CASE REPORT

The One-Couple System as an Innovative Tool for Non-Surgical, Non-Extraction Correction of Skeletal Deformities Caused by Mouth-Breathing

Sangsuwon C[a], Abdullah F[a], Alansari S[a], Alikhani M[a], Nervina JM[a], Teixeira CC[b], Alikhani M[a,c]

a *CTOR Academy, Hoboken, New Jersey*

b *New York University, Department of Orthodontics, New York, New York*

c *Harvard University, Department of Developmental Biology, Boston, Massachusetts*

Corresponding Author:
Mani Alikhani
mani.alikhani@ctor.academy

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ABSTRACT

Here we present a non-surgical, non-extraction treatment of a 15-year-old patient who was a mouth breather, and had a skeletal Class III, hyperdivergent jaw pattern. Treatment included one-couple systems combined with orthopedic and orthodontic corrections to address the patient's transverse, sagittal, and vertical problems. Due to chronic obstruction of the nasal airway, the patient had adopted a mouth-breathing habit early in life, which was associated with a significant skeletal deformity. Maxillary arch constriction, significant extrusion of posterior teeth, an open bite extending to the first molars, high mandibular angle, and increased lower facial height were among the skeletal and dental findings in this patient. While orthognathic surgery is a classic treatment option for these patients (after they stop growing), any surgical approach or extractions were rejected by the patient's parents. Transverse and sagittal correction of the maxilla was addressed through orthopedic treatment by sutural stimulation and cortical drift, while the vertical corrections were mostly achieved through one-couple systems to intrude posterior teeth and extrude anterior teeth. At the end of treatment, we were able to establish a skeletal Class I relation with Class I canine and molar occlusion. The patient's vertical growth pattern was controlled and, more importantly, the patient was able to regain normal nasal breathing.

Background

The nasal passage is the main airway for breathing that not only plays a central role in respiration, but also in olfaction. Nasal breathing can contribute to systemic and brain health of growing children in different ways, such as providing a high concentration of oxygen and acting as the first line of defense against microorganisms and allergens through mucociliary clearance and release of nitric oxide. Nasal breathing also plays a significant role in the health of the respiratory tract by warming, moisturizing and filtering the air [1-9]. However, as children grow, any obstruction in the nasal airway can push the patient toward a mouth breathing pattern. The most common causes of mouth breathing include allergic or non-allergic rhinitis, adenoid or tonsil hypertrophy, turbinate hypertrophy, and septum deviation [10, 11].

Mouth breathing is regarded as a pathological condition that can lead to many local and systemic side effects. Breathing through the mouth can deliver less oxygen and has been considered pathologic for the lining of the respiratory tract and oral cavity because of the impact that cold, dry and impure air can have [10, 12]. As a sign of upper airway obstruction, mouth breathing may be associated with cardiovascular adaptation, changes in growth pattern, decreased respiratory muscle strength, attention deficit disorder, deficiency in learning process, bruxism, TMJ remodeling, sleep and mood disorders, which if sustained can progress to sleep apnea [13-21]. In addition, mouth breathing can contribute to altered neck posture, weakness of orofacial muscles including: lip incompetence, reverted lower lip, change in tongue position (during rest, deglutition, speech, and mastication), increased gingival irritation, caries, halitosis, speech problems and voice abnormalities [22-30]. However, one of the most dominant effects of mouth breathing is the change in craniofacial form due to the emergence of new neuromuscular activity triggered by mouth breathing [31-35].

Unfortunately, even after the cause of mouth breathing is removed, mouth breathing can continue and the dento-skeletal malformation produced by this condition does not necessarily reverse itself and requires treatment [31, 36-38].

While orthognathic surgery can address the skeletal deformities associated with mouth-breathing function, the majority of patients refuse this option due to its side effects, cost, and high possibility of relapse, especially if the mouth breathing continues.

On the other hand, depending on the severity of skeletal deformities, non-surgical orthopedic treatment of these patients can be very challenging. Due to these difficulties many orthodontists select camouflage treatment by extracting teeth, which may further change the function and position of different muscles, especially the tongue, and further add to the instability of the results.

Here we present a male teenager that suffered from mouth breathing for many years due to hypertrophic tonsils and nasal septal deviation. The patient reported difficulty breathing from his nose, and that most of the time he preferred to breathe through his mouth. In addition, clinical examination revealed ankyloglossia. The patient presented with characteristic malformations observed in mouth breathers, such as extrusion of posterior teeth, high mandibular plane angle, constricted maxilla, severe maxillary dental crowding, and severe open bite. The patient's parents were opposed to any surgical correction or tooth extraction. We offered a treatment that included a one-couple system as an efficient mechanotherapy design to maximize the movement of different targets during the non-surgical and non-extraction treatment of these malocclusions. This free object design, when combined with orthopedic treatment, can predictably address different skeletal and dental deformities associated with chronic mouth breathing patterns.

Patient Presentation, Etiology and Diagnosis

A healthy 15.7-year-old Caucasian male presented to our clinic with a chief concern of an open bite.

Extraoral examination and frontal portrait photographs (Figure 1) show a dolichofacial pattern and increased lower facial third. Facial asymmetry was noted as a slight leftward deviation of the mandible.

The lateral portrait photographs (Figure 1) show a straight profile and an obtuse nasolabial and chin-to-throat angle (121º and 120.7º, respectively). The upper lip was deficient, and the lower lip was normal relative to the E-line (-6.9 mm and 1.1 mm, respectively). Upon smiling, he exhibited a 50% incisal display and increased buccal corridor width.

Intraoral examination (Figure 1) showed poor oral hygiene, normal buccal frenum attachments, and the presence of ankyloglossia. An open bite was observed from anterior teeth (-3.5 mm) to the mandibular first molar. The third molars were unerupted. The maxillary midline coincided with the facial midline, while the mandibular midline was deviated to the left by 1.5 mm with respect to the maxillary midline.

The patient presented a mouth breathing pattern with difficulty in nasal breathing. He reported mouth breathing habits for as long as he remembered. Parents reported that he had a problem with hypertrophic tonsils when he was younger, but gradually his tonsils decreased in size. However, he still had a nasal septum deviation that they chose not to address surgically.

Digital cast analysis (Figure 2) showed a Class III molar and canine relationship on both sides. Both maxillary and mandibular dental arch widths were constricted (maxillary inter-canine and inter-molar width were 41 mm and 44.4 mm, respectively; mandibular inter-canine and inter-molar width were 25.9 mm and 36.5 mm, respectively). Severe crowding was found in both dental arches (dental arch space deficiency was 7.5 mm in the maxilla and 9.3 mm in the mandible). The maxillary dental arch showed a moderate reverse Curve of Spee. The overjet and overbite were -3.2 mm and -3.5 mm, respectively. An anterior maxillary dental deficiency resultig in a Bolton discrepancy

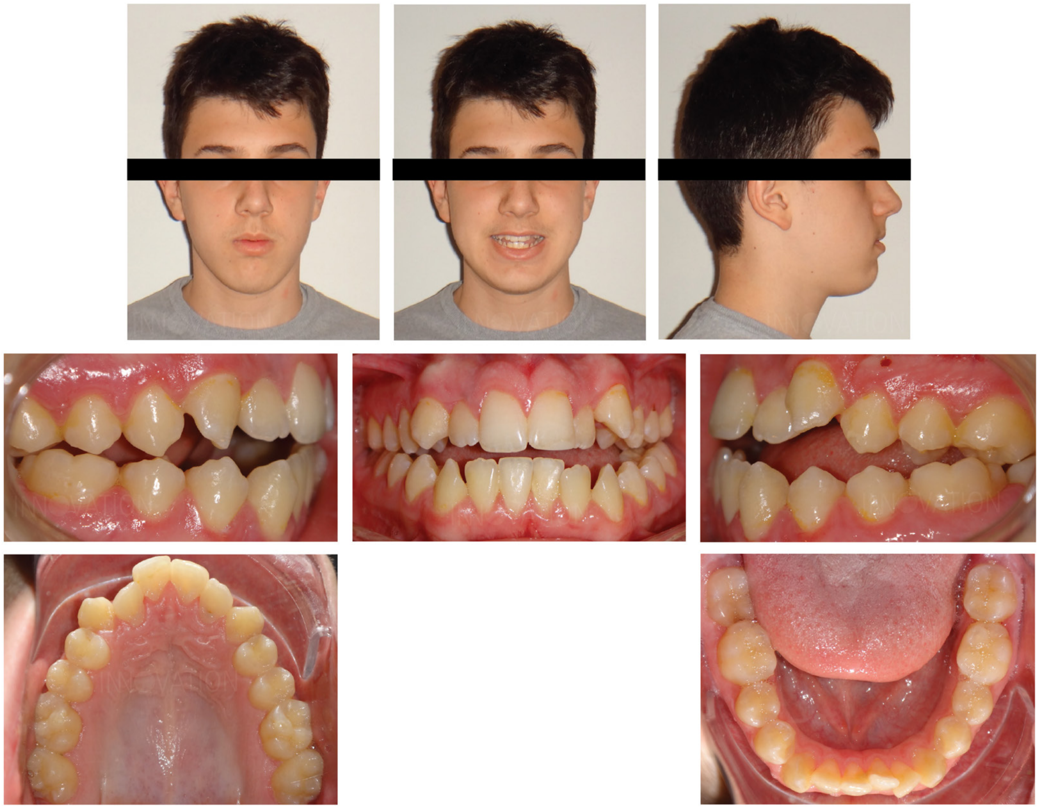

Figure 1: Pre-treatment portrait and intra-oral photographs. *Lateral profile photograph shows a straight profile, increased lower facial third height, and deficient maxillary lip position. Frontal portrait photographs show an open bite, increased buccal corridors, and 50% incisal display upon smiling. The maxillary dental midline coincides with facial midline; however, the mandibular dental midline deviates 1.5 mm to the left in relation to the maxillary midline. Intraoral photographs reveal a constricted maxilla and mandible, crowding in the maxillary and mandibular arches, an open bite from second premolar to second premolar, proclined maxillary anterior teeth, and absent third molars.*

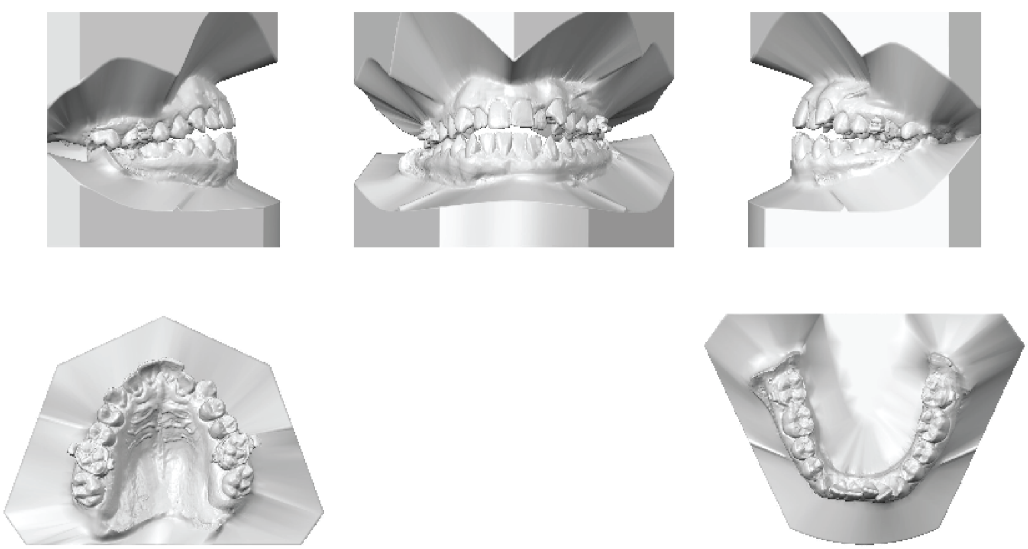

Figure 2: Pre-treatment digital casts. *Pre-treatment digital casts show a Class III molar and canine relationship on both sides with an open bite from the second premolar to second premolar. The maxillary dental arch shows a moderate reverse Curve of Spee. Both maxillary and mandibular dental arches were constricted. Severe anterior crowding was found in both dental arches. A Bolton discrepancy due to an anterior maxillary deficiency was also observed.*

of 5 mm was also measured.

The panoramic radiograph (Figure 3) revealed a complete dentition with unerupted maxillary and mandibular third molars in all quadrants. Roots on all teeth were fully developed and showed no signs of pathology. A condylar asymmetry was observed with the condylar head on the left side flatter than the right side. Lateral cephalometric analysis (Figure 4, Table I) showed a skeletal Class III relation (ANB = -1.3°) with a hyperdivergent mandible (FMA = 40.6°, SN-MP = 44.5°). The maxillary incisors were proclined, while the mandibular incisors presented minor retroclination (U1°- SN = 116.4°, IMPA = 81.1°, respectively).

Figure 3: Pre-treatment panoramic radiograph. *Panoramic radiograph shows a complete dentition with unerupted third molars, and spindle-like dental roots. No bone loss was observed. Condylar asymmetry was also noted with the condylar head on the left side flatter than the right side.*

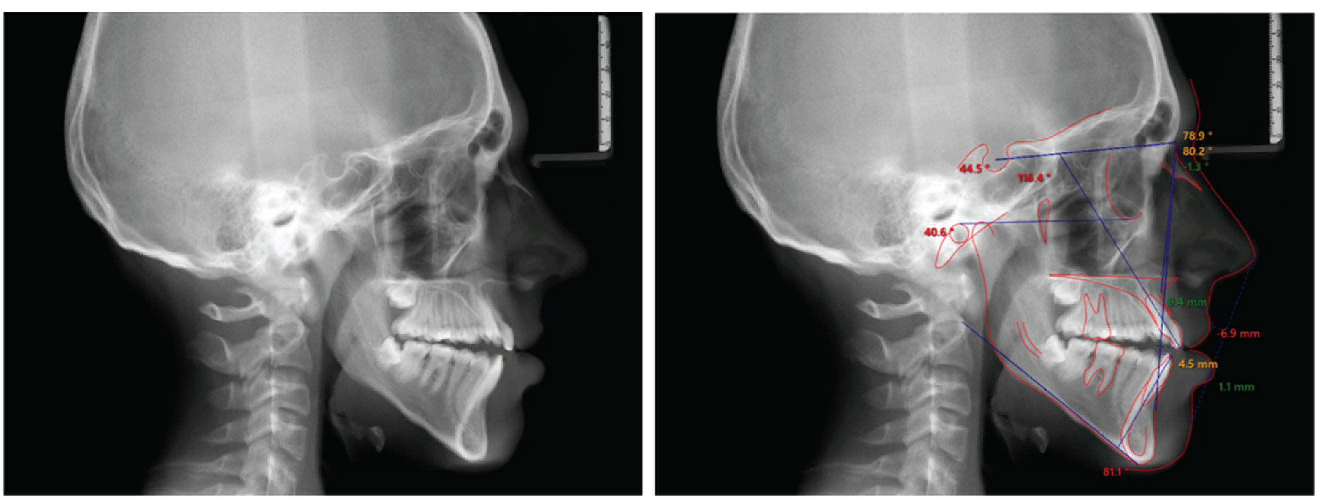

Figure 4: Pre-treatment lateral view of cephalometric radiograph. *Pre-treatment lateral cephalometric radiograph shows a skeletal Class III relation, hyperdivergent profile, proclined maxillary incisors, and a skeletal open bite.*

Measurement	Initial Value	Final Value	Norm
SNA (deg)	78.9°	81.7°	81.4 ± 4.4°
SNB (deg)	80.2°	80.4°	78.2 ± 3.9°
ANB (deg)	-1.3°	1.3°	3.2 ± 2.3°
FMA (deg)	40.6°	36.3°	28.7 ± 5.2°
SN-MP (deg)	44.5°	40.9°	32.9 ± 5.2°
Maxillary Incisor to SN (deg)	116.4°	110.9°	102.4 ± 5.5°
IMPA (deg)	81.1°	79°	95.3 ± 6.6°
Maxillary Incisor to NA (mm)	9.4 mm	4.3 mm	5.5 ± 2.7 mm
Mandibular Incisor to NB (mm)	4.5 mm	4.5 mm	6.1 ± 2.9 mm
Maxillary Lip to E-Plane (mm)	-6.9 mm	-5.5 mm	-2 ± 2 mm
Mandibular Lip to E-Plane (mm)	1.1 mm	-0.6 mm	-2 ± 2 mm
Nasolabial Angle (deg)	121°	118°	90-95°
Labiomental Angle (deg)	115.2°	117.2°	120 ± 10°
Chin-Throat Angle (deg)	120.7°	124.4°	120 - 126°
Chin Throat Length (mm)	26.8 mm	38 mm	42 ± 6 mm

Table I: Cephalometric Analysis Pre- and Post- Treatment. *Angular and linear measurements were taken on craniofacial skeletal, dental and soft tissue landmarks identified on pre- and post- treatment lateral cephalograms (° - degrees, mm - millimeters).*

Treatment Objectives

The overall objective was to establish a long-term functional and stable occlusion, and improve the facial and dental esthetics. The treatment objectives were as follows:

I. Facial esthetics: improve the facial profile and the mandibular asymmetry, decrease the lower facial height, improve the maxillary lip position relative to the E-line, decrease the buccal corridors, and improve incisal display upon smiling.

II. Skeletal objectives: correct the maxillary transverse deficiency and sagittal jaw disharmony, achieve Class I skeletal relation, decrease the hyperdivergency and vertical excess by mandibular auto-rotation.

III. Dental objectives: develop the maxillary and the mandibular arch, relieve dental crowding, eliminate the open bite and establish proper overjet and overbite relation, level the occlusal plane and correct the Curve of Spee, improve maxillary incisal inclination, protract the maxillary dental arch, establish a functional and stable Class I canine and molar relationship, correct the midline, improve marginal ridge discrepancies, level gingival margins and gingival heights of contour around the anterior teeth, maintain alveolar bone height around maxillary and mandibular anterior teeth, and prevent or minimize root resorption of maxillary and mandibular anterior teeth.

Treatment Options

After a comprehensive assessment, different treatment options were discussed with the patient and parents. Orthognathic surgery was suggested due to the severity of the skeletal Class III malocclusion. Mandibular first premolar extractions were also suggested as an alternative camouflage treatment. Both of these options were declined by the patient and parents. However, toward the end of treatment, the dentist extracted the third molars due to their inclination and the possibility of damage to the second molars. Based on patient preference, orthodontic and orthopedic treatment without surgery and premolar extractions was selected with the understanding of the limitations posed by the severity of the skeletal malocclusion. Also, the patient agreed to a lingual frenectomy to improve the tongue position.

Mechanotherapy Plan

The maxillary transverse and sagittal deficiencies were addressed by maxillary expander and facemask. A mandibular posterior bite plate was used to control the eruption of posterior teeth during the application of orthopedic forces to the maxillary arch. The open bite was addressed with a combination of sectional setup and intrusion of the mandibular posterior teeth using a one-couple system and extrusion of anterior teeth using anterior v-bend in a free object design. These steps were followed with full maxillary and mandibular fixed appliances setups. After achieving CIass I canine and molar relationships, the maxillary laterals were bonded to address the Bolton Discrepancy. After treatment, fixed lingual retainers were applied from canine to canine on the maxillary and mandibular arches, and a customized retainer with posterior coverage was designed to prevent further extrusion of posterior teeth. Even though the patient demonstrated no further mouth breathing habits, he was referred for further myofunctional therapy to change the position of the tongue and also improve speech.

Duration of Treatment

The total treatment duration was 30 months, including a 4 months interruption during confinement during the Covid-19 Pandemic in 2020.

Treatment Outcome

I. Facial and Soft Tissue analysis

The overall facial balance was improved and the lower facial height was decreased. Profile analysis showed 1.4 mm improvement in the distance of the maxillary lip relative to the E-line (Figure 5). The chin-throat length improved 11.2 mm, while the chin-throat angle improved 12.6°. Along with these changes, the nasolabial angle and labiomental angle improved 3° and 2°, respectively.

II. Smile analysis

The patient showed a wider maxilla and reduced buccal corridor width upon smile. The correction of the incisal display also contributed to the significant improvement of the smile esthetics. The mandibular midline coincided with the maxillary and facial midline. Gingival display evaluation showed leveling of the gingival margins and the height of contour around the anterior teeth (Figure 5).

Figure 5: Post-treatment portrait and intra-oral photographs. *Post-treatment photographs demonstrate improved facial profile, maxillary lip position, smile esthetics, and correction of open bite. Intra-oral photographs show maxillary and mandibular arch development, aligned dentition in the maxillary and mandibular arches, normalized incisal inclination into an ideal overjet and overbite relation, and Class I molar and canine on both sides. Both maxillary and mandibular dental midlines are aligned with the facial midline. Gingival margins and heights of contour improved around the anterior teeth. Lingual fixed retainers are shown extending from canine to canine in both arches.*

III. Digital Cast Analysis and Intra-oral Photographs

Analysis of casts (Figure 6) and intra-oral photographs (Figure 5) at the end of treatment showed the following outcomes:

1) The maxillary and mandibular dentitions were expanded transversely with an increase in the maxillary inter-molar width of 2.2 mm and inter-canine width of 2.9 mm, while the mandible inter-molar width increased by 2 mm and the inter-canine width increased by 2.7 mm.

2) The crowding in the maxillary and mandibular dental arches was eliminated.

3) The open bite was corrected, and proper overjet (1.7 mm) and overbite (1.8 mm) were established. The reverse Curve of Spee on the maxillary dental arch was corrected.

4) Class I molar and canine relationships were achieved on both sides.

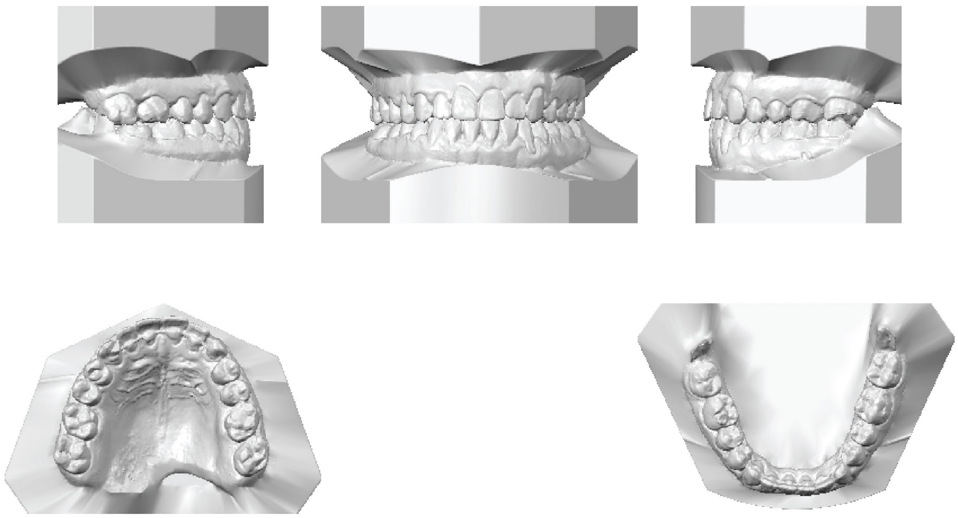

Figure 6: Post-treatment digital casts. *Post-treatment digital cast analysis showed Class I molar and canine relation on both sides and significant improvement in Class III relation on the right side. Maxillary and mandibular transverse dimensions were increased, dentition was aligned on both arches, coincident dental midlines, and an ideal overjet and overbite were established.*

IV. Panoramic Radiograph Analysis

Post-treatment panoramic radiograph (Figure 7) showed good root alignment. No flattening of the condyle was observed at the end of treatment.

Figure 7: Post-treatment panoramic radiograph. *Panoramic radiograph at the end of treatment showed good root alignment and no bone loss.*

IV. Cephalometric Analysis

Pre-treatment and post-treatment comparisons of skeletal and dental cephalometric parameters showed significant improvement in the sagittal skeletal relationship between the maxilla and the mandible. The ANB angle increased from -1.3° to 1.3°. The skeletal vertical dimension improved by autorotation of the mandible as shown by a change in FMA from 40.6° to 36.3°, and SN-MP from 44.5° to 40.9°. Dental analysis showed improvement in the maxillary incisal inclination from 116.4° to 110.9° (Figure 8 and 9).

V. Clinical exam

The patient demonstrated cuspid-rise and mutual protected occlusion with no additional bone loss or gingival recession. No pain or clicking was reported or observed in the TMJ. The patient-reported significant improvement in his nasal breathing but he was not sure about his mouth breathing habit during sleep. Retainers were designed taking into consideration that the patient may still keep his mouth open during sleep. Improvement in speech was observed, but the patient was referred to a speech and myofunctional therapist to maximize the improvement.

Figure 8: Post-treatment lateral cephalometric radiographs. *Post-treatment lateral cephalometric radiograph shows an overall improvement in the maxillary and mandibular relationship, improved mandibular plane angle, correction of the open bite into an ideal overjet and overbite, with improved maxillary incisor inclination.*

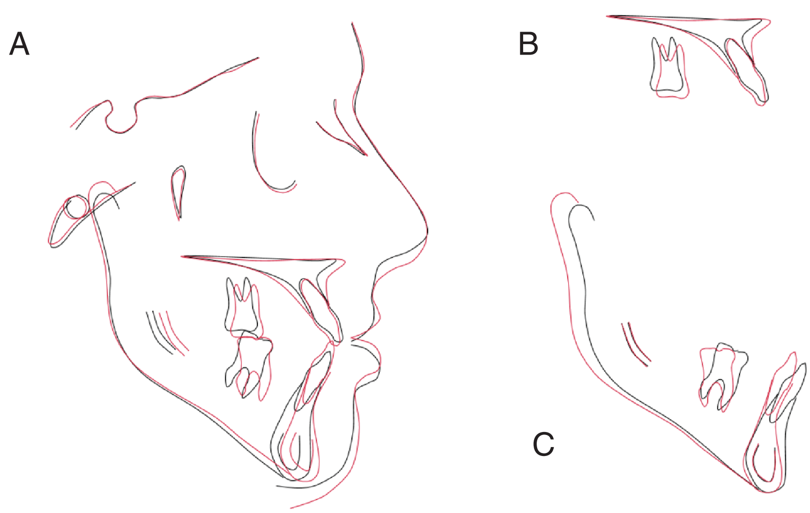

Figure 9: Superimposition of pre- and post-treatment cephalometric tracings. *(A) Cephalometric superimposition of pre-treatment (black tracing) and post-treatment (red tracing) on the anterior cranial base shows counter-clockwise rotation of the mandible by intrusion of the mandibular molars, Class I jaw relation, improved maxillary and mandibular incisor inclination, intrusion and palatal root movement of the maxillary and mandibular anterior teeth, and flattening of the occlusal plane. (B) Superimposition on the body of the maxilla shows maxillary molar extrusion and uprighting, with extrusion and improvement of the incisor inclination. (C) Superimposition based on the inferior alveolar nerve and inner profile of the mandibular symphysis reveals mandibular molar intrusion and uprighting with extrusion and improvement of mandibular incisor inclination.*

Discussion

Chronic upper airway obstruction not only can significantly contribute to systemic and local pathologies, it also has undesirable effects on the development of craniofacial structures. Compensation due to changes in the breathing pattern cause neuromuscular abnormalities in the oral and maxillofacial region, potentially altering facial development and growth. As a negative feedback loop, the craniofacial deformities are in turn associated with further muscular adaptation that makes the return to nasal breathing difficult even in the absence of the original pathology.

Based on a patient's original craniofacial skeletal pattern and the cause of the upper airway obstruction, we know that a mouth breather adapts differently and can develop a severe Class II or Class III growth pattern [31, 39-42]. However, while sagittal adaptation of skeletal form in response to mouth breathing may vary among patients, the vertical malformations are similar between both groups that develop Class II and Class III skeletal deformities.

In these mouth breathers, a continued open mouth posture is associated with extrusion of posterior teeth, which further rotates the mandible downward and backward, increasing the mandibular plane angle, and therefore increasing the lower facial height. In addition, opening the mouth tenses the buccinator muscles, which exerts lingual pressure on the maxillary posterior teeth. When combined with the loss of equalizing pressure from the tongue, which is positioned inferiorly in mouth breathers, the maxillary dental arch become quite narrow and a high-arched palate appears. The maxillary deformity can affect nasal development and it is common to see a narrow nasal cavity and narrow alar base in these patients [38, 43-47].

It should be emphasized that the type of muscular adaptation to mouth breathing can vary from patient to patient. In other words, patients with a similar cause of mouth breathing may demonstrate different neuromuscular adaptation due to different anatomical, systemic, and local variation. However, some general patterns can be observed. For example, the tongue adapts a more downward and backward position in patients with a Class II skeletal pattern and obstruction due to adenoid hypertrophy, which increases mandibular rotation downward and backward [44, 48, 49]. This rotation, can increase the overjet and exaggerate the skeletal Class II pattern. To improve breathing these patients position their head forward, which further changes muscular balance causing the mandible to adapt more backward position. In addition, some dental adaptations, such as extrusion of maxillary anterior teeth, may occur causing a gummy smile. Depending on the extent and duration of mouth breathing, a patient may demonstrate one or more of the above symptoms.

On the other hand, as we saw in this clinical case report, a mouth breather with a Class III skeletal pattern, or enlarged tonsils as the cause of obstruction, and ankyloglossia, may adopt a downward and forward position of the tongue, which can further stimulate mandibular growth due to the distraction effect on the mandibular condyle away from the fossa [39, 40, 50, 51]. In addition, the forward and downward position of the tongue may interfere with the eruption of anterior teeth, which further contributes to development of an open bite. Similar to the case reported here, the mandibular rotation downward and backward may camouflage the underlining skeletal Class III sagittal relation, which resurfaces during treatment when the vertical problem is addressed.

Correcting the maxillary transverse and sagittal problems in these patients is necessary to not only establish proper skeletal and dental relations between maxillary and mandibular jaws, but also to open the nasal passage sufficiently to re-establish nasal breathing [52-54]. However, further research in this area is required.

Another main target of treatment in this patient was the differential intrusion of posterior teeth and extrusion of anterior teeth. This can be achieved by placing an anterior v-bend on the anterior segment in the maxillary arch, and a one-couple system from the posterior main arch wire in the mandibular arch [55]. To maximize the movement of the target units, a sectional set up in the maxillary and mandibular arches is required. A continuous arch wire in this patient can restrict the movement and prolong treatment [55].

While sutures and condyles are targets of orthopedic treatment, cortical drift plays a significant role in improving the skeletal deformity at the alveolar bone level. Free object design and one-couple systems significantly stimulate this important biological phenomenon.

Temporary anchorage devices (TADs) can be used to address many aspects of vertical problems associated with mouth breathing. However, certain characteristics of TADs do not make them the best tool for this patient. First, while they are very useful for intruding posterior teeth, they are not the best choice for extruding anterior teeth. A one-couple system can address both problems simultaneously. Second, the younger the patient, the lesser their bone density, which may cause quick failure of the TADs. Finally, many parents have significant reservations about the insertion of multiple TADs and prefer minimal surgical intervention. However, for an adult patient that presents many mouth breathing-associated deformities, external plates incorporated into the one-couple system design can be very useful. External plates can decrease the probability of TAD failure, increase their versatility and minimize the number of TADs needed [56-59].

Retention in these patients is critically important. Due to orthopedic treatment, and gradual shrinkage of the adenoids and tonsils, these patients will gradually be able to breathe through their nose, which initially occurs during the day when the patient is conscious of their appearance. However, during sleep mouth breathers have the tendency to go back to the habit of mouth breathing, which can provide the opportunity for relapse if clinicians do not design retainers to prevent the extrusion of posterior teeth. Supportive treatment in these patients can be extremely useful. Myofunctional therapy combined with lingual frenectomy (if required) can help in breaking the habit of mouth breathing in the absence of any significant nasal passage obstruction [60, 61].

In conclusion, the correction of deformities caused by mouth breathing requires a multi-disciplinary approach where orthodontists work closely with pediatricians, allergists, and ENT specialists to address the etiology of mouth breathing, and speech therapists and myofunctional therapists to correct the muscular habits associated with mouth breathing. Correcting any malformation, whether surgically or orthopedically, without addressing the etiological factors and patterns of muscular function and jaw position that characterize the malocclusion will not be stable. In this regard, early diagnosis and intervention are significantly important to prevent worsening of the deformity and establishing the wrong muscular adaptation.

Applied Innovation

A one-couple system is an innovative way to apply unidirectional forces and maximize movement due to the lack of any restrictions on the Target Unit. The Target Unit should be set as a free-object and its movement can be predicted based on the relation between the force and the Target Unit's center of resistance (center of resistance of one tooth or a section of teeth). Applying this simple mechanics plan, especially in young patients with low bone density, may reduce the need for TADs. In these patients, a one-couple system significantly stimulates alveolar bone cortical drift and contributes to the efficient correction of the malocclusion synergistically with the orthopedic treatment that targets suture and condyles.

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