Original Article

Three-dimensional cone-beam computed tomography comparison of shorty and standard Class II Carriere Motion appliance

Brian Wilson[a]; Nikoleta Konstantoni[b]; Ki Beom Kim[c]; Patrick Foley[c]; Hiroshi Ueno[d]

ABSTRACT

Objectives: To compare treatment effects of the standard and shorty Class II Carriere Motion appliances (CMAs) on adolescent patients.

Materials and Methods: Fifty adolescents with Class II malocclusion formed group 1, who were treated with shorty CMA ($n = 25$, 12.66 ± 1.05 years), and age- and sex–matched group 2, who were treated with standard CMA ($n = 25$, 12.73 ± 1.07 years). Treatment effects were analyzed by tracing with Invivo software to compare pretreatment (T1) cone-beam computed tomography (CBCT) images with post-CMA (T2) CBCT images. A total of 23 measurements were compared within and between groups.

Results: In groups 1 and 2, maxillary first molars showed significant distal movement from T1 to T2 (1.83 ± 2.11 mm and 2.14 ± 1.34 mm, respectively), with distal tipping and rotation in group 1 ($6.52° \pm 3.99°$ and $3.15° \pm 7.52°$, respectively) but only distal tipping ($7.03° \pm 3.45°$) in group 2. Similarly, in both groups, the maxillary first premolars experienced significant distal movement with distal tipping but no significant rotation. In group 1, maxillary canines did not undergo significant distal movement. In both groups 1 and 2, mandibular first molars experienced significant mesial movement (1.85 ± 1.88 mm and 2.44 ± 2.02 mm, respectively). Group 1 showed statistically significantly less reduction in overjet and less canine distal movement with less distal tipping than group 2 ($\alpha < .05$).

Conclusions: The shorty CMA achieved Class II correction similarly to the standard CMA, with less change in overjet and distal tipping movement of the maxillary canines. (*Angle Orthod.* 2021;91:423–432.)

KEY WORDS: Class II malocclusion; Class II; Carriere Motion appliance; Carriere Distalizer; CBCT evaluation; 3D evaluation

INTRODUCTION

The Carriere Class II 3D Motion appliance (CMA; Henry Schein Orthodontics, Carlsbad, Calif), composed of nickel-free stainless steel formed via injection molding,[1] consists of two bracket pads connected by a rigid bar. It is one of the compliance-dependent Class II appliances, such as headgear.[2–4] In both standard and shorty versions of CMAs, the posterior bracket pad is bonded to the maxillary first molar with a ball and socket joint to allow for tipping and rotation of the maxillary molar (Figure 1).[1] The anterior bracket pad, which has a hook, is bonded to the maxillary canine in the standard CMA and to the maxillary first premolar in the shorty CMA. The simple design makes CMAs more comfortable than the Forsus appliance.[5] To produce distal force on the posterior maxillary segment, elastics are worn from the anterior hook to a button or hook on the mandibular first molar.[1] Anchorage is recommended for the lower arch (Essix retainer, Lower Lingual Holding Arch (LLHA), etc) to prevent side effects associated with Class II elastic wear, including flaring of the mandibular incisors.[6] The standard CMA is recommended in most situations, while the shorty CMA

[a] Private practice, Oklahoma City, Okla.
[b] Private practice, Austin, Tex.
[c] Associate Professor, Department of Orthodontics, Saint Louis University, Saint Louis, Mo.
[d] Assistant Professor, Department of Orthodontics, Saint Louis University, Saint Louis, Mo.
Corresponding author: Dr Hiroshi Ueno, Department of Orthodontics, Center for Advanced Dental Education, Saint Louis University, 3320 Rutger Street, Dreiling Marshall Hall, St. Louis, MO 63104, USA
(e-mail: hueno.thk@gmail.com)

Accepted: October 2020. Submitted: April 2020.
Published Online: February 9, 2021

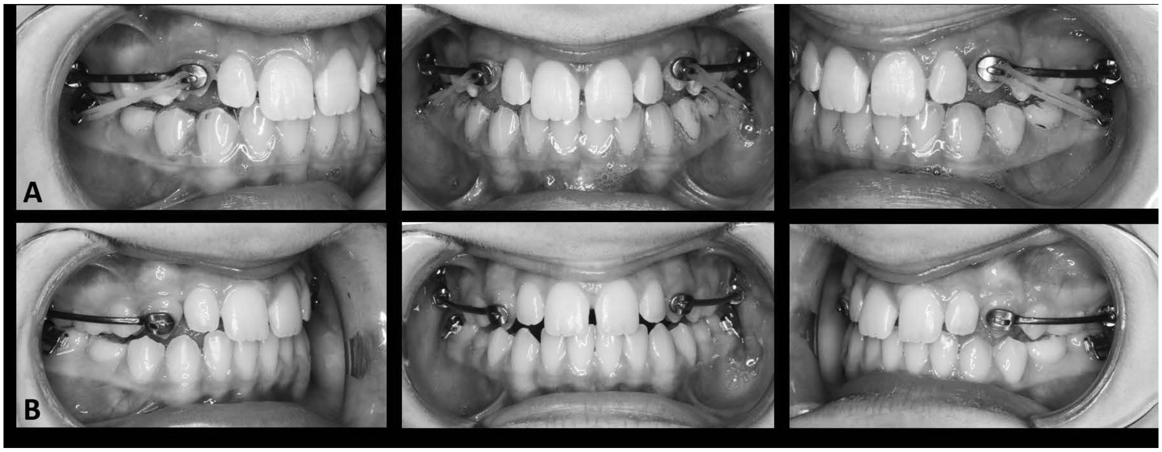

Figure 1. Class II Carriere Motion appliance. (A) Before and (B) after Class II correction.

is suggested for cases with unerupted or ectopically erupted maxillary canines.

There have been case reports showing that CMAs corrected a Class II malocclusion.[7–11] Retrospective case series and cohort studies are also available, in which it was reported that CMAs corrected a mild to moderate Class II malocclusion mainly through dentoalveolar effects in adolescent patients.[12–14] Areepong et al.[15] concluded, in their three-dimensional evaluation, that CMAs brought about not only distal movement of the maxillary first molars and canines with distal tipping, rotation, and extrusion but also mesial movement of mandibular molars.

To date, no study has elaborated on the differences in treatment effects produced by the shorty and standard versions. This study aimed to test the null hypothesis of no statistically significant differences in the three-dimensional treatment effects produced by the standard and shorty CMAs.

MATERIALS AND METHODS

Subjects

The study protocol was approved by the Institutional Review Board at Saint Louis University. Fifty adolescent patients (24 females and 26 males) were collected retrospectively from three private offices. They were collected based on the following inclusion criteria: (1) adolescent patients aged 10–17 years, (2) unilateral or bilateral Class II molar relationship, (3) bilateral Class II canine relationship, (4) use of CMAs for Class II correction, (5) availability of pretreatment (T1) and post-CMA (T2) CBCT images, (6) nonextraction treatment, and (7) use of an Essix retainer in the mandibular dentition for anchorage. The sample excluded the following: (1) posterior crossbite, (2) patients with syndromes, (3) patients with skeletal deformities, and (4) unilateral use of CMAs or the use of both standard and shorty versions of CMAs in the same patient.

The sample was divided into group 1, who were treated with the shorty CMA (n = 25, 13 males/12 females, 12.66 $\pm$ 1.05 years), and the age- and sex-matched group 2, who were treated with the standard CMA (n = 25, 13 males/12 females, 12.73 $\pm$ 1.07 years). There were no significant differences in demographic characteristics between the two groups with regard to age, sex, and Class II molar relationships (Table 1).

Treatment Protocol

First, a CBCT was taken with iCAT FLX at a field of view of 16 cm $\times$ 13 cm or 23 cm $\times$ 17 cm within 0–3 months before treatment (T1). Then, standard or shorty CMAs were placed bilaterally along with hooks bonded to mandibular first molars and an Essix-type retainer. Force 1 elastics (1/4 inch, 6 oz; Henry Schein Orthodontics, Carlsbad, Calif) were used for the first month followed by Force 2 elastics (3/16 inch, 8 oz) from the second month. A CBCT image was then taken at the completion of CMA usage when bilateral Class I canine and molar relationships were achieved (T2). When patients presented with a Class II canine but a Class I molar relationship, CMAs were still bonded and used until the establishment of a Class I canine relationship. However, the elastic protocol for the Class I molar side was to use Force 1 elastics (1/4 inch, 6 oz).

Analysis

The principal investigator (Dr. Wilson) traced the CBCT images using Invivo 6.0 software from Anatomage (San Jose, Calif). No clinically significant difference has been found between CBCT and lateral cephalometric tracings.[16] Custom landmarks and linear and angular measurements (9 singular and 28 paired) defined by Anatomage were identified, similar to

Table 1. Demographics and Molar Relationships in Group 1 and Group 2

	Group 1 (n = 25)	Group 2 (n = 25)	Significance
Age, y	12.66 ± 1.05	12.73 ± 1.07	—
Male:female	13:12	13:12	—
Molar relationship			
Unilateral:bilateral Class II	4:21	4:21	1.000
Class I: end-on: full-step Class II			
Left	4:17:4	1:15:9	.146
Right	1:18:6	3:16:6	.572

Areepong et al.[15] (Tables 2 and Table 3; Figure 2). The Frankfort horizontal was constructed using SN-7°, which represented the *x*-axis, and a perpendicular plane to the *x*-axis was generated to establish a *y*-axis (Figure 3). All right and left paired measurements were averaged for statistical analysis, thereby reducing the 28 paired into 14 averaged measurements. Ultimately, 9 single and 14 averaged measurements were used for comparison.

Statistical Methods

The analysis of covariance (ANCOVA) model adjusted for baseline measures to ensure the starting points. Intrarater reliability was assessed by tracing the same 10 randomly determined CBCT images 1 week apart, using the Cronbach alpha test to determine adequate consistency of measurements (intraclass correlation = .99). At T1 and T2, descriptive statistics were calculated for 23 measurements in both groups. Paired *t*-test was used to compare treatment changes from T1 to T2 within each group. Then, ANCOVA was used to assess differences in the treatment effects between the two groups. Lastly, treatment duration was compared between the two groups using a *t*-test. All analyses were performed using the software R (3.4.2; R Core Team, Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Class I relationships were achieved in all cases. The mean treatment duration in groups 1 and 2 was 5.48 ± 3.04 months and 4.28 ± 1.64 months, respectively, with no significant difference between the groups ($P = .091$).

All 23 measurements at T1 and T2, as well as the T1–T2 differences between the measurements (a positive number indicated a decrease, whereas a negative number indicated an increase from T1 to T2) are described in Table 4 for group 1 and Table 5 for group 2. Table 6 describes the treatment differences between the two groups.

Treatment Changes From T1 to T2 in Group 1

Group 1 did not show any significant skeletal changes from T1 to T2 (Table 4). Maxillary first molars

Table 2. Landmarks, Abbreviations, and Definitions Used for Teeth

Landmark	Abbreviation	Operational Definition
Incision superius	U1	Incisal tip of the right maxillary central incisor
Incision inferius	L1	Incisal tip of the right mandibular central incisor
Maxillary canine cusp tip	U3 cusp	Cusp tip of the maxillary canine (right and left)
Maxillary premolar cusp tip	U4 B cusp	Buccal cusp tip of the maxillary first premolar (right and left)
Maxillary canine mesial	U3 M	Anatomic mesial point of the maxillary canine (right and left)
Maxillary canine distal	U3 D	Anatomic distal point of the maxillary canine (right and left)
Maxillary premolar Mesial	U4 MB	Mesial aspect of the greatest convexity along the mesial-buccal line angle of the maxillary first premolar buccal cusp (right and left); note: this is not the mesial marginal ridge
Maxillary premolar distal	U4 DB	Distal aspect of the greatest convexity along the distal-buccal line angle of the maxillary first premolar buccal cusp (right and left); note: this is not the distal marginal ridge
Maxillary molar mesiobuccal cusp tip	U6 MB cusp	Mesiobuccal cusp tip of the maxillary first molar (right and left)
Maxillary molar distobuccal cusp tip	U6 DB cusp	Distobuccal cusp tip of the maxillary first molar (right and left)
Mandibular molar mesiobuccal cusp tip	L6 MB cusp	Mesiobuccal cusp tip of the mandibular first molar (right and left)
Mandibular molar distobuccal cusp tip	L6 DB cusp	Distobuccal cusp tip of the mandibular first molar (right and left)
Maxillary central incisor root apex	U1 R root	Root apex of the right maxillary central incisor
Mandibular central incisor root apex	L1 R root	Root apex of the right mandibular central incisor
Maxillary canine root apex	U3 root	Root apex of the maxillary canine (right and left)
Maxillary premolar root apex	U4 B root	Buccal root apex of the maxillary first premolar (right and left)
Maxillary molar mesiobuccal root apex	U6 MB root	Mesiobuccal root apex of the maxillary first molar (right and left)
Mandibular molar mesial root apex	L6 M root	Mesial root apex of the mandibular first molar (right and left)

Table 3. Measurements, Abbreviations, and Definitions Used for Teeth

Measurement	Abbreviation	Operational Definition
AP	U1-SN, °	Angle measured through the long axis of the right central incisor to the SN plane viewed from the lateral
	IMPA, °	Angle measured through the long axis of the right mandibular central incisor in relation to the right Gonion-Menton line viewed from the lateral
	Overjet, mm	Horizontal distance from the maxillary right central incisor cusp tip to the mandibular right central incisor tip when projected and viewed from the lateral
	U3 horizontal, mm	Horizontal distance from the canine cusp tip to the *y*-axis and parallel to SN-7 (right and left)
	U4 horizontal, mm	Horizontal distance from the first premolar buccal cusp tip to the *y*-axis and parallel to SN-7 (right and left)
	U6 horizontal, mm	Horizontal distance from the mesiobuccal cusp tip of the maxillary first molar to the *y*-axis and parallel to SN-7 (right and left)
	L6 horizontal, mm	Horizontal distance from the mesiobuccal cusp tip of the mandibular first molar to the *y*-axis and parallel to SN-7 (right and left)
	U3 angle, °	Angle measured through the long axis of the canine (cusp tip to root apex) in relation to the Sella-Nasion line viewed from the lateral (right and left)
	U4 angle, °	Angle measured through the long axis of the first premolar (buccal cusp tip to root apex) in relation to the Sella-Nasion line viewed from the lateral (right and left)
	U6 angle, °	Angle measured through the long axis of the mesiobuccal cusp to the mesiobuccal root apex of the axillary first molar in relation to the Sella-Nasion line viewed from the lateral (right and left)
	L6 angle, °	Angle measured through the long axis of the mesiobuccal cusp to the mesial root apex of the mandibular first molar in relation to the Sella-Nasion line viewed from the lateral (right and left)
Vertical	Overbite, mm	Vertical distance from the maxillary right central incisor cusp tip to the mandibular right central incisor tip when projected and viewed from the lateral
	OP-SN, °	Angle measured by the occlusal plane (bisecting the molars and incisors) to the SN plane
	U3 vertical, mm	Vertical distance from the *x*-axis to the cusp tip of the canine (right and left)
	U4 vertical, mm	Vertical distance from the *x*-axis to the buccal cusp tip of the first premolar (right and left)
	L6 vertical, mm	Vertical distance from the *x*-axis to the mesiobuccal cusp of the mandibular first molar (right and left)
Transverse	U3 rotation, °	Angle measured from the plane created from the anatomic mesial point of the canine to the anatomic distal point of the canine in relation to the Sella-Nasion line viewed from the occlusal (right and left)
	U4 rotation, °	Angle measured from the plane created from the investigator-defined mesial point of the first premolar to the investigator-defined distal point of the first premolar in relation to the Sella-Nasion line viewed from the occlusal (right and left)
	U6 rotation, °	Angle measured from the plane created from the mesiobuccal cusp to the distobuccal cusp of the maxillary first molar in relation to the Sella-Nasion line viewed from the occlusal (right and left)

experienced significant distal movement of 1.83 ± 2.11 mm, with distal tipping of 6.52° ± 3.99° and rotation of 3.15° ± 7.52°. Maxillary first premolars experienced significant changes in all but rotation: significant distal movement of 2.50 ± 2.42 mm with distal tipping of 7.10° ± 5.34° and extrusion of 1.23 ± 1.20 mm. Maxillary canines experienced a statistically significant change in all but distal movement: distal tipping of 5.17° ± 6.10°, rotation of 4.68° ± 8.86°, and significant extrusion of 3.31 ± 3.27 mm. Mandibular first molars experienced significant mesial movement of 1.85 ± 1.88 mm with mesial tipping of 4.01° ± 3.47° and extrusion of 1.92 ± 2.14 mm. Group 1 experienced a significant 2.65° ± 3.01° increase in incisor mandibular plane angle (IMPA).

Treatment Changes From T1 to T2 in Group 2

Group 2 showed a significant decrease of 0.77° ± 0.75° in ANB (Table 5). The maxillary first molars experienced significant distal movement of 2.14 ± 1.34 mm with distal tipping of 7.03° ± 3.45° but without a significant change in rotation. Maxillary first premolars experienced significant changes in all but rotation: significant distal movement of 2.21 ± 1.64 mm with distal tipping of 7.54° ± 5.12° and extrusion of 0.67 ± 1.18 mm. Maxillary canines experienced significant distal movement of 3.16 ± 1.89 mm with distal tipping of 8.74° ± 4.53° and rotation of 3.23° ± 6.47° and extrusion of 1.64 ± 1.19 mm. The mandibular first molar experienced significant mesial movement of 2.44 ± 2.02 mm with mesial tipping of 4.32° ± 4.95° and extrusion of 2.28 ± 1.16 mm. Group 2 also showed a significant 3.37° ± 2.98° increase in IMPA, a significant 2.29 ± 1.50 mm reduction in overjet, and a 1.84 ± 1.36 mm decrease in overbite. In addition, group 2 displayed a significant increase of 1.85° ± 1.46° in the occlusal plane to SN.

Comparisons Between Group 1 and Group 2

Group 1 experienced significantly less reduction in overjet (0.89 ± 2.72 mm) along with less distal movement (–0.36 ± 4.72 mm) and less distal tipping of the maxillary canines (5.17° ± 6.10°) than group 2 (Table 6).

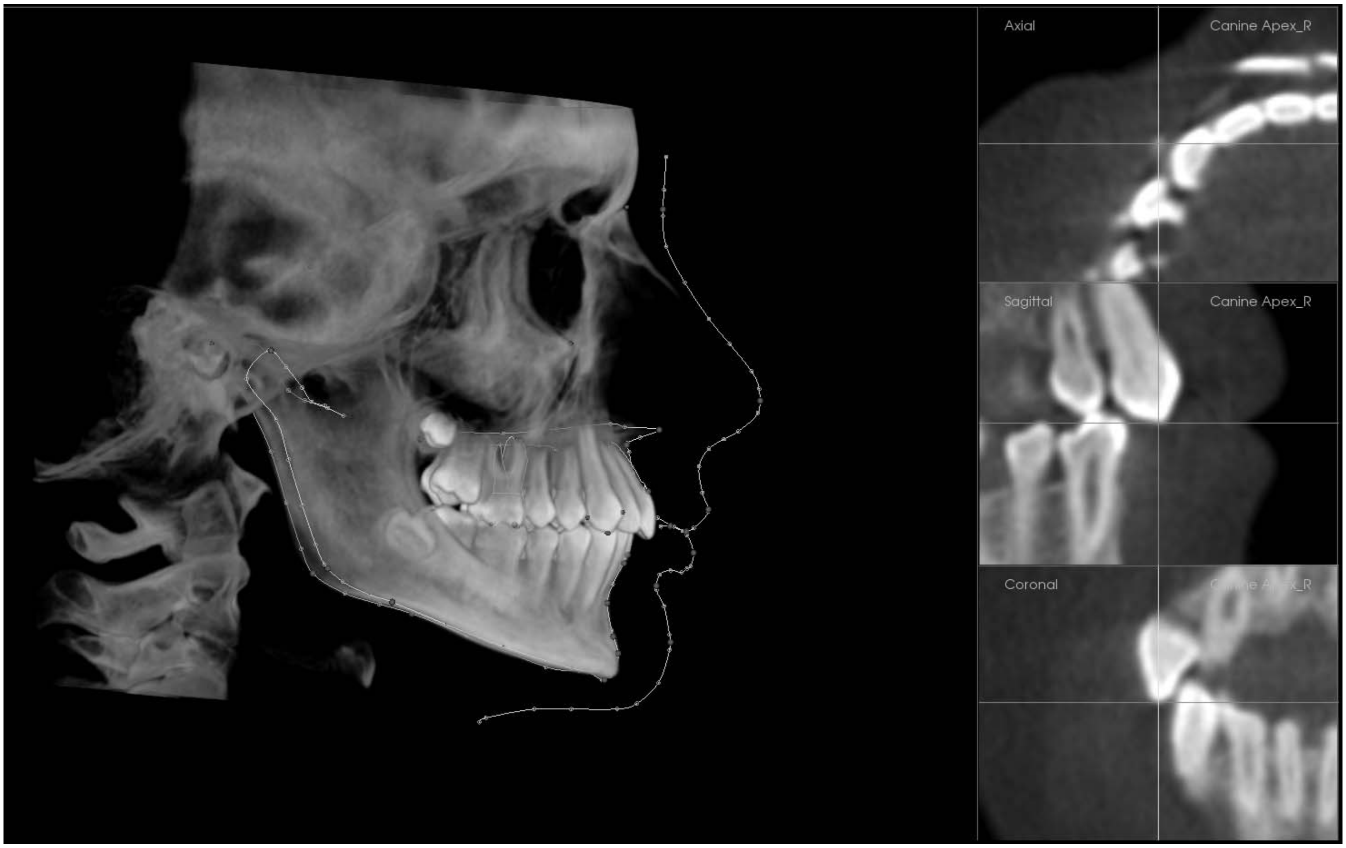

Figure 2. Identification of landmarks in CBCT.

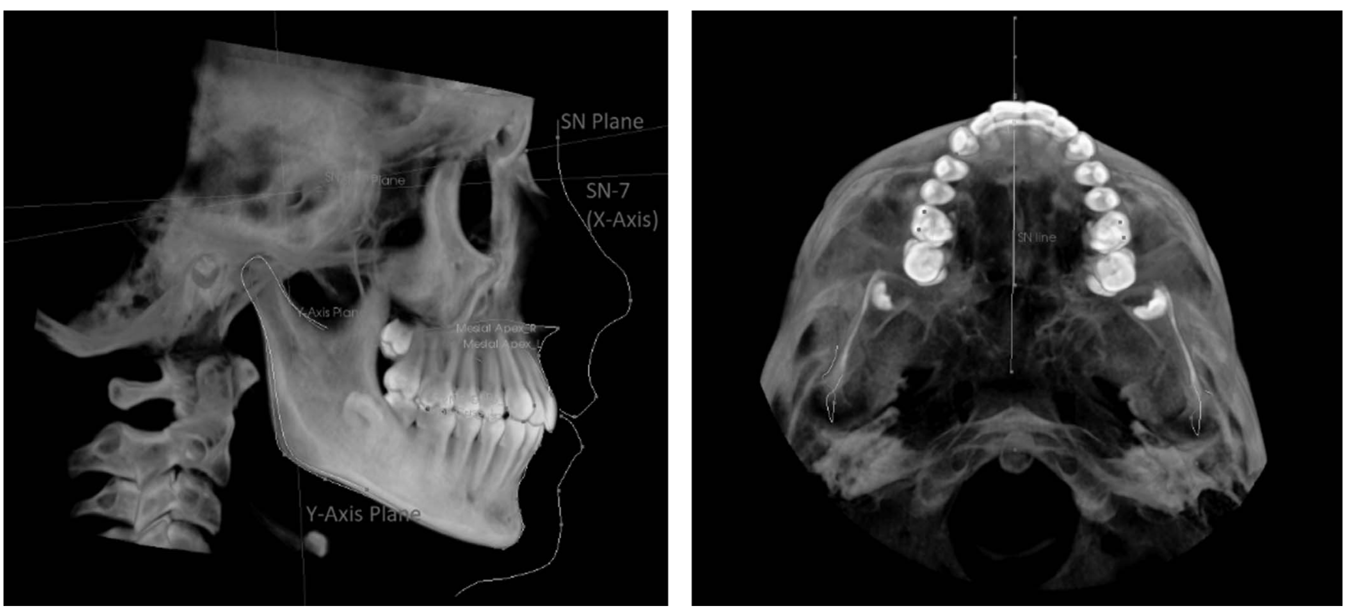

Figure 3. CBCT analysis in anteroposterior and transverse dimensions.

DISCUSSION

This study focused on Class II correction with CMAs, with a treatment time of 5.48 $\pm$ 3.04 months for group 1 and 4.28 $\pm$ 1.64 months for group 2, with no significant time difference between the groups. This was fairly consistent with previous studies: Sandifer et al.[12] (4.4 months), Kim-Berman et al.[14] (5.2 months), and Areepong et al.[15] (4.6 months) but shorter than Yin

Table 4. Changes in Measurements From T1 to T2 in Group 1

	T1		T2		T1–T2 Difference		
	Mean	SD	Mean	SD	Mean	SD	Significance
Skeletal							
AP							
ANB, °	4.38	1.59	4.06	1.62	0.33	0.92	.09
SNA, °	81.21	3.08	81.22	3.18	−0.01	1.32	.97
SNB, °	76.83	3.04	77.16	3.21	−0.33	1.21	.19
Vertical							
MP-SN, °	31.48	5.89	31.78	6.13	−0.30	1.80	.43
Dental							
AP							
U1-SN, °	101.51	9.47	101.43	9.81	0.08	4.73	.93
IMPA, °	96.81	6.43	99.46	6.69	−2.65	3.01	<.01**
Overjet, mm	4.71	1.75	3.83	2.84	0.89	2.72	.12
U3 horizontal, mm	50.36	4.26	50.71	5.19	−0.36	4.72	.71
U4 horizontal, mm	42.47	4.67	39.97	4.82	2.50	2.42	<.01**
U6 horizontal, mm	30.35	4.43	28.52	4.40	1.83	2.11	<.01**
L6 horizontal, mm	29.13	4.30	30.98	4.40	−1.85	1.88	<.01**
U3 angle, °	98.86	8.35	93.69	4.96	5.17	6.10	<.01**
U4 angle, °	81.27	4.99	74.17	5.77	7.10	5.34	<.01**
U6 angle, °	76.26	5.66	69.74	7.35	6.52	3.99	<.01**
L6 angle, °	63.48	4.73	59.47	6.34	4.01	3.47	<.01**
Vertical							
Overbite, mm	4.21	1.27	3.88	6.05	0.33	5.89	.78
OP-SN, °	16.23	4.50	18.15	8.53	−1.92	6.42	.16
U3 vertical, mm	67.38	5.72	70.69	4.89	−3.31	3.27	<.01**
U4 vertical, mm	68.92	3.64	70.16	3.92	−1.23	1.20	<.01**
L6 vertical, mm	63.05	3.87	64.97	4.47	−1.92	2.14	<.01**
Transverse							
U3 rotation, °	39.58	16.22	34.91	13.60	4.68	8.86	<.05*
U4 rotation, °	17.44	7.08	17.61	6.36	−0.17	3.83	.83
U6 rotation, °	16.06	5.73	12.91	6.05	3.15	7.52	<.05*

* Paired *t*-test was significant at the .05 level (two-tailed).
** Paired *t*-test was significant at the .01 level (two-tailed).

et al.[13] (6.3 months). Because of the short duration, the effect from growth on the T1–T2 changes was considered to be minimal. The time required for Class II correction with CMAs was shorter than Class II elastics only, for instance, as reported by Uzel et al.[17] (8.5 months) and Yin et al.[13] (10.3 months).

Skeletal Changes

Group 1 did not show significant changes in SNA, SNB, or ANB from T1 to T2, similar to Yin et al.[13] However, group 2 showed a significant decrease of $0.77° \pm 0.75°$ in ANB but not in SNA or SNB, similar to Kim-Berman et al.[14] Interestingly, Sandifer et al.[12] recorded a significant increase of 0.2° in SNB but no significant change in ANB. Thus, the research suggested that CMAs mainly bring about dentoalveolar changes without much skeletal change to correct Class II malocclusions.

There were no significantly different changes in SNA, SNB, or ANB between the two groups, implying that the sagittal skeletal changes are minimal and relatively the same for both shorty and standard CMAs.

Significant changes in MP-SN were not observed for either group, which was consistent with previous studies on CMAs.[12–15] There were no significantly different changes in MP-SN between the groups, indicating that both shorty and standard CMAs did not rotate the mandible open during Class II correction.

Maxillary First Molar Movements

In both groups, the maxillary first molars experienced significant distal movement with distal tipping, which was consistent with previous studies.[12,15] Group 1 displayed significant distal rotation of the maxillary first molar from T1 to T2, while group 2 did not. Although there were no significantly different changes between the groups, this might have been related to the shorter arm of the shorty design in group 1, which rotated the maxillary first molars more. This contrasted the findings of Areepong et al.,[15] who reported significant distal rotation of the first molar, perhaps because approximately 20% of their sample included shorty CMA cases. There were no significant differences in the movements associated with the maxillary first molars

Table 5. Changes in Measurements From T1 to T2 in Group 2

	T1		T2		T1–T2 Difference		
	Mean	SD	Mean	SD	Mean	SD	Significance
Skeletal							
AP							
ANB, °	4.65	1.93	3.88	1.98	0.77	0.75	<.01**
SNA, °	83.14	3.71	82.84	3.80	0.30	1.15	.21
SNB, °	78.45	3.83	78.94	3.86	−0.49	1.28	.06
Vertical							
MP-SN, °	30.29	4.80	30.43	5.48	−0.14	1.28	.58
Dental							
AP							
U1-SN, °	102.99	9.13	103.99	7.95	−1.00	3.22	.13
IMPA, °	98.22	6.06	101.59	7.00	−3.37	2.98	<.01**
Overjet, mm	5.07	2.05	2.78	2.00	2.29	1.50	<.01**
U3 horizontal, mm	52.92	5.04	49.76	5.33	3.16	1.89	<.01**
U4 horizontal, mm	44.61	4.81	42.40	4.96	2.21	1.64	<.01**
U6 horizontal, mm	32.88	4.44	30.74	4.69	2.14	1.34	<.01**
L6 horizontal, mm	31.77	4.59	34.21	4.47	−2.44	2.02	<.01**
U3 angle, °	96.55	4.41	87.81	5.66	8.74	4.53	<.01**
U4 angle, °	82.74	5.06	75.20	6.55	7.54	5.12	<.01**
U6 angle, °	77.53	5.91	70.50	7.88	7.03	3.45	<.01**
L6 angle, °	62.77	6.11	58.44	8.19	4.32	4.95	<.01**
Vertical							
Overbite, mm	3.86	1.30	2.02	1.42	1.84	1.36	<.01**
OP-SN, °	14.36	5.16	16.21	5.59	−1.85	1.46	<.01**
U3 vertical, mm	71.30	2.69	72.94	3.08	−1.64	1.19	<.01**
U4 vertical, mm	69.57	2.76	70.24	3.23	−0.67	1.18	<.01**
L6 vertical, mm	64.53	2.68	66.81	3.31	−2.28	1.16	<.01**
Transverse							
U3 rotation, °	26.68	8.04	23.45	6.29	3.23	6.47	<.05*
U4 rotation, °	18.42	5.48	17.44	4.52	0.98	3.71	.20
U6 rotation, °	14.37	6.37	11.42	10.18	2.95	9.55	.14

* Paired *t*-test was significant at the .05 level (two-tailed).
** Paired *t*-test was significant at the .01 level (two-tailed).

between the groups, indicating that maxillary first molar movements were relatively the same for both shorty and standard CMAs.

Maxillary First Premolar Movements

In both groups, maxillary first premolars experienced significant distal movement with distal tipping and extrusion but exhibited a lack of significant rotation. There were no significant differences between the groups. The lack of rotation was interesting, especially in group 1, considering the maxillary canine experienced significant distal rotation in both groups.[15] Considering that the maxillary first premolars were positioned more buccally in the arch than the maxillary canines, the transverse vector of the force system may have been less with the shorty version. In addition, the shorter anterior–posterior distance of elastic wear with the shorty version might have generated a lighter distal force. Lack of significant rotation of premolars is clinically ideal, as it is usually not needed during orthodontic treatment.

Maxillary Canine Movements

In group 2, maxillary canines experienced significant distal movement with distal tipping, rotation, and extrusion, similar to Areepong et al.[15] In contrast, group 1 did not experience significant distal movement. In fact, group 1 showed significantly less distal movement (–0.36 ± 4.72 mm), with less distal tipping of the maxillary canine (5.17° ± 6.10°) than did group 2. The standard CMA was bonded directly to the maxillary canine; therefore, it makes sense that canines would experience greater movements than the shorty CMA. For this reason, it may be clinically important to overcorrect the buccal segments with the shorty CMA, considering extra anchorage may be needed for correcting a Class II canine relationship after the removal of CMAs. There were no significant differences in the vertical changes between the groups, regardless of the vertical force of Class II elastics on the canines in group 2. This may have been a result of the initially unerupted, blocked out, or impacted position of canines in group 1. It is possible that the shorty CMA may have successfully created adequate

Table 6. Comparison of the Treatment Changes Between Group 1 and Group 2

	T1–T2 Difference in Group 1		T1–T2 Difference in Group 2		
	Mean	SD	Mean	SD	Significance
Skeletal					
AP					
ANB, °	0.33	0.92	0.77	0.75	.08
SNA, °	−0.01	1.32	0.30	1.15	.52
SNB, °	−0.33	1.21	−0.49	1.28	.55
Vertical					
MP-SN, °	−0.30	1.80	−0.14	1.28	.82
Dental					
AP					
U1-SN, °	0.08	4.73	−1.00	3.22	.25
IMPA, °	−2.65	3.01	−3.37	2.98	.40
Overjet, mm	0.89	2.72	2.29	1.50	<.05*
U3 horizontal, mm	−0.36	4.72	3.16	1.89	<.01**
U4 horizontal, mm	2.50	2.42	2.21	1.64	.49
U6 horizontal, mm	1.83	2.11	2.14	1.34	.74
L6 horizontal, mm	−1.85	1.88	−2.44	2.02	.14
U3 angle, °	5.17	6.10	8.74	4.53	<.01**
U4 angle, °	7.10	5.34	7.54	5.12	.99
U6 angle, °	6.52	3.99	7.03	3.45	.50
L6 angle, °	4.01	3.47	4.32	4.95	.84
Vertical					
Overbite, mm	0.33	5.89	1.84	1.36	.21
OP-SN, °	−1.92	6.42	−1.85	1.46	.88
U3 vertical, mm	−3.31	3.27	−1.64	1.19	.28
U4 vertical, mm	−1.23	1.20	−0.67	1.18	.08
L6 vertical, mm	−1.92	2.14	−2.28	1.16	.60
Transverse					
U3 rotation, °	4.68	8.86	3.23	6.47	.16
U4 rotation, °	−0.17	3.83	0.98	3.71	.37
U6 rotation, °	3.15	7.52	2.95	9.55	.76

* ANCOVA was significant at the .05 level (two-tailed).
** ANCOVA was significant at the .01 level (two-tailed).

space for the maxillary canine to undergo its normal process of eruption.

Mandibular First Molar Movements

Mandibular first molars showed significant mesial movement with significant mesial tipping and extrusion for both groups, which was consistent with Areepong et al.[15] but not with Sandifer et al.,[12] which could be attributed to the two-dimensional nature of that study. There were no significant differences in any movements associated with mandibular first molars between the two groups.

Maxillary Incisors

Neither group 1 nor 2 experienced a significant change in U1-SN, indicating that neither shorty nor standard CMAs produced much effect on maxillary incisors, which could be advantageous for patients with a high risk for root resorption. There were no significant differences between the groups. Unlike Class II elastics,[17] these results suggested CMAs did not retrocline the maxillary incisors, consistent with previous studies.[12,15]

Mandibular Incisors

As with many Class II appliances,[6,18–25] both groups experienced significant flaring of the mandibular incisors, similar to results shown in previous studies.[12,14,15] There were no significant differences between the groups, suggesting significant and similar amounts of flaring should be expected with both shorty and standard CMAs.

Overjet and Overbite

There was a significant decrease in overjet and overbite only in group 2, consistent with previous studies.[12,14,15] In contrast, there were a lack of significant changes in overjet and overbite in group 1. There was no significant difference in overbite change between the groups, but group 1 experienced a significantly smaller reduction (0.33 ± 5.89 mm) than group 2 (1.84 ± 1.36 mm). This may have been related to the initial position of the maxillary canines and the shorty design in group 1, limiting retraction of the maxillary incisors. This suggests that the shorty design may be recommended when little incisor movement is desired.

OP-SN

A significant increase of less than 2° was observed in OP-SN change for group 2 but not for group 1, probably because of the design differences. Previous studies also reported a significant increase in OP-SN.[12,14,15] There was no significant difference in MP-SN changes between the groups, indicating that changes to MP-SN were relatively the same for both shorty and standard CMAs.

Limitations

The limitations of this study included the following: (1) No comparison with a nontreated sample, (2) no report available for patient compliance or the initial amount of crowding, and (3) no completion of treatment at the time of data collection. As a reference line, SN-7 was used instead of the FH plane because some CBCT images did not include the external auditory meatus.

CONCLUSIONS

The null hypothesis was rejected. There were statistically significant differences in the three-dimensional treatment effects produced between the standard and the shorty CMAs.

- Both shorty and standard CMAs achieved Class I relationships from Class II prior to comprehensive orthodontic treatment mainly through dentoalveolar changes (mean treatment durations of 5.48 and 4.28 months, respectively).
- The shorty CMA brought about the following dentoalveolar movements: significant distal movement with distal tipping and rotation of the maxillary first molar; significant distal movement with distal tipping, but no rotation, and extrusion of the maxillary first premolar; significant distal rotation and tipping, and extrusion of the maxillary canine; and significant mesial movement with mesial tipping and extrusion of the mandibular first molar.
- The standard CMA corrected Class II relationships similarly. However, there were several important differences. (1) The maxillary first molar did not show significant distal rotation as it moved and tipped distally. (2) The maxillary canines showed significant distal movement with distal tipping and rotation as well as extrusion. (3) Significant reductions in overjet and overbite were shown.
- Approximately 3° of lower incisor proclination were shown with both shorty and standard CMAs.
- When comparing the treatment effects of shorty and standard CMAs, there were few differences between them except for less reduction in overjet and less distal tipping movement of maxillary canines with the shorty CMA.

ACKNOWLEDGMENTS

The authors wish to acknowledge Dr David Paquette, Dr Becky Schreiner, and Dr Thomas Shipley for providing the sample and Anatomage for the training for the software.

REFERENCES

1. Carriere L. A new Class II distalizer. *J Clin Orthod*. 2004;38: 224–231.
2. Baumrind S, Molthen R, West EE, Miller DM. Distal displacement of the maxilla and the upper first molar. *Am J Orthod*. 1979;75:630–640.
3. Firouz M, Zernik J, Nanda R. Dental and orthopedic effects of high-pull headgear in treatment of Class II, division 1 malocclusion. *Am J Orthod Dentofacial Orthop*. 1992;102: 197–205.
4. Keeling SD, Wheeler TT, King GJ, et al. Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear. *Am J Orthod Dentofacial Orthop*. 1998;113:40–50.
5. Hamilton CF, Saltaji H, Preston CB, Flores-Mir C, Tabbaa S. Adolescent patients' experience with the Carriere distalizer appliance. *Eur J Paediatr Dent*. 2013;14:219–224.
6. Janson G, Sathler R, Fernandes TM, Branco NC, Freitas MR. Correction of Class II malocclusion with Class II elastics: a systematic review. *Am J Orthod Dentofacial Orthop*. 2013;143:383–392.
7. Rodriguez HL. Unilateral application of the Carriere distalizer. *J Clin Orthod*. 2011;45:177–180.
8. Rodriguez HL. Nonextraction treatment of a Class II open bite in an adult patient. *J Clin Orthod*. 2012;46(6):367–371.
9. Singh DP, Arora S, Yadav SK, Kedia NB. Intraoral approaches for maxillary molar distalization: case series. *J Clin Diagn Res*. 2017;11:ZR01–ZR04.
10. Balut N, Popnikolov P, Ades A. Long-term stability of two-phase Class II treatment with the Carriere motion appliance. *J Clin Orthod*. 2019;53:449–457.
11. Rodriguez HL. Long-term stability of two-phase class II treatment with the Carriere motion appliance. *J Clin Orthod*. 2019;53:481–487.
12. Sandifer CL, English JD, Colville CD, Gallerano RL, Akyalcin S. Treatment effects of the Carrière distalizer using lingual arch and full fixed appliances. *World J Orthod*. 2014;3:e49–e54.
13. Yin K, Han E, Guo J, et al. Evaluating the treatment effectiveness and efficiency of Carriere distalizer: a cephalometric and study model comparison of Class II appliances. *Prog Orthod*. 2019;20:24.
14. Kim-Berman H, McNamara JA Jr, Lints JP, McMullen C, Franchi L. Treatment effects of the Carriere((R)) Motion 3D appliance for the correction of Class II malocclusion in adolescents. *Angle Orthod*. 2019;89:839–846.
15. Areepong D, Kim KB, Oliver DR, Ueno H. The Class II Carriere Motion appliance: a 3D CBCT evaluation of the effects on the dentition. *Angle Orthod*. In press.

16. Grauer D, Cevidanes LS, Styner MA, et al. Accuracy and landmark error calculation using cone-beam computed tomography-generated cephalograms. *Angle Orthod*. 2010; 80:286–294.
17. Uzel A, Uzel I, Toroglu MS. Two different applications of Class II elastics with nonextraction segmental techniques. *Angle Orthod*. 2007;77:694–700.
18. Antonarakis GS, Kiliaridis S. Maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusion: a systematic review. *Angle Orthod*. 2008;78: 1133–1140.
19. Franchi L, Alvetro L, Giuntini V, et al. Effectiveness of comprehensive fixed appliance treatment used with the Forsus fatigue resistant device in Class II patients. *Angle Orthod*. 2011;81:678–683.
20. Ludwig B, Glasl B, Kinzinger GS, Walde KC, Lisson JA. The skeletal frog appliance for maxillary molar distalization. *J Clin Orthod*. 2011;45:77–84.
21. Papadopoulos MA. Orthodontic treatment of Class II malocclusion with miniscrew implants. *Am J Orthod Dentofacial Orthop*. 2008;134:604 e1–16.
22. Jones G, Buschang PH, Kim KB, Oliver DR. Class II nonextraction patients treated with the Forsus fatigue resistant device versus intermaxillary elastics. *Angle Orthod*. 2008;78: 332–338.
23. Pancherz H. Treatment of class II malocclusions by jumping the bite with the Herbst appliance: a cephalometric investigation. *Am J Orthod*. 1979;76:423–442.
24. Paulose J, Antony PJ, Sureshkumar B, et al. PowerScope a Class II corrector: a case report. *Contemp Clin Dent*. 2016;7: 221–225.
25. Zymperdikas VF, Koretsi V, Papageorgiou SN, Papadopoulos MA. Treatment effects of fixed functional appliances in patients with Class II malocclusion: a systematic review and meta-analysis. *Eur J Orthod*. 2016;38:113–126.