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Effects of the reciprocal mini-chin cup appliance

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SUMMARY The aim of this prospective study was to evaluate the dentofacial effects of the reciprocal mini-chin cup (RMCC) appliance in subjects with pubertal growth and development potential (group 1) and in subjects that had completed this period (group 2). Eighteen patients (13 females, five males) with an Angle Class II division 1 and nine patients (six females, three males) with a Class II division 2 malocclusion, with mandibular dentoalveolar retrusion and optimal vertical facial dimension were included. A control group consisting of 14 subjects (nine females, five males) with pubertal growth and development potential was constructed for comparison with group 1. In both treatment groups a RMCC was used.

A Class I molar relationship was achieved in an average period of 5.11 months in group 1 and 10.57 months in group 2. From lateral cephalometric tracings, beside the angular and linear parameters, eight parameters that determined the ratio of the skeletal and dental effects of RMCC were measured and statistically evaluated. A paired comparison *t*-test was used to assess the differences in each group and a Student's *t* text to evaluate the differences between the groups. In both groups, no effect of RMCC was found on either the maxilla and/or the sagittal position of the mandible. In group 1, lower anterior face height was increased more compared with group 2; the mandibular plane angle increased and the mandible developed mostly in the vertical dimension. While a Class I molar relationship and correction of the overbite and overjet were achieved in both groups, a greater correction of overjet was found in group 1. Retrusion of the upper incisors without extrusion, protrusion, or proclination of the lower incisors, distalization of the upper molars, mesialization and extrusion of the lower molars and mesialization of the mandibular dentoalveolar structures were observed in both groups. Contributions to the correction of overjet and molar relationship were mostly dentoalveolar in both groups.

Introduction

In selected subjects, an Angle Class II dental malocclusion can exist with mandibular dentoalveolar retrusion together with an increased overbite. In these cases, the aim of treatment is to provide maximum anchorage in the maxillary dental arch, minimum anchorage in the mandibular dental arch, with an advancement of the mandibular dental arch, and correction of the deep overbite (Bell *et al.*, 1984; Langlade, 1997).

Class II elastics, which are mostly used in the treatment of dental Class II malocclusions, cause posterior movement of the maxilla and maxillary arch as well as anterior movement of the mandible and the mandibular dentoalveolar arch (Profitt and Fields, 1986; Philippe, 1995). The vertical component of Class II elastics has a tendency to extrude the mandibular molars and maxillary incisors and to rotate the anterior segment of the maxilla posteriorly and downward. If the vertical side effects of Class II elastics are not controlled, this will lead to posterior rotation of the mandible (Profitt, 1991; Philippe, 1995). Consequently, although Class II elastics are effective in correcting Class II malocclusion, there may be unfavourable skeletal effects and deleterious changes to facial aesthetics (Profitt and Fields, 1986; Philippe, 1995). To reduce these vertical side effects, various methods have been reported (Hocevar, 1982; Schudy, 1992; Philippe, 1995; Aras *et al.*, 2001).

The reciprocal mini-chin cup (RMCC), introduced by Langlade (1997), distalizes the maxillary molars while advancing the mandibular dentoalveolar segment. This appliance also prevents the unfavourable effects of Class II elastics on the incisors and arch position.

Orthodontic correction is more difficult in adults and achieved by dental changes because somatic maturation occurs during adolescence (Harris *et al.*, 1991; Ahn and Schneider, 2000). Therefore, Class II young adult borderline malocclusions are usually treated by orthognathic surgery or dental camouflage (Proffit and Sarver, 2003).

While there is limited research regarding early use of RMCC exists, there is no research on late term use of the RMCC (Langlade, 1997; Uzel, 2004). Only Langlade (1997) has reported on an adult subject which suggested that RMCC could avoid orthognathic surgery in borderline cases.

The aim of this study was to evaluate the skeletodental effects of the RMCC appliance in patients with pubertal growth development potential and in young adults with minimal growth expectation.

Subjects and methods

Twenty-seven Turkish Anatolian patients referred to the Faculty of Dentistry of Gazi University with the following criteria were included in this prospective study.

1. Angle Class II division 1 or 2 malocclusion with mandibular dentoalveolar retrusion according to the A-Pog line (overjet 5.5–10 mm)
2. ANB angle between 1 and 5 degrees,
3. Optimal vertical facial dimension, (SnGoGn 26–38 degrees)
4. Non-extraction treatment plan
5. Permanent dentition

Eighteen subjects had an Angle Class II division 1 and nine a division 2 malocclusion. The patients were divided into two groups according to their skeletal age and growth potential. Group 1 (early period) had pubertal growth and development potential and group 2 (late period) had already completed this period. To eliminate the effects of growth and development in group 1, a control group was formed of 14 subjects, that referred to the Faculty of Dentistry, Gazi University (Table 1). At the end of the observation period, all subjects in the control group were treated.

Group 1 had completed an average 90.82 per cent of their growth potential, the control group 90.89 per cent, and group 2, 99.55 per cent.

The RMCC (Rocky Mountain Orthodontics, Illkirch, Cedex, France) was used in both treatment groups (Figure 1). Generous Roth brackets, triple tube bands (GAC, Bohemia, New York, USA) on the maxillary first molars, and double tube bands on the mandibular first molars were used as fixed appliances. The RMCC was inserted after an overjet increase in nine Class II division 2 patients; levelling of the mandibular arch was achieved in all cases. A 0.016 × 0.022-inch Ni-Ti archwire was used in the mandibular arch and a 0.016 × 0.016-inch Blue Elgiloy archwire (Rocky

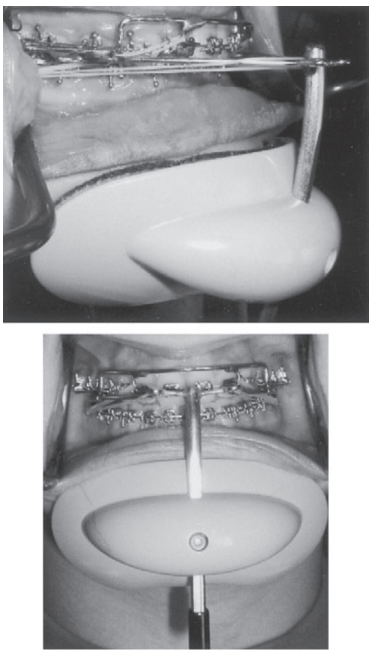

Figure 1 The reciprocal mini-chin cup appliance.

Table 1 Chronological age before application of reciprocal mini-chin cup, treatment and control duration of control and treatment groups.

Group	*n*	Mean chronological age (year)	SD	Minimum	Maximum	Treatment duration x	Treatment duration SD
Control	14	12.06	1.35	10.25	14.08	6.36	0.84
Group 1	13	12.28	0.81	11.08	13.83	5.11	1.85
Group 2	14	17.55	3.13	13.67	24.58	10.57	3.11

Mountain Orthodontics) segmented in three pieces in the maxillary arch as the RMCC at the start of treatment.

A force of 150 g for the reciprocal maxillary arch and 200 g for the mini-chin cup was used for each side. In both treatment groups, the reciprocal maxillary arch and Class II elastics were worn for 24 hours, and the mini-chin cup for 14 hours, at home and during sleep.

Lateral cephalometric radiographs were obtained for both treatment groups at the beginning of RMCC application and after a Class I molar relationship was achieved. In the control group, lateral cephalograms were obtained at the beginning and end of the control period. Twenty-eight cephalometric measurements were performed on tracing paper by a single investigator (BIA) (Figures 2 and 3); skeletal age and growth potential were determined according to hand-wrist radiographs (Greulich and Pyle, 1959) and treatment duration was evaluated.

In order to determine the percentage of the skeletal and dental components in the correction of overjet and molar relationship, Pancherz's (1982, 1985) method was used with some modification. Superimposition on the anterior wall of sella turcica and the stable CT (cranial base) line, with registration on point T, followed by superimposing on the inner structure of the triangle described by Viazis (1991) was preferred. Instead of Pancherz's (1982, 1985) OLp line, the CTV line was used as the vertical reference line which is perpendicular to the CT line passing through point T. (Figure 4)

Absolute dentoalveolar movements of the incisors and first molars in the maxilla and mandible were calculated as below (Figure 4):

U1CTV-ACTV (mm): Position change of the maxillary central incisor.

L1CTV-PogCTV (mm): Position change of the mandibular central incisor.

U6CTV-ACTV (mm): Position change of the maxillary first molar.

L6CTV-PogCTV (mm): Position change of the mandibular first molar.

The skeletal and dental percentage contributing to the correction of the overjet and molar relationship was determined according to calculations of the measurements.

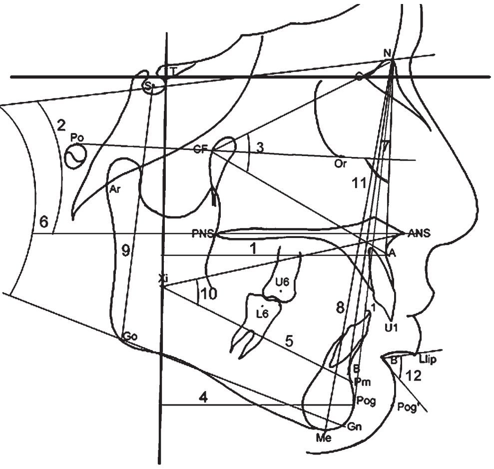

Figure 2 Skeletal and soft tissue measurements on lateral cephalograms. 1, A-CTV (mm): the perpendicular distance from point A to CTV vertical reference line perpendicular to the CT line passing through point T; 2, SN/(ANS-PNS) (°): the angle between the anterior cranial plane and the palatal plane; 3, N-CF-A (°): the angle between N-CF (centre of the face) plane and CF-A plane; 4, Pog-CTV(mm): the perpendicular distance from pogonion to CTV; 5, Xi-Pm(mm): the distance between points Xi and Pm. Mandibular corpus length; 6, SN/GoGn (°): the angle between SN and GoGn. Mandibular plane; 7, ANB(°): the angle defining the sagittal interrelationship between the maxilla and mandible; 8, N-Me (mm): the distance between nasion and menton. Anterior face height; 9, S-Go (mm): the distance between sella and gonion. Posterior face height; 10, ANS-Xi-Pm(°): the angle between the planes of ANS-Xi and Xi-Pm. Lower face height; 11, NPog/FH (°): the angle between the facial plane (N-Pog) and the Frankfort horizontal plane; 12, labiomental angle(°): the angle between a tangent passing through the lower lip and supramental (B′) point and a tangent passing through soft tissue pogonion and supramental (B′) points.

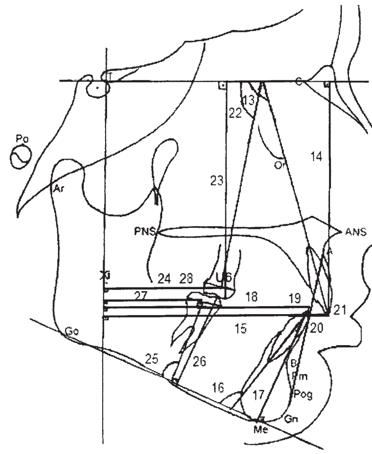

Figure 3 Dentoalveolar measurements on lateral cephalograms. 13, U1/CT (°): the angle between the long axis of the most protrusive maxillary central incisor and a horizontal reference plane passing through sella and point T; 14, U1-CT (mm): the perpendicular distance from the incisive edge of the most protrusive maxillary central incisor to the CT horizontal reference plane; 15, U1-CTV (mm): the perpendicular distance from the incisive edge of the most protrusive maxillary central incisor to the CT horizontal reference plane; 16, L1/GoMe (°): the angle between the long axis of the most protrusive mandibular central incisor and the mandibular plane; 17, L1-GoMe (mm): the perpendicular distance from the incisive edge of the most protrusive mandibular central incisor to the mandibular plane; 18, L1-CTV (mm): the perpendicular distance from the incisive edge of the most protrusive mandibular central incisor to the CTV vertical reference plane; 19, L1-APog (mm): the perpendicular distance from the incisive edge of the most protrusive mandibular central incisor to the A-Pogonion line; 20, overjet (mm): the difference between the distance of U1 to the CTV vertical reference plane and the distance of L1 to CTV (U1CTV-L1CTV); 21, overbite (mm): the difference between the distance of U1 to CT horizontal reference plane and the distance of L1 to CT (U1CT-L1CT); 22, U6/CT (°): the angle between the long axis of the upper first molar passing through point U6 and the CT horizontal reference plane; 23, U6-CT (mm): the perpendicular distance between point U6 and the CT horizontal reference plane; 24, U6-CTV (mm): the perpendicular distance between point U6 and the CTV vertical reference plane; 25, L6/GoMe (°): the angle between the long axis of lower first molar passing through point L6 and the mandibular plane (GoMe); 26, L6-GoMe (mm): the perpendicular distance between point L6 and the mandibular plane (GoMe); 27, L6-CTV (mm): the perpendicular distance between point L6 and the CTV vertical reference plane; 28, molar relationship (mm): the difference between the distance of U6 to CTV vertical reference plane and the distance of L6 to CTV (U6CTV-L6CTV).

Twenty randomly selected lateral cephalometric radiographs were retraced and recalculated by the same examiner at least one month after the first measurement. Intraclass correlation coefficients were nearly 1.00 for all variables, confirming the reliability of the measurements (Winer *et al.*, 1991).

A paired comparison *t*-test was used to assess the differences in each group, and to evaluate the differences between the groups, a Student's *t* test was used (Sheskin, 2000). The Statistical Package for Social Sciences (Windows version 13.00 SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis.

Results

An Angle Class I molar relationship was achieved in an average period of 5.11 months in group 1 and 10.57 months in group 2 (Table 1). Photographs of a subject in group 1 are shown in Figure 5a,b and from group 2 in Figure 6a,b.

Skeletal age and growth potential changes are shown in Tables 2 and 3.

Skeletal and soft tissue changes

The increase in A-CTV, Xi-Pm measurements were found to be significant in group 1 and the control group. SN/GoGn angle showed a statistically significant increase and ANB angle a significant decrease but only in group 1 (Table 2).

N-Me and S-Go measurements demonstrated a significant increase in all three groups yet when the groups were compared only the change in N-Me was found to be significant. The increase in ANS-Xi-Pm and labiomental angle was found to be significant in groups 1 and 2, and the change in ANS-Xi-Pm angle demonstrated a significant difference when the groups were compared (Tables 2 and 3).

Dentoalveolar changes

The decrease in U1-CTV, overjet, overbite, U6/CT, and U6-CTV measurements was found to be significant in groups 1 and 2, but only the change in overjet was significant when the groups were compared. The increase in L1/GoMe, L1-CTV, L1-APog, L6-CTV measurements were found to be

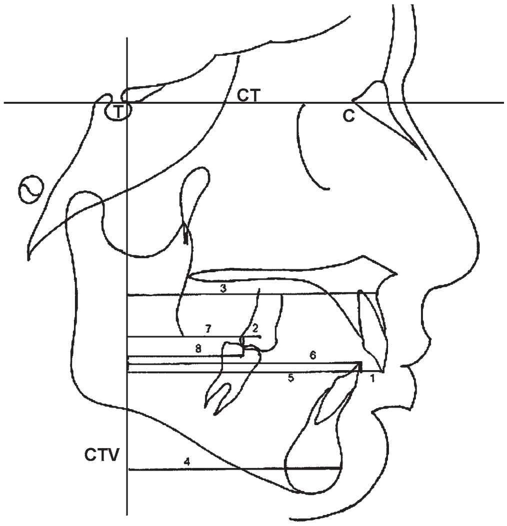

Figure 4 Measurements used to determine the skeletal and dental component in the correction of overjet and molar relationship. 1, U1CTV-L1CTV (mm): overjet; 2, U6CTV-L6CTV (mm): molar relationship (+distal, –mesial); 3, A-CTV (mm): maxillary position; 4, Pog-CTV (mm): mandibular position; 5, U1-CTV (mm): maxillary first incisor position; 6, L1-CTV (mm): mandibular first incisor position; 7, U6-CTV (mm): maxillary first molar position; 8, L6-CTV (mm): mandibular first molar position.

significant in groups 1 and 2. U1-CT, U6-CT measurements showed a significant increase in group 1 and the control group. The increase in L6-GoMe and the decrease in molar relationship were found to be significant in all three groups, whereas only the difference between group 1 and the control group was significant. U1/CT angle showed a significant decrease in group 1 when compared with the control group. L1-GoMe demonstrated a significant decrease in group 2 and a significant increase in the control group and the differences were also found to be significant when the groups were compared. L6/GoMe showed a significant increase only in group 2 (Tables 2 and 3).

In group 1, the dentoalveolar contribution to the correction of overjet was 95.47 per cent, 44.15 per cent of which was obtained by maxillary and 51.32 per cent by mandibular incisor movement. Skeletal contribution was 4.53 per cent, of which 10.57 was by mandibular movement (Figure 7a). In group 2, the dentoalveolar contribution to the correction of overjet was 88.02 per cent (37.42 per cent maxillary and 50.6 per cent mandibular incisor movement). Skeletal contribution was 11.98 per cent with 13.69 per cent of this correction due to mandibular movement (Figure 7b).

In group 1, dentoalveolar contribution in the correction of molar relationship was 94.16 per cent (31.87 per cent by maxillary molar distalization and 62.29 per cent by mandibular molar mezialization). The skeletal contribution was 5.84 per cent, 13.63 per cent of which was obtained by mandibular movement (Figure 7a). In group 2, the dentoalveolar contribution in the correction of the molar relationship was 86.65 per cent (27.25 per cent maxillary molar distalization and 59.40 per cent mandibular molar mezialization). Skeletal contribution was 13.35 per cent and 15.26 per cent of this correction was obtained by mandibular movement (Figure 7b).

Discussion

In this investigation, it was found that RMCC had no significant effects on maxillary sagittal and vertical position in groups 1 or 2. Uzel (2004) also reported that the RMCC had no effect on the sagittal position and inclination of the maxilla in a study that compared the effects of Class II elastics to RMCC in the early treatment period. Several studies (Edwards, 1983; Ellen *et.al*., 1998; Manav, 1999; Nelson *et al.*, 1999; Reddy *et al.*, 2000) have found that Class II elastics prevent maxillary growth, while some authors (Marşan and Uğur, 1997; Ferreire, 1998; Nelson *et al.*, 2000; Uzel, 2004) reported no effect on maxillary growth. Ball and Hunt (1991a, b), Ellen *et al.* (1998), and Nelson *et al.* (2000), when using Class II elastics, observed no effect on the inclination of the maxilla whereas other investigators (Schudy, 1992; Philippe, 1995) noted that the vertical component of Class II elastics caused a downward and posterior rotation of the anterior segment of the maxilla while the mandibular molars were extruded. In this study, no significant effect was found on the inclination of the maxilla since the elastics were attached to the reciprocal maxillary arch instead of the canine brackets.

The results showed that the RMCC has no significant effect on the sagittal position of the mandible and the magnitude of the corpus. This finding can be related to the mini-chin cap part of the RMCC that uses the chin as the anchorage unit and applies force in a posterior direction while applying an anterior force vector to the mandibular dentition. In group 1, it could be hypothesized that the RMCC might result in a posterior rotation of the mandible, yet the non-significant increase in CTV-Pog showed that the chin did not move posteriorly, but vertically. According to the lower molar extrusion caused by elastics, forward growth of the mandible could be decreased and the vertical potential increased. Some investigators (Manav, 1999; Reddy *et al.*, 2000) state that Class II elastics stimulate forward growth of the mandible, whereas others (Marşan and Uğur, 1997; Ellen *et al.*, 1998; Nelson *et al.*, 2000; Uzel, 2004) found no significant mandibular effect. Nelson *et al.* (1999) reported that SNB decreases and the mandible rotates posteriorly as the duration of wear of Class II elastics increases. Langlade (1997) claimed that the RMCC does not demonstrate an orthopaedic effect with backward mandibular rotation, but only produces orthodontic tooth movement.

In the present investigation, total and lower anterior face height increased more in group 1; the posterior force applied to the chin by mini-chin cup could cause this increment through molar extrusion. Harris *et al.* (1991) found, in their adolescent group, that the symphysis moved 2.9 mm

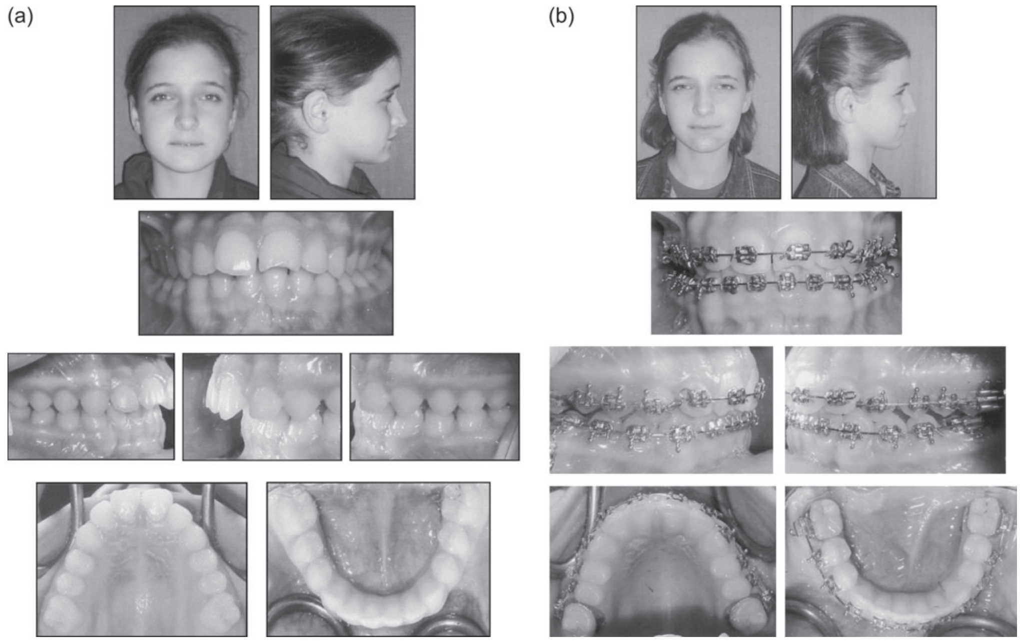

Figure 5 Photographs of a subject in group 1 before (a) and after (b) reciprocal mini-chin cup application.

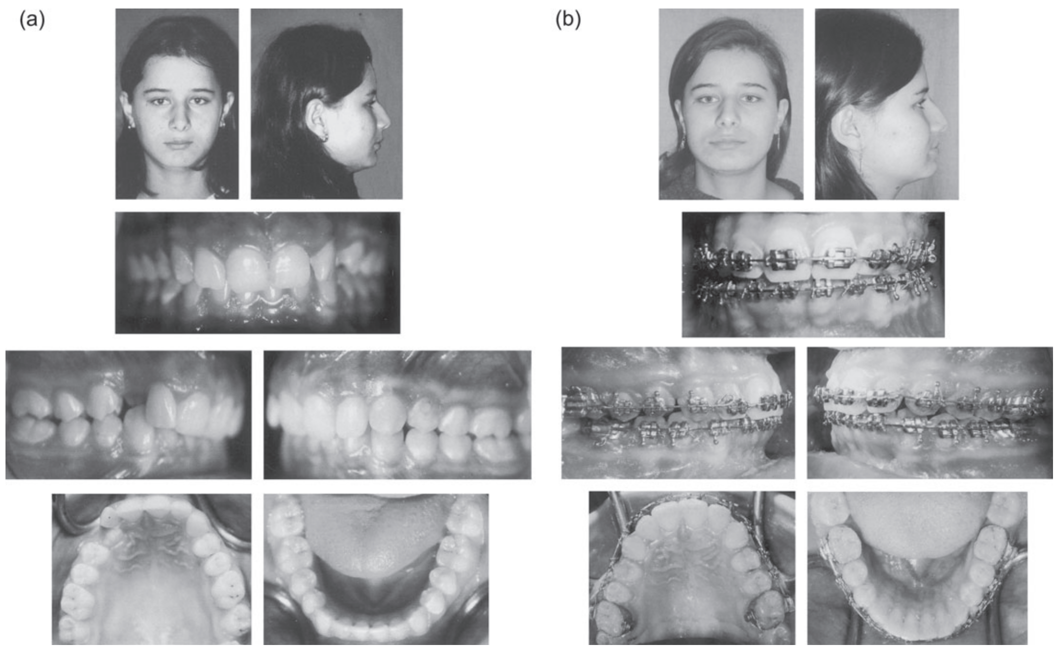

Figure 6 Photographs of a subject in group 2 before (a) and after (b) reciprocal mini-chin cup application.

downward and 2.4 mm forward whereas in the adult group the symphysis moved 0.9 mm downward and 0.6 mm backward as the result of Class II premolar extraction treatment. Uzel (2004) and Langlade (1997) reported similar effects on lower face height in their RMCC investigations. Previous Class II elastic investigations (Manav, 1999; Nelson *et al.*, 2000; Reddy *et al.*, 2000; Uzel, 2004) also have shown a significant increase in lower face height.

The significant increase in posterior face height in group 1 in the present study can be explained by growth and development, whereas in group 2 this increase could be due to the positional change of the mandible according to the mechanics of the RMCC appliance. The effects of the positional change of the mandible on the temporomandibular joint (TMJ) require further investigation. There are experimental studies (Meikle, 1970; Payne, 1971) regarding the effects of Class II elastics on

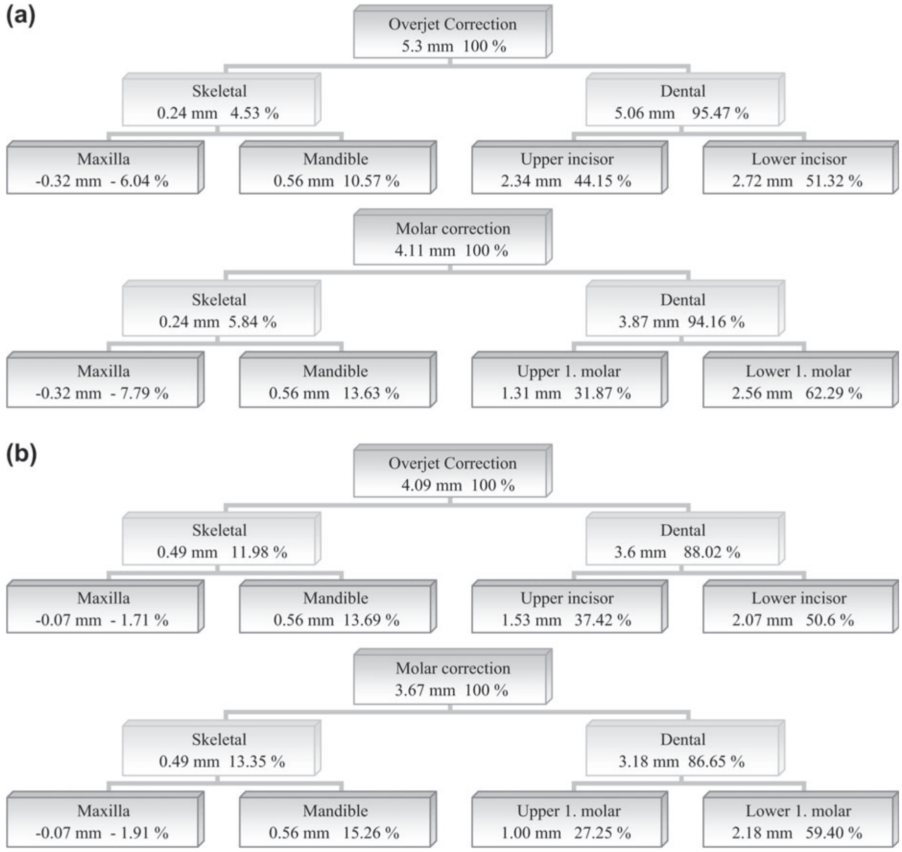

Figure 7 Skeletal and dental contributions in the correction of overjet in group 1 (a) and group 2(b) after treatment with a reciprocal mini-chin cup.

the TMJ but limited clinical studies on the effects on the condyle (Wyatt, 1987; O'Reilly *et al.*, 1993). The vertical facial increase in group 2 could also be due to late growth and development. Deickle and Pancherz (2005) reported that changes in the sagittal and vertical direction still occur after fusion of the radius and ulna. Akgül and Toygar (2002) suggested that lower facial and dentoalveolar heights continue to increase in the third decade of life.

In this study, although segmented arches were used in the maxilla and Class II elastics were attached to the auxillary arch, significant retrusion of upper incisors occurred. This retrusion can be explained by the force vector transmission to the anterior teeth from the molars. Nelson *et al.* (2000) reported 2.2 mm retrusion of the upper incisors with the Herbst appliance although they used segmented arches in the maxilla. In Class II elastic studies, a 'gummy' smile is reported to be due to retrusion and extrusion of the upper incisors (Profitt, 1991; Marşan and Uğur, 1997; Nelson *et al.*, 2000). In this investigation, no significant change in the vertical position of the upper incisors was found since the Class II elastics were not attached directly to the anterior teeth.

In both treatment groups in this study, lower incisor protrusion and proclination was found. Future investigations should evaluate lower incisor position before treatment because lower incisor protrusion and proclination was found in both groups. Intrusion of lower incisors in both groups could be called 'relative intrusion' because no archwire bending was done and a continuous archwire was used. Uzel (2004) found more lower incisor intrusion which could be due to the use of utility arches with gable bends and lingual crown torque.

Overjet correction was greater in group 1 and the lower incisor contribution was more than that of the upper incisors. Konik *et al.* (1997) in their Herbst study reported that overjet decreased 3.3 mm more in the late group compared with the early group. The decrease in overbite in both treatment groups in the present study could be due to relative intrusion of the lower incisors and extrusion of the lower molars in conjunction with an increase in lower and anterior face heights. There are various opinions about opening of incisal overbite; in particular, how much is due to lower incisor intrusion or extrusion of molars by Class II elastics (Bell et al., 1984; Ball and Hunt, 1991a, b; Marşan and Uğur, 1997; Nelson *et al.*, 1999; Reddy *et al.*, 2000).

In this investigation, upper first molar extrusion was within growth and development expectations in group 1 while in

Table 2 Mean values (x) before and after reciprocal mini-chin cup (RMCC) application and significance values of differences in each group.

	Group 1, $n=13$				P	Group 2, $n=14$				P	Control group, $n=14$				P
	Before RMCC		After RMCC			Before RMCC		After RMCC			First control		Final control		
	x	SD	x	SD		x	SD	x	SD		x	SD	x	SD	
A-CTV (mm)	61.78	4.77	62.1	4.71	0.02*	61.01	4.95	61.08	5.02	0.75	59.96	3.97	60.47	4.19	0.03*
SN/(ANS-PNS) (°)	8.69	3.27	8.72	3.14	0.89	8.45	3.36	8.56	3.46	0.15	9.88	3.82	10.04	3.55	0.41
N-CF-A (°)	59.35	4.12	59.8	3.83	0.1	60.51	2.03	60.57	2.07	0.55	61.02	3.51	61.14	3.42	0.62
Pog-CTV (mm)	53.58	5.91	54.15	5.96	0.06	54.09	8.33	54.64	8.16	0.26	51.47	6.33	52.34	6.93	0.08
Xi-Pm (mm)	68.25	3.2	69.19	3.09	0.00**	71.32	5.07	71.46	5.14	0.08	68.48	3.31	69.7	3.82	0.00**
SN/GoGn (°)	30.16	4.41	31.45	4.35	0.00**	28.03	3.62	28.2	3.79	0.53	30.88	4.29	30.59	4.26	0.31
ANB (°)	3.83	1.29	3.09	1.3	0.00**	3.34	1.32	3.02	1.41	0.18	3.76	1.12	3.54	1.24	0.22
N-Me (mm)	116.75	5.02	120.48	5.29	0.00**	123.69	9.04	125.06	9.4	0.01**	117.52	6.67	118.66	7.17	0.00**
S-Go (mm)	77.3	3.32	79.24	3.92	0.00**	85.16	7.59	86.75	7.6	0.00**	76.97	4.51	78.16	4.98	0.01**
ANS-Xi-Pm (°)	42.14	4.21	44.42	3.57	0.00**	43.63	4.96	44.62	5.03	0.00**	40.28	4.45	40.23	4.79	0.76
NPog/FH (°)	87.12	2.97	87.34	2.78	0.5	88.10	3.05	88.04	3.19	0.87	86.73	3.43	86.87	3.59	0.5
Labiomental angle (°)	82.1	14.6	102.5	16	0.00**	79.25	15.00	90.89	9.6	0.00**	86.54	21.1	87.6	18.16	0.69
U1/CT (°)	109.32	6.11	102.81	5.92	0.00**	109.51	7.33	106.89	5.37	0.08	98.36	11.95	99.34	12.55	0.07
U1-CT (mm)	77.58	3.25	78.52	3.19	0.00**	81.31	5.24	81.61	5.42	0.2	79.19	5.43	79.74	5.7	0.02*
U1-CTV (mm)	64.58	5.42	62.57	5.62	0.00**	64.59	6.63	63.12	6.3	0.01**	59.82	6.51	60.36	6.7	0.16
L1/GoMe (°)	92.17	7.13	101.47	7.73	0.00**	93.41	5.58	102.5	6.3	0.00**	89.73	6.25	89.26	6.35	0.35
L1-GoMe (mm)	38.84	2	38.64	2.47	0.4	41.68	3.95	40.54	4.11	0.00**	38.82	1.8	39.28	2.25	0.04*
L1-CTV (mm)	57.36	5.31	60.65	5.04	0.00**	58.05	6.12	60.68	6.29	0.00**	55.11	5.04	55.58	5.09	0.22
L1-APog (mm)	–1.2	1.93	2.13	1.36	0.00**	–0.54	2.01	2.21	2.08	0.00**	–1.99	2.15	–2.14	2.45	0.44
Overjet (mm)	7.85	1.61	2.55	1.77	0.00**	7.05	1.36	2.96	1.25	0.00**	6.06	2.76	6.21	2.8	0.51
Overbite (mm)	4.74	2.23	0.92	1.02	0.00**	4.17	2.09	1.01	1.25	0.00**	5.59	2.26	5.66	2.52	0.73
U6/CT (°)	76.88	4.11	73.88	6.06	0.02*	78.86	4.46	76.41	5.53	0.00**	74.82	4.52	74.53	3.65	0.69
U6-CT (mm)	65.73	3.29	66.64	3.64	0.01**	70.76	5.43	70.81	5.29	0.74	65.25	4.39	66.25	4.78	0.00**
U6-CTV (mm)	29.6	4.23	28.61	4.59	0.00**	29.41	5.17	28.48	4.84	0.00**	27.04	4.8	27.61	5.08	0.05*
L6/GoMe (°)	77.75	4.31	80.14	5.63	0.08	77.28	4.06	78.98	4.05	0.05*	76.95	3.73	78.44	4.52	0.06
L6-GoMe (mm)	25.05	2.01	26.91	2.01	0.00**	27.4	2.92	28.72	3.32	0.00**	24.7	2.28	25.29	2.26	0.00**
L6-CTV (mm)	26.75	4.78	29.87	4.95	0.00**	25.77	6.03	28.51	5.89	0.00**	24.21	5.1	24.89	5.29	0.3
Molar relationship (mm)	1.45	1.38	–2.66	1.72	0.00**	1.88	1.48	–1.79	1.17	0.00**	1.8	1.55	1.31	1.5	0.02*
Skeletal age (year)	11.99	0.93	12.91	0.87	0.00**						12.02	1.56	12.58	1.62	0.00**
Growth potential (%)	90.82	4.33	93.45	4.42	0.00**	99.55	0.75	99.91	0.68	0.08	90.89	4.76	92.09	5.89	0.18

$^{*}P<0.05$; $^{**}P<0.01$.

group 2 no significant extrusion occurred, demonstrating that the RMCC has no significant effects on the vertical position of the upper first molars. Although similar upper first molar distalization was found in both groups, when the significant mesialization of upper molars in the control group was considered, it was concluded that distalization was more in group 1. Upper first molar distalization is obtained by the force vector applied directly to the first molars and the lip bumper effect of the reciprocal maxillary arch. Langlade (1997) found 0.6 mm distalization of the upper first molars in his Class II elastic group, 1.24 mm in the reciprocal maxillary arch group, and 1.9 mm in the RMCC group. In the current investigation, the upper second molars were erupted in six subjects in group 1, while in seven these teeth were not fully erupted. Thus, it was considered that upper first molar distalization is not greatly affected by the second molars as similar distalization of the upper first molars was noted in groups 1 and 2. In three-dimensional bimetric distalization studies, upper first molar distalization and intrusion have been found (Muse *et al.*, 1993; Üçem *et al.*, 2000; Altuğ, 2002).

Schudy (1968) reported that lower molar mesialization is more difficult and two or three times more resistant to treatment compared with the upper molars. In this investigation, lower molar mesialization was observed in both groups, thus the RMCC appliance can be used when minimum anchorage or advancement of the lower dental arch is required, for example, in subjects with congenital absence of the second premolars or when forward movement of the lower incisors and anterior space closure is required. McKinney and Harris (2001) found more lower molar mesialization with the straightwire technique compared with the Begg and edgewise techniques. Moreover, they found more lower molar mesialization in the younger age group in their study of Class II division 1 extraction cases. Langlade (1997) reported that the most lower molar mesialization and tipping was found in the RMCC group. In this study, the similar lower molar extrusion found in both groups was due to the vertical component of the elastics.

A Class I relationship was achieved in both groups, so as claimed by Langlade (1997) the RMCC appliance can help

Table 3 The mean (D) differences in each group and significance values of the differences between groups 1 and 2 and between group 1 and control group.

	Group 1		Group 2		Control group		Difference between groups	
	D	SD	D	SD	D	SD	Groups 1–2	Groups 1–control
							P	*P*
A-CTV (mm)	0.32	0.44	0.07	0.8	0.51	0.78	0.32	0.45
SN/(ANS-PNS) (°)	0.02	0.59	0.11	0.28	0.16	0.69	0.61	0.59
N-CF-A (°)	0.45	0.91	0.06	0.39	0.11	0.84	0.16	0.33
Pog-CTV (mm)	0.56	0.99	0.56	1.77	0.87	1.73	0.99	0.58
Xi-Pm (mm)	0.94	0.95	0.14	0.28	1.22	1.01	0.01**	0.46
SN/GoGn (°)	1.29	1.31	0.17	0.99	–0.29	1.02	0.02*	0.00**
ANB (°)	–0.74	0.74	–0.32	0.85	–0.23	0.67	0.71	0.07
N-Me (mm)	3.73	1.92	1.37	1.52	1.14	1.17	0.00**	0.00**
S-Go (mm)	1.94	1.07	1.59	1.25	1.19	1.31	0.44	0.12
ANS-Xi-Pm (°)	2.28	1.59	1.00	0.9	–0.05	0.6	0.02*	0.00**
NPog/FH (°)	0.22	1.11	–0.06	1.45	0.14	0.81	0.58	0.85
Labiomental angle (°)	20.4	12.4	11.6	11.1	1.01	9.4	0.06	0.00**
U1/CT (°)	–6.51	5.48	–2.61	5.05	0.98	1.87	0.07	0.00**
U1-CT (mm)	0.95	0.86	0.3	0.83	0.55	0.8	0.06	0.23
U1-CTV (mm)	–2.02	1.63	–1.46	1.75	0.54	1.33	0.55	0.00**
L1/GoMe (°)	9.3	4.66	9.09	4.68	–0.47	1.8	0.91	0.00**
L1-GoMe (mm)	–0.2	0.82	–1.14	0.87	0.46	0.76	0.01**	0.04*
L1-CTV (mm)	3.28	1.27	2.63	1.39	0.46	1.36	0.21	0.00**
L1-APog (mm)	3.33	1.23	2.74	0.84	–0.15	0.71	0.16	0.00**
Overjet (mm)	–5.3	1.96	–4.09	1.68	0.14	0.8	0.05*	0.00**
Overbite (mm)	–3.82	2.03	–3.16	1.67	0.06	0.68	0.37	0.00**
U6/CT (°)	–2.99	3.86	–2.45	2.4	–0.29	2.7	0.66	0.04*
U6-CT (mm)	0.91	1.11	0.05	0.54	1	0.85	0.02*	0.81
U6-CTV (mm)	–0.99	0.68	–0.93	0.9	0.57	1.02	0.84	0.00**
L6/GoMe (°)	2.39	4.44	1.72	2.95	1.49	2.7	0.65	0.52
L6-GoMe (mm)	1.86	0.92	1.31	0.81	0.59	0.53	0.11	0.00**
L6-CTV (mm)	3.12	0.95	2.74	1.49	0.68	2.33	0.45	0.00**
Molar relationship (mm)	–4.11	1.1	–3.67	1.59	–0.49	0.67	0.53	0.00**
Skeletal age (year)	0.92	0.52			0.56	0.29		0.04*
Growth potential (%)	2.63	1.47	0.36	0.45	1.2	3.2	0.00**	0.15

to avoid surgery in borderline adult cases. In the correction of overjet and molar relationship, the skeletal contributions were greater in group 2. The magnitude of mandibular movement (growth) was same in both groups, yet in group 1 the maxilla also moved in a forward direction affecting molar and overjet correction negatively; as a result the skeletal contribution was more in group 2. The molar relationship correction was mostly dentoalveolar and by lower molar mesialization in both groups. It is reported that in subjects with residual growth potential, the molar relationship is corrected mostly by dental movement (Harris *et al.*, 1991, 2001; McKinney and Harris, 2001). In this investigation, in agreement with Langlade's (1997) assessment that RMCC provides only reciprocal tooth movement, a Class I relationship was achieved by mostly dentoalveolar changes. This result is contrary to the finding of Uzel (2004), which showed more molar distalization (2.3 mm) and intrusion (0.4 mm) and the molar relationship change was achieved mostly by upper molar distalization. This difference could be due to their use of utility arches as intra-oral fixed appliances used.

Conclusion

The RMCC appliance is as useful in the late as in the early treatment period in Angle Class II subjects with mandibular dentoalveolar retrusion and optimum vertical facial dimensions. In both groups, the molar relationship correction was mostly dentoalveolar and by lower molar mesialization. The RMCC also prevents the unfavourable effects of Class II elastics on the upper incisors and provides forward movement of the incisors.

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