perimeter showed statistically significant changes in the expansion group. The mandibular width values demonstrated no significant changes as measured from a point 2 mm apical to the CEJ, whereas the maxillary width values demonstrated significant changes as measured from a point 2 mm apical to the CEJ.* ***Conclusions****: This study indicates that the Schwarz appliance primarily affects the dento-alveolar complex, while it has little effect on either the mandibular bodies, any associated structures including the maxillary midpalatal suture and the inter-width of the nasal cavity in the middle turbinate region. In addition, the center of rotation of the mandibular and maxillary first molar was observed apical to the root apex.*

Keywords: *Three-dimensional (3D) CBCT, multiplanar reconstruction (MPR) image analysis, superimposition, iterative closest point (ICP) method, Schwarz appliances*
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INTRODUCTION

Orthopedic expansion via rapid maxillary expansion (RME) is gained not only by bodily separation of the midpalatal suture, but also by additional buccal rotational force on the maxillary alveolar shelves.[1-3] However, the effects of mandibular expansion are localized to alveolar bones and mainly induce tooth inclination.[4] Reporting the amount of expansion in the maxilla and mandible differs because of this fundamental difference in the mechanism of expansion. Although expansion of the mandible has theoretically never been successful, several studies have reported good clinical results with the technique.[5-12] There has been some criticism in the literature for a slow expansion technique in the maxilla, since the midpalatal suture does not separate.[13,14] Nevertheless, for lateral expansion of the maxilla and mandible in the mixed dentition, appliances with expansion screws, such as the Schwarz appliance, have been widely used.[15,16]

Now a better method to objectively evaluate changes in the maxillary and mandibular shape that have been treated with the same type of appliances needs to be developed. The current, analytical methods utilize cast models or cephalometric radiographs.[17-19] The purpose of this research is to

* Kiyoshi Tai, DDS, Visiting Adjunct Assistant Professor, Postgraduate Orthodontic Program, Arizona School of Dentistry & Oral Health, A.T. Still University, Mesa, AZ, and PhD Program, Okayama Department of Oral and Maxillofacial Reconstructive Surgery, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, and Private Practice of Orthodontics, Okayama, Japan.

** Jae Hyun Park, DMD, MSD, MS, PhD, Associate Professor and Chair, Postgraduate Orthodontic Program, Arizona School of Dentistry & Oral Health, A.T. Still University, Mesa, AZ and International Scholar, the Graduate School of Dentistry, Kyung Hee University, Seoul, Korea.

Send all correspondence to: Dr. Jae Hyun Park, Postgraduate Orthodontic Program, Arizona School of Dentistry & Oral Health, A.T. Still University, 5855 East Still Circle, Mesa, AZ 85206.

Tel:480.248.8165
Fax: 480.248.8180

E-mail: JPark@atsu.edu

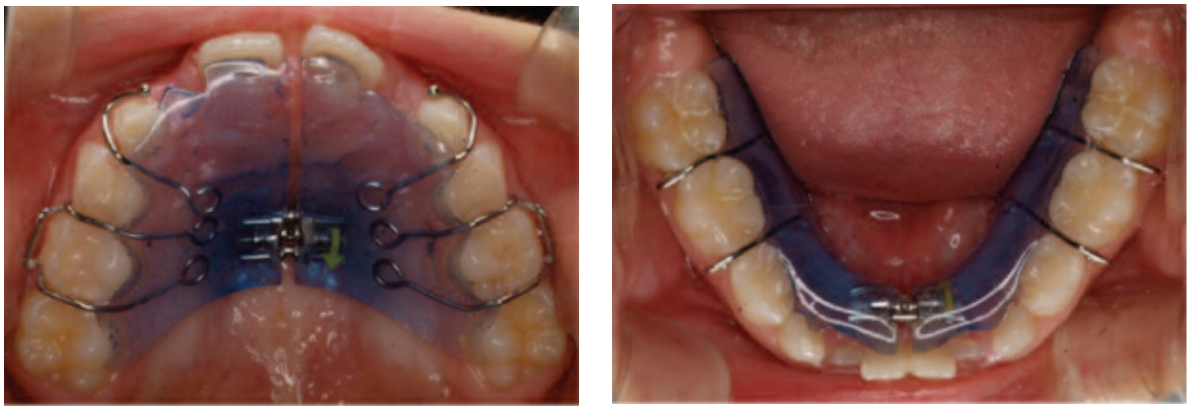

Figure 1. Upper and lower Schwarz appliances used in this study.

analyze the efficacy of the Schwarz appliance using cone-beam computed tomography (CBCT) imaging.

MATERIALS AND METHODS

The initial data was recorded in a private orthodontic office, where 28 patients were randomized into two groups: patients treated with the Schwarz appliances (Exp. Group) and a non-expanded control group (Non-exp. Group). The subjects were diagnosed as having Angle Class I malocclusions with crowding and normal vertical dimensions with no posterior crossbites. 3D-Rugle CBCT software was used to measure various reference points before treatment (T0) and during the retention period approximately 9 months after 6 to 12 months of expansion (T1). The first CBCT (T0) was taken on patients with an average age of 7 years 11 months (Schwarz Expansion Group, 14 subjects) and 8 years 0 months (Control Group, 14 subjects), and then the second CBCT (T1) was taken on patients in both the expansion and control groups at an average age of 9 years 8 months.

The expanded group used a Schwarz expansion appliance on both arches to relieve the anterior crowding (Figure 1). The maxillary dental arches were also expanded using a Schwarz appliance in order to maintain the bucco-lingual relationships of occlusal contact in the posterior teeth during expansion. Patients wore their expansion appliances at night. They were activated by rotating the screws once a week. After 6 to 12 months of expansion, the screws were fixed with cured composite and were then used as retainers.

Table I. Summary of measured parameters and associated landmarks

Landmark for parameter	*Measured landmarks*
UM1/LM1Crown	Distance b/w crowns (the lingual surfaces of the maxillary/mandibular right and left first molar crown at a point 3 mm coronal to the CEJ)
UM1/LM1CEJ	Distance b/w CEJs
UM1/LM1LAP(lingual-alveolar process)	Distance b/w lingual surfaces of the alveolar processes at the maxillary/mandibular right and left first molar area at a point 2 mm apical to the CEJ
UM1/LM1BAP(buccal-alveolar process)	Distance b/w buccal surfaces of the alveolar processes at the maxillary/mandibular right and left first molar area at a point 2 mm apical to the CEJ
UM1/LM1Root	Distance b/w roots (the distance between the maxillary/mandibular right and left first molar roots at a point 7 mm apical to the CEJ)
MT (middle turbinate)	Distance b/w the right and left nasal cavity at the outermost part of the middle turbinate
IT (inferior turbinate)	Distance b/w the right and left nasal cavity at the outermost part of the inferior turbinate
UZyg/LZyg (zygomatic bone)	Distance b/w zygomatic bones at the outermost part of the zygomatic buttresses on the maxillary/mandibular first molar plane
LM1IMB (inner mandibular body)	Distance b/w inner surface of the mandibular bodies at a point 13 mm apical to the CEJ
LM1OMB (outer mandibular body)	Distance b/w outer surface of the mandibular bodies at a point 13 mm apical to the CEJ
CoO (outermost condylar head)	Distance b/w the outermost part of the condylar heads
Ag (antegonial notch)	Distance b/w antegonial notches

UM1, the maxillary first molars; *LM1,* the mandibular first molar.

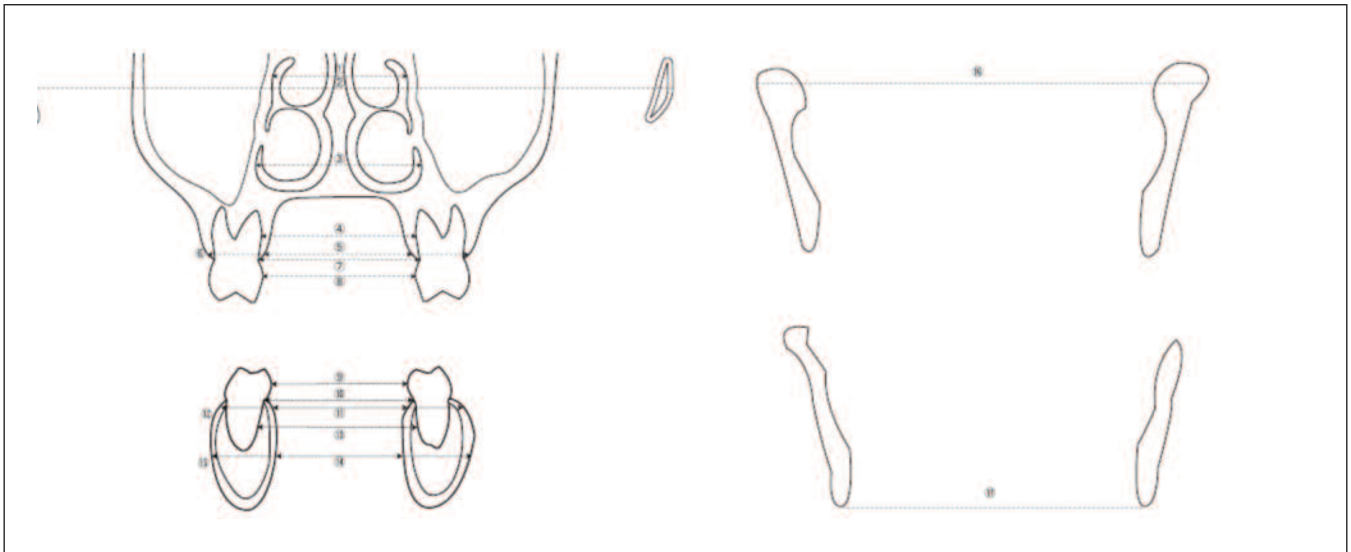

Figure 2. Reference points and lines: 1, middle turbinate; 2, zygomatic bone; 3, inferior turbinate; 4, UM1 root; 5, UM1 lingual-alveolar process; 6, UM1 buccal-alveolar process; 7, UM1 CEJ; 8, UM1 crown; 9, LM1crown; 10, LM1 CEJ; 11, LM1 lingual-alveolar process; 12, LM1 buccal-alveolar process; 13, LM1 root; 14, LM1 inner mandibular body; 15, LM1 outer mandibular body; 16, outermost condylar head; 17, antegonial notch.

To generate images for measurement, a CB MercuRay (Hitachi Medical Corporation, Tokyo, Japan) was used with patients seated and their heads oriented in a natural position.[20]

Five different software programs, Volume-Rugle (Medic Engineering, Kyoto, Japan), MicroAVS (KGT, Tokyo, Japan), VVD2RGL, Point-Rugle and 3D-Rugle (Medic Engineering, Kyoto, Japan) were used to transform the Digital Imaging and Communication in Medicine (DICOM) data from the CBCT images into polygon data. Since the iterative closest point (ICP) method[21,22] is able to superimpose images very precisely with repeatability where numerous corresponding points are utilized to compare point-based registrations,[23,24] the ICP method was used to superimpose the two 3-dimensional (3D) images at T0 and T1. These methods make an accurate superimposition of two separate multiplanar reconstruction (MPR) images possible. Specific points of the cranial base were used as reference points for registration (superimposition) to enhance the accuracy of the ICP method since the cranial base is not greatly influenced by growth.[25,26]

The combined images were cut down an arbitrary plane and separated into two units. The MPR images, which display excellent dimensional accuracy,[27] were used to compare T0 and T1 data.

A slice plane perpendicular to the occlusal plane, passing through both sides of the mesial buccal cusp tips of the maxillary and mandibular first molars, was prepared for the measurements. The 3D-Rugle software program was used for the measurements, and the distances at T0 and T1 were measured as follows.

Seventeen points of interest were measured, including the maxillary and mandibular first molar crowns, cementoenamel junctions (CEJs), roots, buccal and lingual alveolar processes, the inner surface of the nasal cavity at the middle turbinate and inferior turbinate, mandibular bodies, zygomatic bones, condylar heads, and antegonial notches (Table I, Figure 2). In addition, the distances of the crowns, CEJs, labial and lingual alveolar processes, and the labial and lingual outer mandibular cortices at the first mandibular deciduous molars (13 mm apical to the CEJ) were measured at a point 18 mm anterior from the mesial cusps of the mandibular first molars. The same measurements were made on the first maxillary deciduous molars, at a point 16 mm anterior from the mesial cusps of the maxillary first molars.

To see if there was a relationship between the amount of expansion or tipping and the change in cortical bone thickness at the mandibular and maxillary first molars, the first mandibular and maxillary deciduous molars, and the second mandibular and maxillary deciduous molars, axial CBCT images were taken at 2 mm apical to the CEJ (Figures 3 and 4).

In order to compare clinical changes in the control and the expansion groups, cephalometric and cast measurements were made. Lateral cephalometric radiographs were traced by a single investigator (KT) to minimize measurement error. Sixteen points were digitized on each cephalometric radiograph, and 12 cephalometric measurements were made.

Three measurements were made on mandibular and maxillary casts: arch crowding,[28] arch perimeter,[29,30] and arch length.[29,30] The dental cast measurements were made with a Digimatic Caliper (no. NTD 12-15PMX, Mitsutoyo, Kanagawa, Japan) accurate to 0.01 mm.

Measurement error

One examiner (KT) performed all the measurements to eliminate inter-examiner errors. Intra-examiner reliability was evaluated to identify systematic errors and to compare measurement accuracy. Sources of error included landmark location, anatomic contours, and tracing from the cephalo-

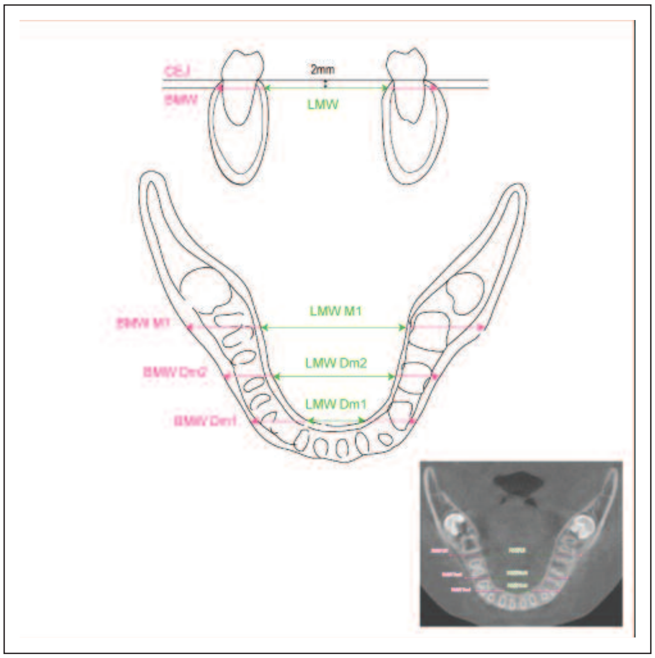

Figure 3. An axial plane depicting measurements at 2 mm apical to the CEJ. BMW (Buccal mandibular width): distance b/w right and left buccal cortical plates, LMW (Lingual mandibular width): distance b/w right and left lingual cortical plates.

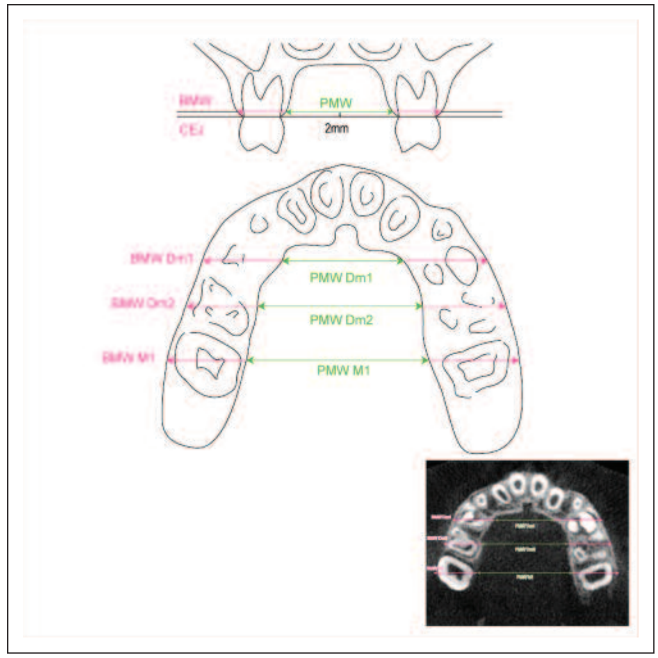

Figure 4. An axial plane depicting measurements at 2 mm apical to the CEJ. BMW (Buccal maxillary width): distance b/w right and left buccal cortical plates, PMW (Palatal maxillary width): distance b/w right and left palatal cortical plates.

grams, and digitizing of the cephalograms, the data conversion from different software programs, and all linear and angular measurements from the CBCT, as well as all linear measurements from the dental casts. In addition, the investigator was blinded with respect to the group being measured to prevent bias in the measurement of the expansion versus non-expansion groups. Tracing and digitizing errors of cephalograms, the data conversion errors from different software programs, linear and angular measurement error of CBCT, as well as all linear measurements from the dental casts were determined by performing each measurement at least ten times on two separate occasions, 2 weeks apart. Five randomly selected subjects from each group (expansion/non-expansion) were measured at least twice on two separate occasions, 2 weeks apart, by the same investigator. No statistically significant differences were found between any measurements based on the intraclass correlation coefficients (ICC).[31]

Statistical analysis

Descriptive statistics were calculated for each measurement. The data was analyzed using a statistical software package (SPSS version 16.0). Treatment changes between the control and treatment groups and between T0 and T1 were analyzed by the Mann-Whitney U-test. A value of $P < .05$ was considered to indicate statistical significance.

RESULTS

The MPR images revealed that the Schwarz expansion group showed a marked expansion in comparison to the control group. The mean inter-mandibular first molar length increased by 5.41 mm at the crown level, by 4.39 mm at the CEJ, by 2.40 mm at the root, by 3.75 mm at the mandibular alveolar lingual point, and by 3.84 mm at the mandibular alveolar buccal point in the Schwarz expansion group. Significant ($P < .05$) differences were observed between the groups with regard to the teeth and alveolar bone. However, no significant differences were seen regarding the mandibular bodies ($P = .695$), zygomatic bones ($P = .893$), condylar heads ($P = .913$), and antegonial notches ($P = .724$) (Figure 5).

The deciduous mandibular first molars were also observed to have expanded. However, due to the root resorption process, the root itself was not measured. For the Schwarz expansion group, the mean inter-crown width of the deciduous mandibular first molar crowns increased by 5.90 mm, the mean width at the CEJ by 4.69 mm, the mean width at the mandibular alveolar lingual point by 4.20 mm, and the mean mandibular alveolar buccal point by 4.25 mm. Significant ($P < .05$) differences were observed between the groups in regard to the teeth and alveolar bone (Figure 5).

The mean inter-maxillary first molar length increased by 6.04 mm at the crown level, by 5.14 mm at the CEJ, by 3.32 mm at the root, by 3.55 mm at the maxillary alveolar lingual point, and by 4.05 mm at the maxillary alveolar buccal point in the Schwarz expansion group. Significant ($P < .05$) differences were observed between the groups with regard to the teeth, alveolar bone and nasal cavity at the level of the inferior turbinates. However, no significant differences were seen regarding the nasal cavity at the middle turbinates ($P = .127$) and zygomatic bones ($P = .732$) (Figure 6).

The deciduous maxillary first molars were also observed to have expanded. However, due to the root resorption process, the root itself was not measured. For the Schwarz

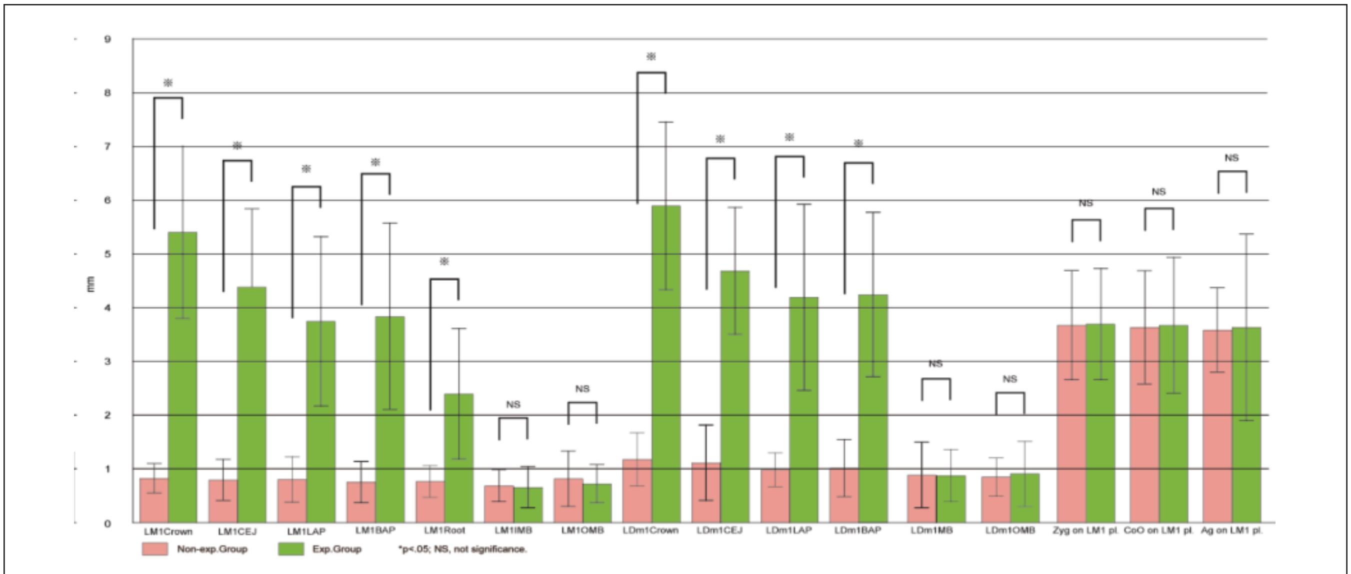

Figure 5. Comparison of the amount of expansion between the control and the treatment groups in the mandible. A Schwarz appliance expands mandibular teeth mainly by inclination movement; in addition it slightly expands the alveolar process and the root tips. Mandibular bodies, zygomatic bones, condylar heads and antegonial notches are not significantly affected by Schwarz appliances.

expansion group, the mean inter-crown width of the deciduous maxillary first molar crowns increased by 6.21 mm, the mean width at the CEJ by 5.19 mm, the mean width at the maxillary alveolar lingual point by 3.80 mm, and the maxillary alveolar buccal point by a mean of 4.36 mm. Significant ($P < .05$) differences were observed between the groups in regard to the teeth and alveolar bone (Figure 6).

When comparing T_0 and T_1 values at 2 mm apical to the CEJ level, the buccal and lingual maxillary and mandibular width values showed significant ($P < 0.05$) differences in the expansion group (Table II). However, with the maxillary width (BMW-PMW) showed significant ($P < 0.05$) changes compared with the mandibular width (BMW-LMW) which did not show significance (Table III).

Table IV shows the measurements at T_0 and T_1 of both groups. There were no significant skeletal, dental, and soft tissue lip profile changes at T_0 and T_1. However, in mandibular and maxillary cast measurements, there were statistically significant changes in arch crowding and arch perimeter from T_0 to T_1 in the expansion group.

CBCT images can show precise changes in internal structures, including tooth roots, where the center of rotation of

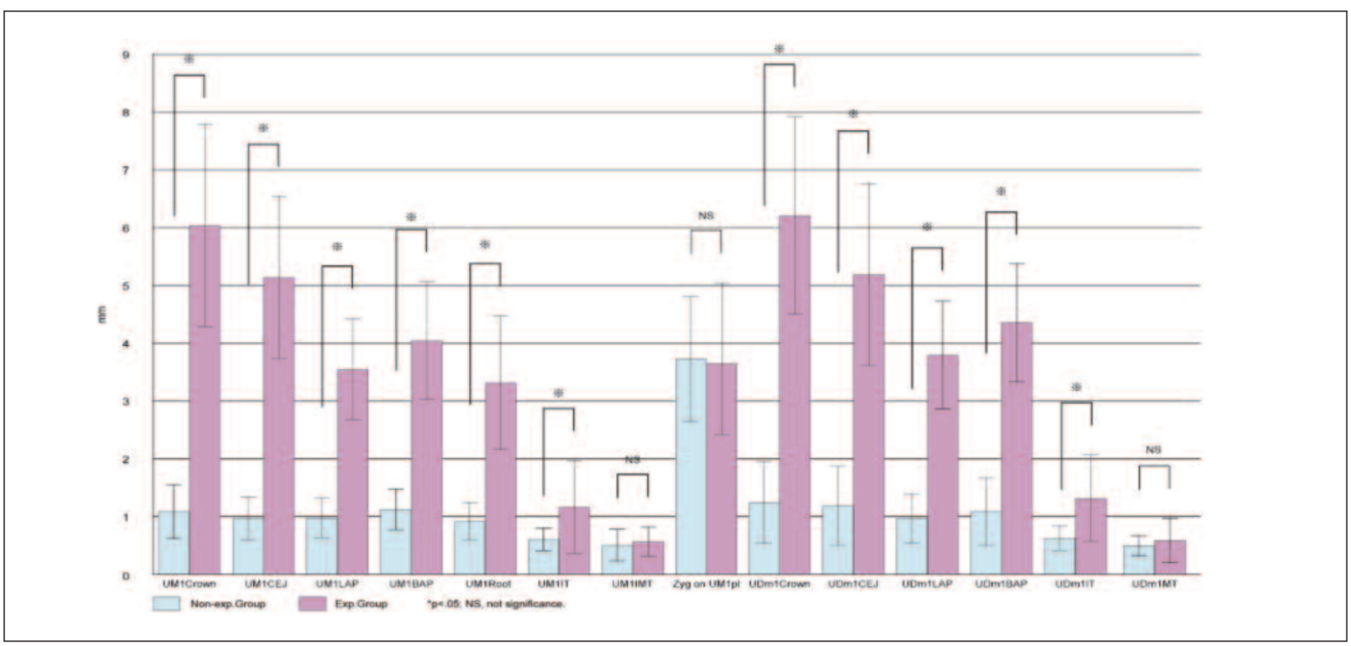

Figure 6. Comparison of the amount of expansion between the control and the treatment groups in the maxilla. A Schwarz appliance expands maxillary teeth mainly by inclination movement; plus it slightly expands the alveolar process, the root tip and nasal cavity at the inferior turbinates. Zygomatic bones and the nasal cavity at the middle turbinates are not significantly affected by Schwarz appliances.

teeth expanded by the Schwarz appliance was seen below the root tip. Plotting the points of crowns, necks and roots generated a straight line. This line demonstrated that the mean center of rotation was 2.49 mm (SD, 1.13 mm; range, 0.08-4.21 mm) apical to the root tip on the long axis of the mandibular first molar. The mean maxillary rotation center was located at 6.31 mm (SD, 1.49 mm; range, 4.34-8.95 mm) apical to the equivalent part to the root tips (the intersection of the long axis of the tooth and a line that was connected with the lingual and buccal root tips) of the maxillary

Table II. Comparison of Non-exp. Group and Exp. Group mandibular and maxillary widths measurements

	Non-exp. Group						Exp. Group						
	T0		T1		Changes with growth		T0		T1		Changes with treatment		Mann-Whitney U-test (Sig)
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Maxillary arch													
At 2mm apical to the CEJ (mm)													
BMxW Dm1	52.02	3.78	53.11	3.52	1.09	0.59	50.36	3.52	54.72	3.77	4.36	1.03	*
PMxW Dm1	28.04	3.22	29.01	3.11	0.97	0.43	26.21	2.16	30.01	3.67	3.80	0.94	*
BMxW Dm2	55.98	3.45	57.08	2.98	1.10	0.58	54.20	3.25	58.39	3.73	4.19	0.83	*
PMxW Dm2	30.26	3.43	31.19	2.76	0.93	0.64	29.36	2.87	33.07	3.42	3.71	0.76	*
BMxW M1	61.19	2.97	62.32	3.87	1.13	0.36	59.36	3.24	63.41	4.02	4.05	1.02	*
PMxW M1	32.78	3.04	33.76	3.63	0.98	0.35	31.04	2.89	34.59	3.03	3.55	0.88	*
Mandibular arch													
At 2mm apical to the CEJ (mm)													
BMnW Dm1	39.44	5.52	40.46	5.68	1.02	0.54	38.87	5.58	43.12	5.61	4.25	1.54	*
LMnW Dm1	23.22	6.03	24.21	6.12	0.99	0.32	22.47	4.84	26.67	4.75	4.20	1.74	*
BMnW Dm2	49.12	4.05	50.04	4.15	0.92	0.53	48.12	3.87	52.22	4.05	4.10	1.68	*
LMnW Dm2	29.41	4.34	30.30	4.19	0.88	0.48	28.04	3.13	32.07	3.56	4.02	1.35	*
BMnW M1	57.91	5.28	58.72	5.22	0.81	0.43	56.04	4.51	59.88	5.12	3.84	1.74	*
LMnW M1	34.06	4.84	34.81	4.79	0.75	0.40	32.49	3.29	36.24	3.98	3.75	1.58	*

BMxW, buccal maxillary width; PMxW, palatal maxillary width; BMnW, buccal mandibular width; LMnW, lingual mandibular width; Dm1, first deciduous molar; Dm2, second deciduous molar; M1, first molar.
*P <0.05; NS, not significant; Sig, significance.

Table III. Comparison of the width changes between maxillary and mandibular bone in the control and the treatment groups

	Non-exp. Group						Exp. Group						
	T0		T1		Changes with growth		T0		T1		Changes with treatment		Mann-Whitney U-test (Sig)
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Maxillary arch													
At 2mm apical to the CEJ (mm)													
MxW Dm1	23.98	2.13	24.10	1.96	0.12	0.02	24.15	1.49	24.64	1.87	0.49	0.13	*
MxW Dm2	25.72	1.87	25.89	2.01	0.17	0.05	24.84	2.24	25.43	2.01	0.59	0.20	*
MxW M1	28.41	1.65	28.56	2.24	0.15	0.08	28.32	2.43	28.87	2.65	0.55	0.19	*
Mandibular arch													
At 2mm apical to the CEJ (mm)													
MnW Dm1	16.22	1.24	16.25	1.13	0.03	0.01	16.40	1.09	16.45	1.17	0.05	0.02	NS
MnW Dm2	19.71	1.52	19.74	1.43	0.04	0.01	20.08	1.83	20.15	1.99	0.08	0.03	NS
MnW M1	23.85	2.14	23.91	2.02	0.06	0.02	23.55	1.68	23.64	1.79	0.09	0.04	NS

MxW, maxillary width (BMW-PMW); MnW, mandibular width (BMW-LMW); Dm1, first deciduous molar; Dm2, second deciduous molar; M1, first molar.

*P <0.05; NS, not significant; Sig, significance.

first molar (Figure 7).

The CBCT images in the expansion group revealed that the mandibular right first molar was uprighted an average of 8.5° (SD, 1.5°; range, 6.2-11.3°) and the average clinical crown inclination value became -24.0° (SD, 3.8°; range, -28.9-18.1°). The mandibular left first molar was uprighted an average of 8.9° (SD, 1.4°; range, 6.7-11.2°) and the average clinical crown inclination value became -22.5° (SD, 3.4°; range, -29.1-17.5°) (Figure 7).

The maxillary right first molar was bucally tipped by an average of 7.6° (SD, 1.4°; range, 5.8-10.3°) and the average clinical crown inclination became -4.61° (SD, 1.7°; range, -9.4-2.5°). The maxillary left first molar was bucally tipped by an average of 8.4° (SD, 1.6°; range, 5.6-10.5°) and the average clinical crown inclination value became -5.31° (SD, 1.9°; range, -10.1-2.9°) (Figure 7).

DISCUSSION

The posteroanterior (PA) cephalometric radiograph analysis has not been popular due to the inability to reproduce the measurement points.[32-35] The width change of the jaw in the canine part, the first premolar part and the first molar part respectively were impossible to determine using conventional radiographic evaluations. By using this new superimposition technique, the axial and coronal sections of 3D images can be easily analyzed.

The 3D superimposition technique for monitoring a young, growing patient over time is much more complicated than the 2D superimposition method because 3D projections cannot be used for precise landmark location or selection of anatomic regions, therefore this study had to develop a process for the creation, registration, and superimposition of 3D images. The 3D data at T0 and T1 were superimposed at the cranial base utilizing the ICP method. The fusion data was then cut with an arbitrary plane and the MPR images were easily analyzed. Using this method, the mandibular and maxillary first molar inclination changes were accurately determined by measuring the angles between horizontal reference lines connecting the center of the zygomatic bones and the long axis of the mandibular first molars.

The lingual crown inclination of normally occluded mandibular posterior teeth progressively increases from

Table IV. Comparison of Non-exp.Group and Exp.Group cephalometric and cast measurements

	Non-exp. Group						Exp. Group						
	T0		T1		Changes with growth		T0		T1		Changes with treatment		Mann-Whitney U-test (Sig)
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Angular skeletal (°)													
Facial angle	84.39	2.64	83.80	2.59	-0.59	0.39	83.57	2.63	83.71	2.61	0.14	0.12	NS
Angle of convexity	4.21	1.89	3.80	1.79	-0.41	0.77	4.17	1.32	3.61	1.29	-0.56	0.40	NS
FMA	29.79	2.64	30.26	2.54	0.47	0.93	28.90	2.28	29.49	2.25	0.59	0.51	NS
SNA	82.16	3.73	82.23	3.66	0.07	0.05	81.56	4.05	82.11	4.02	0.55	0.11	NS
SNB	80.01	2.43	80.12	2.32	0.11	0.09	79.59	3.45	80.01	3.39	0.43	0.14	NS
ANB	2.15	0.73	2.11	0.64	-0.04	0.04	1.97	1.55	2.10	1.49	0.13	0.10	NS
Angular (°) and Linear (mm) dental													
U1 to SN	100.90	11.60	104.52	10.50	3.62	3.59	101.19	7.82	105.14	7.01	3.95	3.39	NS
Interincisal angle	132.03	9.04	125.54	10.52	-6.49	3.02	133.37	7.54	124.86	7.74	-8.51	5.53	NS
IMPA	92.60	7.11	93.89	7.52	1.29	2.10	93.59	5.45	96.36	4.85	2.78	1.91	NS
L1-APO (degree)	25.19	2.84	25.73	2.63	0.54	0.45	24.29	2.36	25.28	2.28	0.99	0.50	NS
L1-APO (mm)	3.06	1.50	3.39	1.40	0.34	0.29	2.97	1.81	3.70	1.52	0.73	0.45	NS
Linear soft tissue (mm)													
Upper lip E-Line	2.00	1.71	1.37	1.68	-0.63	0.50	2.08	1.90	1.60	1.75	-0.48	0.35	NS
Lower lip E-line	2.61	2.04	1.91	1.67	-0.71	0.63	2.95	1.73	2.39	1.57	-0.56	0.50	NS
Maxillary cast measurements (mm)													
Arch crowding	-4.12	0.92	-3.39	0.89	0.73	0.27	-3.91	1.15	-0.82	0.46	3.09	0.94	*
Arch perimeter	70.31	5.03	71.29	5.21	0.98	0.32	69.78	3.99	73.74	4.58	3.96	1.02	*
Arch length	26.25	2.46	27.09	1.69	0.84	0.55	26.38	1.76	27.31	2.14	0.93	0.38	NS
Mandibular cast measurements (mm)													
Arch crowding	-3.83	0.87	-3.17	1.27	0.66	0.50	-3.59	1.21	-0.78	0.70	2.80	1.14	*
Arch perimeter	66.26	4.77	67.04	4.95	0.78	0.65	66.35	3.36	70.11	3.58	3.76	1.62	*
Arch length	23.06	2.28	23.87	2.56	0.81	0.75	24.92	2.11	25.84	1.95	0.92	0.80	NS

*P <0.05; NS, not significant; Sig, significance.

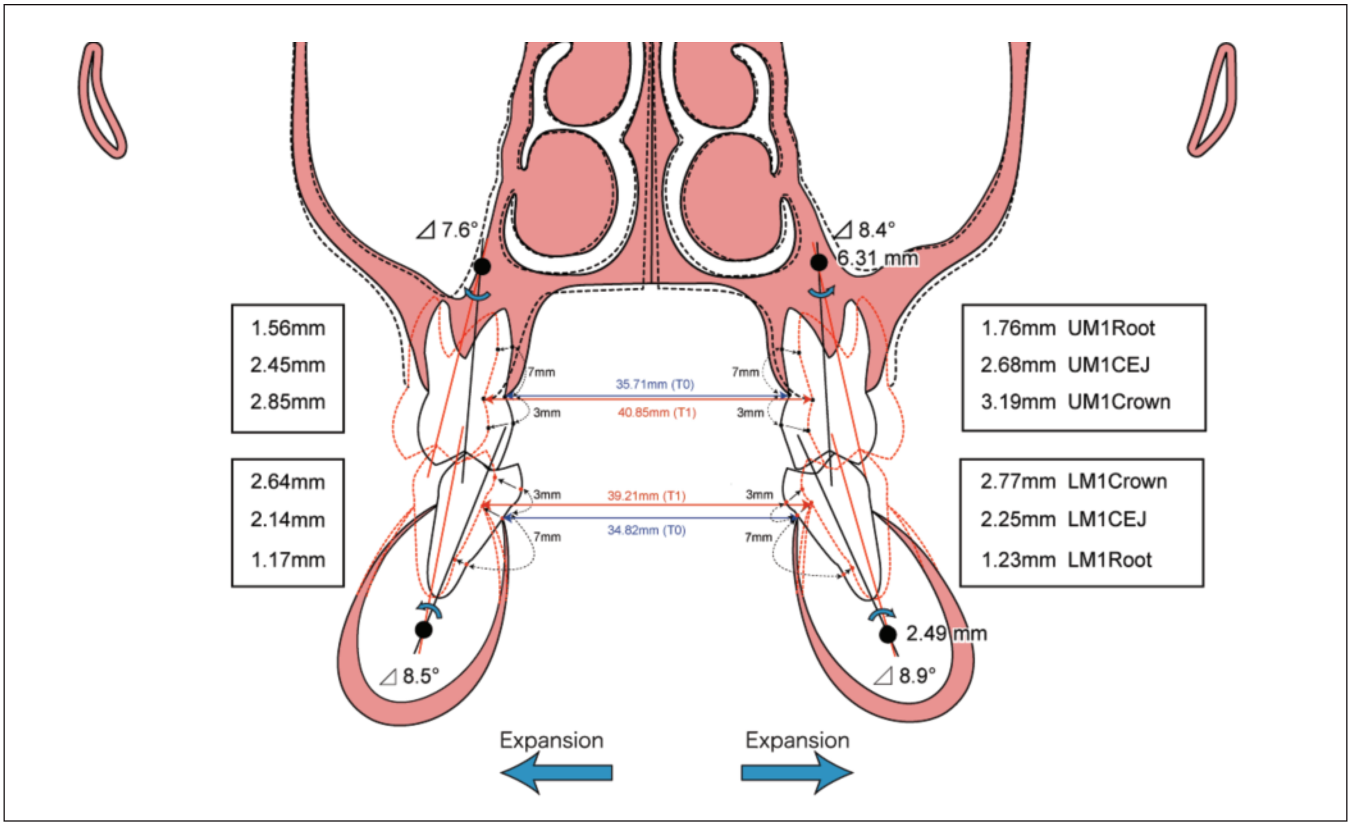

Figure 7. Coronal section at the level of the first molars. During expansion (dashed lines), the alveolar ridges tip and bend buccally, the teeth also tip buccally within the alveoli. The measurements show the amount of change in the expansion group including patient growth.

canines through second molars. Andrews[36] suggested that the degree of buccolingual inclination of the mandibular first molar is approximately -30°. In the present study, the mandibular molars after treatment were uprighted to approximately -23°, not straight upright (approximately 0 to -12°) which would be detrimental to masticatory mandibular movements.[37,38] The data would indicate the permissible limit for mandibular expansion.[39,40]

CBCT analysis was able to demonstrate that mandibular bodies are not affected by Schwarz appliances even after teeth and alveolar bases have been expanded. Some reports have stated that Schwarz appliances produce mandibular expansion in just the alveolar bone and may induce tooth inclination.[15,16] Although dental arches expand mainly by tooth inclination, the distance between the root tips also increases and the amount of displacement of the alveolar bone is almost the same on the buccal and the lingual side.[39,40] This similarity may be due to the remodeling of the alveolar process.

As defined originally by Frost,[41,42] bone modeling is an uncoupled process that results in a net change in size or form of osseous tissue. In human adults, typical remodeling rates are about 3% per year for cortical and 24% per year for trabecular bone.[41-43] The lower rate in mandible occurs because only the inner portion of the cortex undergoes the intense turnover of the metabolic fraction, whereas the outer cortex is protected by mechanical function. Therefore, when orthodontic force is applied, clinically the maxillary teeth tend to move faster than those in the mandible.[43]

In mandibular and maxillary cast measurements the arch length change was not significant because the Schwarz appliance expanded the arch widths transversely rather than sagittaly. According to cephalometric measurements, IMPA and L1-AP_O increased slightly more in the expansion group than in the non-expansion group, but the difference was not significant. Furthermore, soft tissue lip profile changes were not significant because of a corresponding growth of the patient's nose.

A fixed RME appliance compresses the periodontal ligament, bends the alveolar processes, tips anterior teeth, and gradually opens the midpalatal suture.[44] During the maxillary expansion, the nasal cavity is also widened since its lateral walls and floor are formed by maxillary processes. Because of the maxillary expansion, an increase in width of the nasal cavity is sometimes observed, possibly leading to decreased nasal resistance and improved airflow.[44-48] A fixed RME appliance expands the nasal cavity width by an average 1.9 mm, but it widens it as much as 8 to 10 mm[47] at the inferior turbinates, while the more superior areas might move medially.[48] The increase in width of the nasal cavity has an important clinical implication concerning nasal breathing since several authors[49-53] have shown increased permeability. Another supporting factor in the improvement of the nasal permeability is the lowering of the palate as a consequence of a fixed RME.

From this study, expansion across the nasal floor was

1.17 mm, or 19% of the mean Schwarz appliance expansion of 6.04 mm. This is similar to findings with computed tomography by Garib et al,[54] who found nasal floor separation to be one-third of the fixed RME appliance. Other studies report that fixed RME appliances increase nasal volume, possibly leading to decreased nasal resistance and improved airflow.[55,56]

A fixed RME is believed to result in maximum skeletal displacement and bodily tooth movement with minimum dental tipping.[45,57] The mean rate of slow appliance expansion in this study was 0.175 mm per week. Slow expansion, on the other hand, is supposed to produce less tissue resistance in the circummaxillary structures and better bone formation in the intermaxillary suture; these help to minimize posterior relapse.[57] Even so, greater buccal tipping of the molars has been reported in patients treated with slow expanders such as the quad-helix or the nickel-titanium expander compared with those treated with RME appliances.[58,59]

Removable expansion plates are not recommended if significant skeletal changes are required. Midpalatal splitting with such appliances is possible, but not certain. For these appliances to be effective, they must be used in the deciduous or early mixed dentition and must have sufficient retention to be stable during the expansion period.[60,61] In conjunction with the enhanced response to maxillary expansion, early treatment appears to allow less complex and lower-force expansion systems to be used to increase in maxillary arch width. The primary consideration ultimately involves determination of an appropriate expansion protocol which would promote orthopedic movement of the maxillary segments while maintaining optimal tissue intergirty and minimizing orthodontic tipping effects.

The removable expander is still able to generate considerable forces that may be able to generate considerable forces in young children to stimulate the midpalatal suture, especially when the appliance is worn for many hours. The findings of this research and clinical experience are encouraging when answering the efficacy of the removable expander, but studies on long-term stability still need to be done.

Future studies will include long-term data including post-expansion measurements. The present study was focused more on evaluating overall dentoalveolar changes over time in patients using a Schwarz appliance in comparison to a control group using MPR image analysis derived from 3D superimposition.

CONCLUSIONS

According to our results with the methodology used, we conclude the following:

1. The MPR image measurements demonstrated that the Schwarz appliance expands the maxillary and mandibular first molars mainly by inclination movement; plus it slightly expands the alveolar processes and root tips. The mandibular bodies, zygomatic bones, condylar heads and antegonial notches are not significantly affected by the Schwarz appliance. In some cases midpalatal suture was opened.
2. Mandibular bone width was not expanded significantly by the Schwarz appliance, whereas width changes of maxillary bone were observed.
3. The center of rotation of a mandibular molar by Schwarz expansion is located 2.49 mm below the mandibular root tip on the long axis, and the center of rotation of a maxillary molar located 6.31 mm below the equivalent part to the root tips (the intersection of the long axis of the tooth and a line that was connected with the lingual and buccal root tips) of the maxillary first molar.
4. It was difficult to predict midpalatal suture opening. However when the mid palatal suture was opened, expansion of the lower nasal cavity side wall was observed.

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