Case Report

Extraction treatment of a Class II division 2 malocclusion with mandibular posterior discrepancy and changes in stomatognathic function

Kunihiro Nagayama[a]; Hiroshi Tomonari[a]; Fumiaki Kitashima[b]; Shouichi Miyawaki[c]

ABSTRACT

This case report describes the successful extraction treatment of a Class II division 2 malocclusion with mandibular posterior discrepancy and a congenitally missing maxillary lateral incisor on the left side. The posterior space in the mandibular arch was small, and the mandibular second molars were impacted, with distal tipping. The discrepancies in the maxillary and mandibular arches were resolved by extraction of the maxillary lateral incisor on the right side and the mandibular second premolars on both sides. The mesial movement of the mandibular first molars occurred appropriately, with the second molars moving into an upright position. A lip bumper was used with a preadjusted edgewise appliance in the maxillary dentition to reinforce molar anchorage and labial movement of the retroclined incisors. Despite the extraction treatment, a deep bite could be corrected without aggravation as a result of the lip bumper and utility arch in the mandibular dentition. Thus, an Angle Class I molar relationship and an ideal overbite were achieved. The occlusal contact area and masticatory muscle activities during maximum clenching increased after treatment. The maximum closing velocity and the maximum gape during chewing increased, and the chewing pattern changed from the chopping to grinding type. The findings in the present case suggest that the correction of a deep bite might be effective for improving stomatognathic function. (*Angle Orthod.* 2015;85:314–321.)

KEY WORDS: Class II division 2; Posterior discrepancy; Stomatognathic function; Lip bumper

INTRODUCTION

Class II division 2 malocclusions are reportedly difficult to treat and are associated with a high risk of relapse.[1] The important considerations in orthodontic treatment of adult malocclusion include the decision regarding extraction of teeth and the improvement of a deep bite. The decision should be planned according to arch length discrepancy, stability after orthodontic treatment, and the anteroposterior position of the incisors in relation to the lips.[2–4] In cases involving Class II division 2 malocclusion, a nonextraction approach is often chosen when the patient shows a tendency toward a short face because the extraction of premolars can exacerbate a deep bite.[5] In nonextraction cases, resolution of the discrepancy is generally achieved through lateral expansion of the dentition, labial movement of the incisors, and molar distalization. However, the use of these techniques is limited by the patient's maxillofacial morphology and stability.

Dentition space analysis is valuable for orthodontic diagnosis and design. Arch length discrepancy is sometimes used as a rationale for tooth extraction in orthodontic treatment. However, Merrifield[6] has reported that a discrepancy in the posterior dental arch might be evidence of a posterior discrepancy. Discrepancies in the posterior area have been assigned great importance in decisions regarding tooth extraction.[6,7]

Malocclusion has been reported[8–12] to reduce stomatognathic function during mastication. However, the chewing

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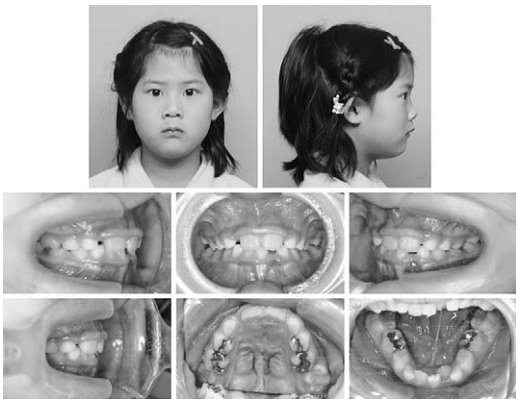

Figure 1. Facial and intraoral photographs at the first examination.

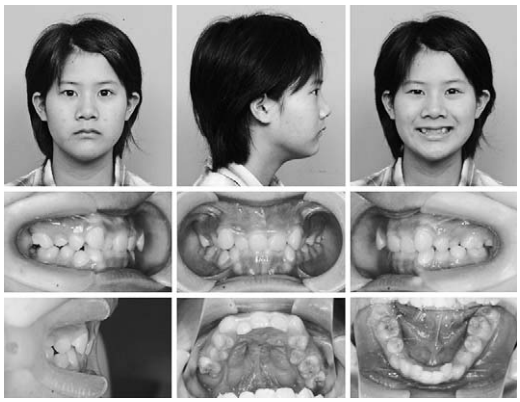

Figure 2. Pretreatment facial and intraoral photographs.

pattern of a patient with a Class II division 2 malocclusion and the changes in stomatognathic function after orthodontic treatment remain unclear. This article demonstrates the extraction treatment of a Class II division 2 malocclusion with mandibular posterior discrepancy and describes the subsequent functional changes.

CASE REPORT

The female patient, aged 6 years and 11 months at the first examination, had maxillary and mandibular retroclined incisors, a repaired cleft palate, and a narrow maxillary arch (Figure 1). The cleft palate had been reconstructed by conventional push-back palatoplasty when the patient was 1 year and 11 months old. There was no family history of cleft lip or palate. The orthodontic treatment undertaken during the mixed dentition period consisted of lateral expansion of the maxillary dentition using a rapid expansion appliance and labial movement of the maxillary incisors using a sectional arch.

When the patient was 13 years and 2 months old, edgewise treatment was initiated. The patient complained of crowded mandibular anterior teeth and labioversion of the maxillary canines (Figure 2). The frontal view of the face revealed no facial asymmetry. The patient had a straight facial profile, and the upper lip protruded slightly against the lower lip. The patient had an Angle Class II molar relationship with a 3.5-mm overjet and a 6.0-mm overbite. The maxillary lateral incisor on the left side was congenitally missing, and the maxillary dental midline had deviated 2.0 mm to the left side. Both the maxillary and mandibular arches were of the square type, with 8.0-mm maxillary and 7.5-mm mandibular arch length discrepancies. The intraoral view showed a narrow maxillary arch and a bilateral posterior crossbite on the second premolars. The maxillary second molar on the right side had not yet erupted. The lateral cephalometric analysis indicated a skeletal Class I jaw base relationship with an ANB angle of 3.7° and an average mandibular plane angle (Figure 3; Table 1).[13,14] The maxillary and mandibular incisors were inclined lingually (U1-FH angle, 95.2°; FMIA, 69.5°). The panoramic radiograph findings showed that the mandibular second molars on both sides were severely tipped distally, and the maxillary and mandibular third molars were present (Figure 3C).

The anteroposterior position of the maxillary first molars was normal (U6-PTV, 13.0 mm) (Table 1). However, the mandibular first molars were located posteriorly, because the second molars on both sides were tipped distally, and the distance along the occlusal plane between the distal contact point of the first molar and the anterior border of the ramus was small (C-LMD, 5.0 mm).[13]

The functional findings revealed no signs or symptoms of a temporomandibular disorder. The maximum occlusal force was weak, and the occlusal contact area was narrower than that of normal subjects (Table 2).[15] During unilateral mastication of gummy jelly on the right and left sides, the chewing cycle width was narrow in the frontal plane, and the chewing pattern was of the chopping type (Figure 4; Table 3).

This case report has been approved by the Kagoshima University Ethics Committee (#183), and we have obtained written informed consent from the patient to publish her photographs.

Diagnosis and Treatment Objectives

This patient was diagnosed as an Angle Class II division 2 malocclusion with a discrepancy in the mandibular molars, a repaired cleft palate, a congenitally missing maxillary lateral incisor on the left side, skeletal Class I, and an average mandibular plane angle.

The main treatment objectives were to create an ideal overbite and to resolve a discrepancy in the mandibular molars. The discrepancies in the arches would be resolved by extraction of the maxillary lateral incisor on the right side and the mandibular second premolars on both sides. Maximum anchorage of the maxillary molars and minimum anchorage of the

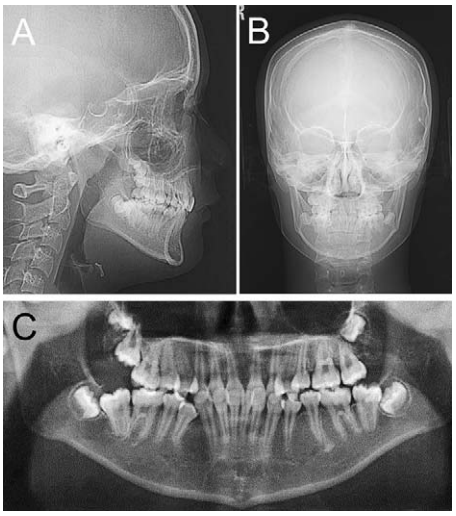

Figure 3. Pretreatment cephalograms and a panoramic radiograph. (A) Lateral cephalogram. (B) Posteroanterior cephalogram. (C) Panoramic radiograph.

mandibular molars were planned in order to achieve an Angle Class I molar relationship. We also chose to maintain the initial anteroposterior position of the maxillary central incisors to achieve the desired level of stability and to optimize the interincisal angle.

Treatment Alternatives

The presence of an Angle Class II molar relationship and mandibular crowding would lead many orthodontists to consider nonextraction treatment of the mandible; however, we determined that extraction treatment would be ideal for this patient. This decision was based on a discrepancy in the mandibular molars. If nonextraction treatment of the mandible had been selected, the mandibular second molars might have remained impacted with distal tipping, and excessive labial movement of the incisors would have been necessary to resolve the discrepancy.

For the maxillary extraction site, the lateral incisor was chosen over the first premolar on the right side to maximize anchorage of the maxillary molars and to produce a symmetric appearance. Extraction of the mandibular second premolars on both sides was planned in order to create an Angle Class I molar relationship, thus improving the distal tipping of the second molars.

A lip bumper in the maxillary dentition was used for reinforcement of molar anchorage and to alleviate lip pressure and thereby facilitate labial movement of the retroclined incisors. To improve the deep bite, we elected to use a utility arch in the mandible that would induce intrusion and labial movement of the incisors. Orthodontic miniscrews were not used for anchorage because we have found that they frequently loosen in adolescent patients at the time that treatment is initiated.[16]

Treatment Progress

The maxillary lateral incisor on the right side and mandibular second premolars on both sides were

Table 1. Cephalometric Summary[a]

	Pretreatment	Posttreatment	Postretention	Norms, Mean ± SD[b]	
Measurements	13 y, 2 mo	16 y, 1 mo	19 y, 5 mo	14-y-old girls	Adult females
Angular, °					
SNA	79.7	79.4	79.4	80.8 ± 3.6	80.8 ± 3.6
SNB	76.0	76.3	76.5	78.0 ± 4.4	77.9 ± 4.5
ANB	3.7	3.1	2.9	2.7 ± 2.2	2.8 ± 2.4
Facial angle	85.9	86.1	86.3	85.1 ± 3.6	84.2 ± 4.4
FMA	27.4	28.4	28.4	29.4 ± 3.5	30.5 ± 3.6
SN-MP	35.6	36.6	36.6	36.9 ± 5.1	37.1 ± 4.6
Gonial angle	127.0	127.2	127.2	122.8 ± 5.2	122.1 ± 5.3
U1-FH	95.2	110.2	110.5	113.7 ± 8.2	112.3 ± 8.3
IMPA	83.1	90.7	90.7	93.3 ± 6.1	93.4 ± 6.8
FMIA	69.5	60.9	60.9	57.1 ± 6.8	56.0 ± 8.1
Interincisal angle	154.0	130.4	130.1	123.3 ± 11.2	123.6 ± 10.6
Linear, mm					
U1 to A-Pog	2.0	3.0	3.0	6.2 ± 1.5	6.2 ± 1.5
L1 to A-Pog	−1.5	0.0	0.0	3.0 ± 1.5	3.0 ± 1.5
U6-PTV	13.0	14.0	14.0	15.1 ± 3.1	18.8 ± 3.1
C-LMD	5.0	14.5	14.8	15.0 ± 0.3	20.1 ± 0.6
E-line: upper lip	0.0	−2.0	−2.2	−3.0 ± 1.0	−3.0 ± 1.0
E-line: lower lip	−2.5	−2.5	−2.5	1.9 ± 1.5	1.1 ± 1.5
Overjet	3.5	2.5	2.5	3.1 ± 0.8	3.1 ± 1.1
Overbite	6.0	2.5	2.5	3.1 ± 1.7	3.3 ± 1.9

[a] C-LMD[13]: distance between the intersection of the occlusal plane with the anterior border of the ramus and the distal contact point of the mandibular first molar.

[b] Japanese norms from Wada.[14] SD indicates standard deviation.

Table 2. Changes in Occlusal Force, Contact Area, and Electromyographic Activities of Masticatory Muscles During Maximum Clenching

Variables	Pretreatment	Posttreatment	Normative Value[a] Mean ± SD
Occlusal force, N	522.1	738.6	850.4 ± 231.9
Occlusal contact area, mm^2	12.5	21.1	19.6 ± 6.6
Masseter muscle activities, μVs			
On the right side	82.8	167.8	–
On the left side	90.8	135.1	–
Temporal muscle activities, μVs			
On the right side	46.7	205.1	–
On the left side	83.7	140.2	–

[a] Normative values from Miyawaki et al.[15] SD indicates standard deviation.

extracted, and maxillary tooth alignment was initiated using a preadjusted edgewise appliance (0.018 × 0.025 inches) combined with a lip bumper. Meanwhile, the mandibular teeth, except for the incisors, were aligned with a preadjusted edgewise appliance. Retraction of the mandibular first premolars and mesial movement of the mandibular first molars were initiated using an elastic chain. Within 4 months, the maxillary incisors were flared, and mesial rotation of the maxillary first molar on the left side had improved. The mandibular incisors were then bonded with a preadjusted edgewise appliance and intruded using a utility arch (Figure 5A). After improvement of the deep bite, spaces in the maxillary dentition were closed using an elastic chain and 0.016 × 0.022-inch stainless-steel wire (Figure 5B). Mesial movement of the mandibular first molars was continued during intrusion of the incisors, and an Angle Class I molar relationship was obtained within 12 months (Figure 5C). Then the mandibular third molar on the right side was extracted because of horizontal impaction, and the maxillary and mandibular erupted second molars were corrected (Figure 5D).

The total active treatment period was 35 months. The patient wore Begg-type and Hawley-type retainers for her maxillary and mandibular dentition, respectively.

Treatment Results

An appropriate overbite (2.5 mm) and degree of incisor inclination (U1-FH angle, 110.2°; FMIA, 60.9°) were obtained (Figures 6 and 7; Table 1). The anteroposterior positions of the maxillary and mandib-

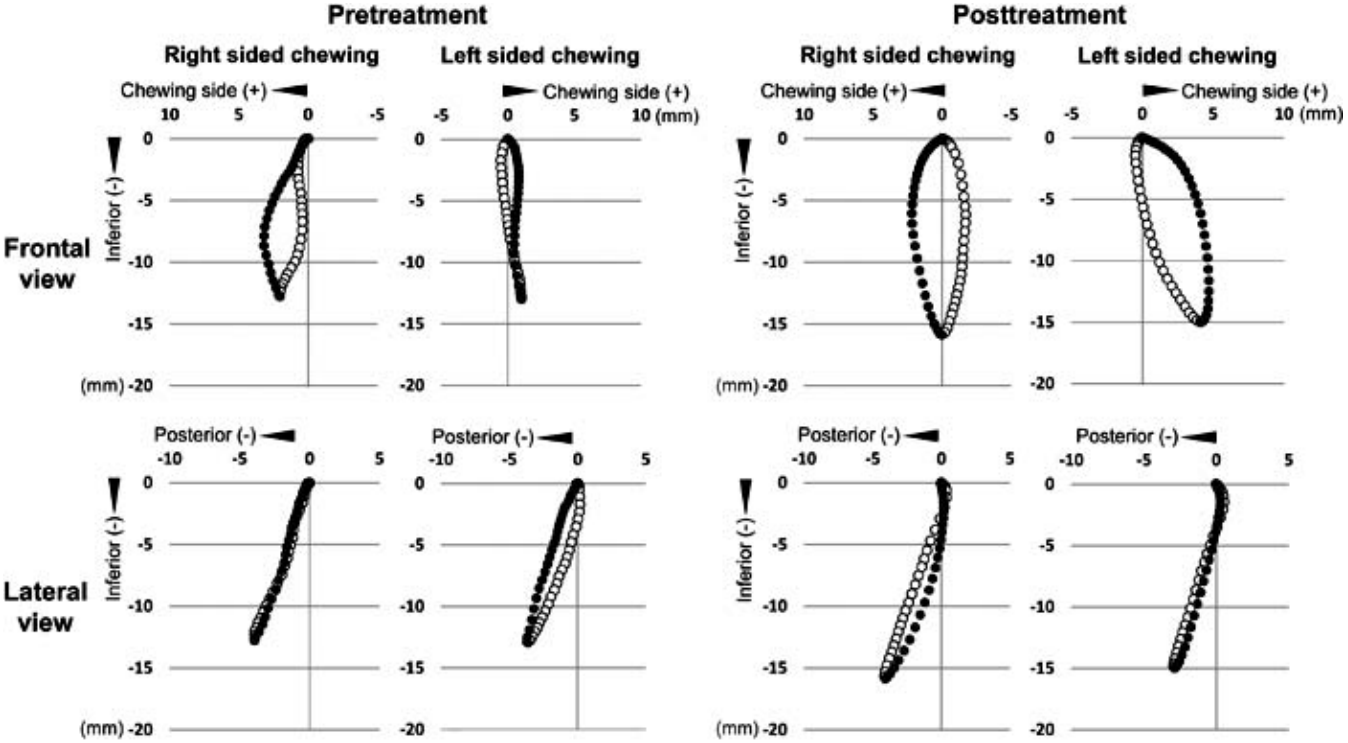

Figure 4. Mean path of 10 representative cycles of the lower central incisor point during the chewing of gummy jelly before and after treatment. The white circles represent opening paths, while the black circles represent closing paths. (0, 0, 0); the maximum intercuspation position.

Table 3. Variables Related to Jaw Movement During Unilateral Mastication[a]

	Pretreatment				Posttreatment			
	Right Side		Left Side		Right Side		Left Side	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cycle duration, s	1.4	0.7	1.5	0.6	1.3	0.4	1.2	0.3
Maximum closing velocity, mm/s	51.7	14.5	51.7	9.6	87.6	19.3	89.3	22.6
Maximum gape, mm	13.1	2.3	13.1	2.8	15.9	3.7	15.6	3.8
Width, mm	1.0	0.3	1.6	0.2	3.0	0.2	3.1	0.3
Closing angle, °	25.2	15.6	23.7	4.4	39.1	1.5	47.2	0.7

[a] SD indicates standard deviation.

ular central incisors were similar to those observed before orthodontic treatment (Figure 8), and the maxillary dental midline had been corrected (Figure 6). The patient achieved an Angle Class I molar relationship with 5.5-mm mesial movement of the mandibular molars, 1.0-mm mesial movement of the maxillary first molar on the right side, and distal rotation of the maxillary first molar on the left side (Figure 8). In profile, the protruded upper lip retruded because the maxillary canines moved palatally and distally (Figure 6). In the skeletal view, the mandibular plane angle increased slightly (1.0°), and the mandible grew upward (Figure 8; Table 1). The occlusal force, contact area, and electromyographic activities of mastication muscles during clenching increased (Figure 9; Table 2). Maximum closing velocity increased, and cycle duration decreased during unilateral mastication (Table 3). In addition, the width and height of the chewing cycle increased after treatment, and the chewing pattern changed from the chopping to the grinding type (Figure 4). Panoramic radiographs obtained after the treatment showed no marked apical root resorption (Figure 7C). The mandibular third molar on the left side was extracted after active treatment. The occlusion and facial profile have been maintained without relapse for 3 years and 4 months (Figures 10 and 11; Table 1), and no signs or symptoms of a

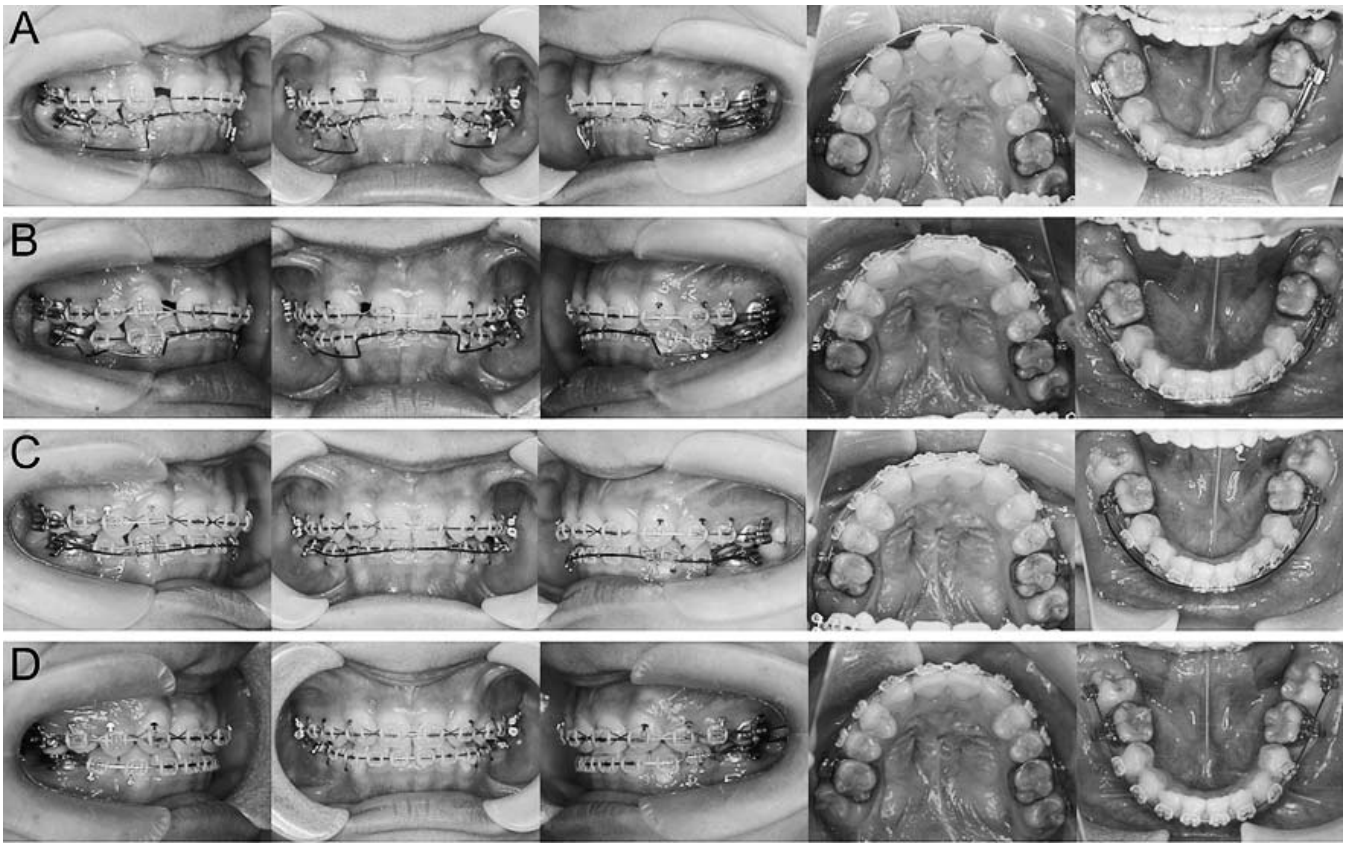

Figure 5. Photographs taken during the treatment process. (A) Early intrusion of the mandibular incisors by a utility arch. (B) The initiation of space closure in the maxillary dentition. (C) 12 Months after the start of mesial movement of the mandibular first molars. (D) Early leveling of the maxillary and mandibular second molars.

Figure 6. Posttreatment facial and intraoral photographs.

temporomandibular disorder have been noted. The upper third molars on both sides had been extracted at 3 years and 5 months during the retention stage.

DISCUSSION

We suspected a discrepancy in the mandibular molars because the posterior space in the mandibular arch (C-LMD)[13] was small and the mandibular second molars were impacted, with distal tipping, despite eruption to the occlusal plane. Therefore, we decided on a treatment strategy involving extraction of the mandibular second premolars on both sides and mesial movement of the mandibular first molars. Our plan resolved this discrepancy and changed the Angle Class II molar relationship to an Angle Class I molar relationship. If the mandibular second premolars had not been extracted, the mandibular second molars might have remained impacted and might not have contacted the opposite maxillary molars. Our results

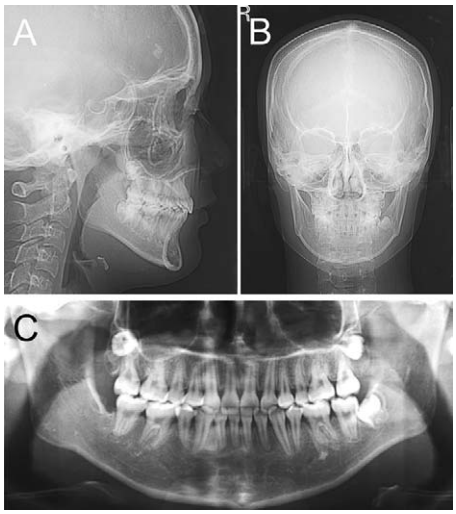

Figure 7. Pretreatment cephalograms and a panoramic radiograph. (A) Lateral cephalogram. (B) Posteroanterior cephalogram. (C) Panoramic radiograph.

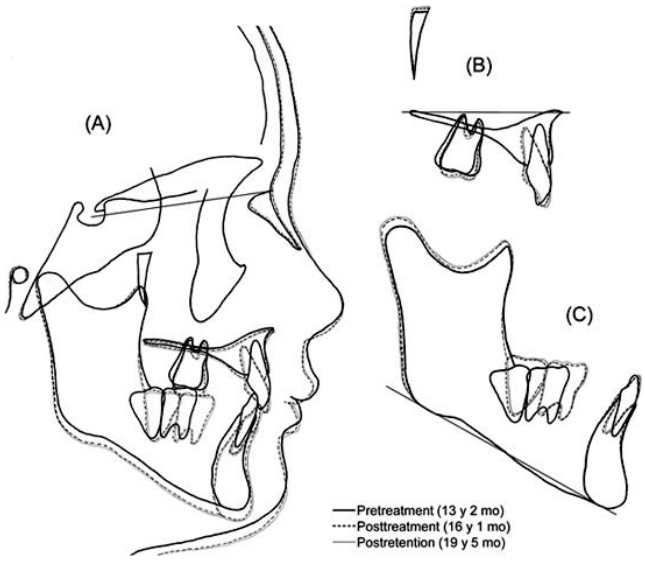

Figure 8. Superimposed cephalometric tracings showing changes from the pretreatment phase to the retention stage at 3 years and 4 months. (A) An overall superimposition with best-fit on the anterior wall of the sella turcica, the greater wings of the sphenoid, the cribriform plate, the orbital roofs, and the surface of the frontal bone. (B) Superimposition of the maxilla, with best-fit on the lingual curvature of the palate and the maxillary bony structures. (C) Superimposition of the mandible with best-fit on the internal cortical outline of the symphysis and the mandibular canal.

suggest that a posterior discrepancy is of great importance when deciding whether to extract teeth.

The maxillary first molar on the right side moved mesially because the molar was tipped distally before treatment and was pulled mesially during close of the space adjacent to the right lateral incisor. In contrast, the maxillary first molar on the left side was rotated distally using a lip bumper. The asymmetric anteroposterior position of the maxillary first molars and the bilateral molar relationship were thus improved.

Despite the extraction treatment, a deep bite was corrected without aggravation as a result of labial movement of the incisors, mandibular growth during the treatment, or the extruding force exerted by the lip bumper on the molars in the maxillary dentition and the utility arch in the mandibular dentition. The use of a lip bumper in the maxillary dentition easily induced labial movement of the incisors by ameliorating lip pressure. In addition, use of this appliance reinforced maxillary molar anchorage and resulted in an Angle Class I molar relationship. The primary reasons for use of a lip bumper are the need to reduce mandibular anterior crowding by excluding lip pressure and the need to increase arch width and length in mixed dentition.[17,18] This appliance is also effective in extraction cases with Class II division 2 malocclusion involving a deep bite or when the reinforcement of molar anchorage is necessary.

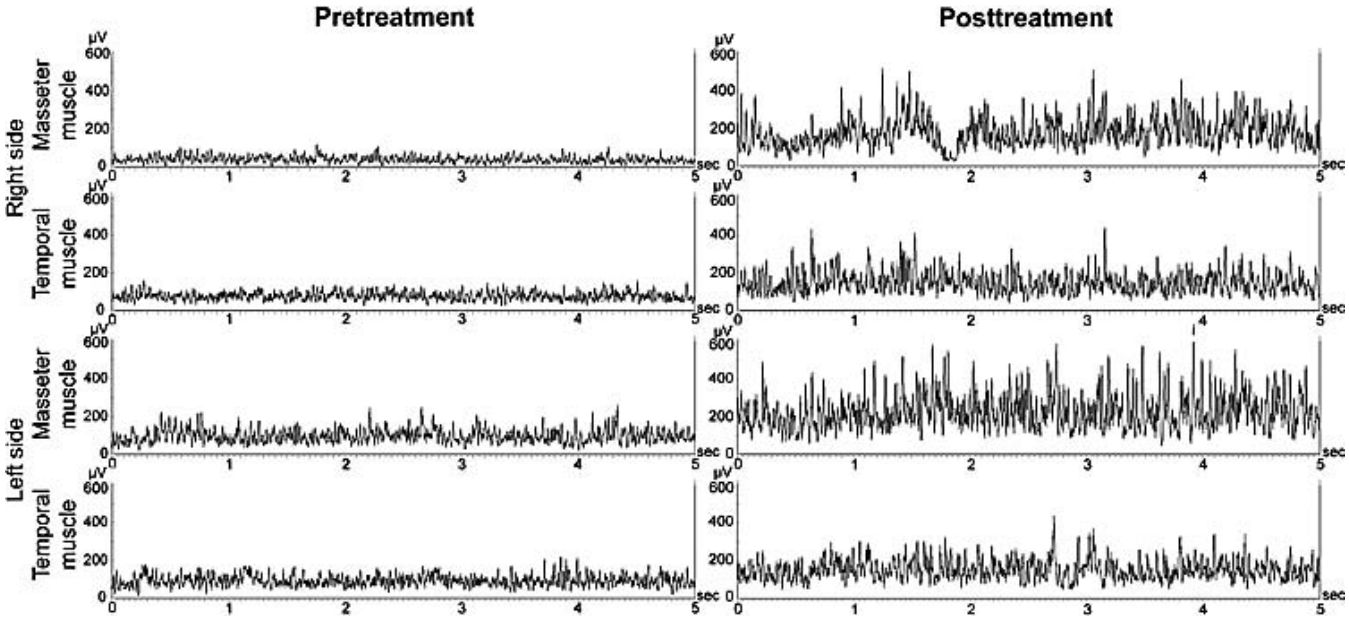

Figure 9. Masseter and temporalis muscle activity during maximum clenching.

In this case, the occlusal contact area and level of masticatory muscle activity during maximum clenching increased after treatment. During maximum clenching, occlusal bite force as well as contact area are distributed mainly on the first and second molars.[19] Extraction of the mandibular second premolars improved the distal tipping of the second molars and thus allowed contact with the opposing maxillary molars and, subsequently, enhanced bite force support, predominantly posteriorly.

Malocclusion has been reported[8–12] to induce predominantly vertical or chopping type chewing and a prolonged cycle duration during chewing. While the chewing pattern of patients with a Class II division 2 malocclusion remains to be established, studies[20,21] have suggested that deep bite malocclusion influences the shape of the chewing cycle and the consistency of chewing cycle kinematics. In this case, the lateral excursion of jaw movement increased, and the chewing pattern changed from the chopping to the grinding type after treatment because jaw movement was no longer restricted by a deep bite with retroclined incisors. Furthermore, the orthodontic correction of an incisor crossbite has been shown to result in a broader jaw movement pattern, as evaluated from the frontal view, and increased jaw movement velocity.[22] Similar functional changes were observed in the case presented here during unilateral gummy jelly mastication. Sensory input from the periodontal mechanoreceptors

Figure 10. Facial and intraoral photographs obtained at 3 years and 4 months, during the retention stage.

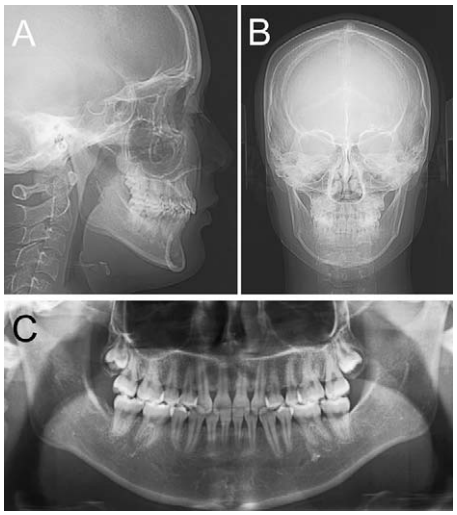

Figure 11. Cephalograms and a panoramic radiograph obtained at 3 years and 4 months, during the retention stage. (A) Lateral cephalogram. (B) Posteroanterior cephalogram. (C) Panoramic radiograph.

of the incisor is assumed to influence masticatory jaw movement because of the increased sensitivity of periodontal afferents innervating anterior, as compared to posterior, teeth.[23] As the height of the chewing cycle has also been reported[24,25] to increase as a child grows, this aspect of the chewing cycle might have been influenced by vertical mandibular growth in our patient.

CONCLUSION

We suggest the following guidelines regarding orthodontic treatment for a Class II division 2 malocclusion:

- A posterior discrepancy is of great importance in decisions regarding tooth extraction.
- Use of a lip bumper in the maxillary dentition is effective for the improvement of a deep bite and for the reinforcement of molar anchorage.
- The correction of a deep bite might be effective for improving stomatognathic function.

REFERENCES

1. Canut JA, Arias S. A long-term evaluation of treated Class II division 2 malocclusions: a retrospective study model analysis. *Eur J Orthod*. 1999;21:377–386.
2. Bock N, Ruf S. Post-treatment occlusal changes in Class II division 2 subjects treated with the Herbst appliance. *Eur J Orthod*. 2008;30:606–613.
3. Millett DT, Cunningham SJ, O'Brien KD, Benson P, Williams A, de Oliveira CM. Orthodontic treatment for deep bite and retroclined upper front teeth in children. *Cochrane Database Syst Rev*. 2006;18:CD005972.
4. Dyer FM, McKeown HF, Sandler PJ. The modified twin block appliance in the treatment of Class II division 2 malocclusions. *J Orthod*. 2001;28:271–280.
5. Yousefian J, Trimble D, Folkman G. A new look at the treatment of Class II division 2 malocclusions. *Am J Orthod Dentofacial Orthop*. 2006;130:771–778.
6. Merrifield LL. Differential diagnosis with total space analysis. *J Charles H. Tweed Int Found*. 1978;6:10–15.
7. Merrifield LL, Klontz HA, Vaden JL. Differential diagnostic analysis system. *Am J Orthod Dentofacial Orthop*. 1994; 106:641–648.
8. Yashiro K, Takagi M, Takada K. Smoothness of chewing jaw movements in adults with mandibular prognathism. *J Oral Rehabil*. 2012;39:100–110.
9. Tome W, Yashiro K, Takada K. Orthodontic treatment of malocclusion improves impaired skillfulness of masticatory jaw movements. *Angle Orthod*. 2009;79:1078–1083.
10. Piancino MG, Isola G, Merlo A, Dalessandri D, Debernardi C, Bracco P. Chewing pattern and muscular activation in open bite patients. *J Electromyogr Kinesiol*. 2012;22: 273–279.
11. Miyawaki S, Tanimoto Y, Araki Y, Katayama A, Kuboki T, Takano-Yamamoto T. Movement of the lateral and medial poles of the working condyle during mastication in patients with unilateral posterior crossbite. *Am J Orthod Dentofacial Orthop*. 2004;126:549–554.
12. Maeda A, Soejima K, Ogura M, Ohmure H, Sugihara K, Miyawaki S. Orthodontic treatment combined with mandibular distraction osteogenesis and changes in stomatognathic function. *Angle Orthod*. 2008;78:1125–1132.
13. Chen LL, Xu TM, Jiang JH, Zhang XZ, Lin JX. Longitudinal changes in mandibular arch posterior space in adolescents with normal occlusion. *Am J Orthod Dentofacial Orthop*. 2010;137:187–193.
14. Wada K. A study on the individual growth of maxillofacial skeleton by means of lateral cephalometric roentgenograms. *J Osaka Univ Dent Sch*. 1977;22:239–269.
15. Miyawaki S, Araki Y, Tanimoto Y, et al. Occlusal force and condylar motion in patients with anterior open bite. *J Dent Res*. 2005;84:133–137.
16. Lee SJ, Ahn SJ, Lee JW, Kim SH, Kim TW. Survival analysis of orthodontic mini-implants. *Am J Orthod Dentofacial Orthop*. 2010;137:194–199.
17. Hashish DI, Mostafa YA. Effect of lip bumpers on mandibular arch dimensions. *Am J Orthod Dentofacial Orthop*. 2009;135:106–109.
18. O'Donnell S, Nanda RS, Ghosh J. Perioral forces and dental changes resulting from mandibular lip bumper treatment. *Am J Orthod Dentofacial Orthop*. 1998;113:247–255.
19. Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. *J Dent Res*. 1999;78: 1336–1344.
20. Piancino MG, Vallelonga T, Debernardi C, Bracco P. Deep bite: a case report with chewing pattern and electromyographic activity before and after therapy with function generating bite. *Eur J Paediatr Dent*. 2013;14:156–159.
21. Buschang PH, Throckmorton GS, Austin D, Wintergerst AM. Chewing cycle kinematics of subjects with deepbite malocclusion. *Am J Orthod Dentofacial Orthop*. 2007;131: 627–634.
22. Sohn BW, Miyawaki S, Noguchi H, Takada K. Changes in jaw movement and jaw closing muscle activity after orthodontic correction of incisor crossbite. *Am J Orthod Dentofacial Orthop*. 1997;112:403–409.
23. Johnsen SE, Svensson KG, Trulsson M. Forces applied by anterior and posterior teeth and roles of periodontal afferents during hold-and-split tasks in human subjects. *Exp Brain Res*. 2007;178:126–134.
24. Kubota N, Hayasaki H, Saitoh I, et al. Jaw motion during gum-chewing in children with primary dentition. *Cranio*. 2010;28:19–29.
25. Wickwire NA, Gibbs CH, Jacobson AP, Lundeen HC. Chewing patterns in normal children. *Angle Orthod*. 1981; 51:48–60.