Dental changes evaluated with a 3D computer-assisted model analysis after long-term tongue retaining device wear in ....

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CASE REPORT

Dental changes evaluated with a 3D computer-assisted model analysis after long-term tongue retaining device wear in OSA patients

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Abstract Oral appliances (OAs) have been used to treat obstructive sleep apnea (OSA) patients for decades. However, detailed dental side effects in long-term OA cases analyzed with an accurate three-dimensional (3D) measurement tool have seldom been reported. The purpose of this study is to evaluate dental side effects in five OSA patients, who had used a tongue retaining device (TRD) (with occasional other OA wear) for an average of 6 years and 4 months. The baseline and follow-up orthodontic study models were measured with a newly developed MicroScribe-3DX analysis system. High compliance of TRD wear was confirmed in all cases and different patterns and amounts of dental changes were observed. The most common appliance-induced dental changes included anterior and/or unilateral posterior open-bites and reduced anterior overjets. It was hypothesized that there might be two possible mechanisms for the TRD side effects—one is the forward pressure of the tongue upon the anterior dental arch and the other is the lateral pressure of the tongue upon the posterior arch. Considerations to correct the TRD dental side effects should be guided by these different mechanisms of the tongue on the dental arch. Possible solutions to minimize occlusal changes and maximize the benefits for OSA patients are also discussed.

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Introduction

Oral appliances (OAs) have been established as an alternative and effective treatment option for obstructive sleep apnea (OSA) patients [1, 2]. OAs work nonsurgically to open the airway during sleep by realigning the tongue and lower jaw in relation to the head. They can reduce snoring and/or obstructive apnea events during sleep but may increase the possibility of occlusal changes in long-term subjects.

Over 100 designs of OAs have been marketed for dentists to treat OSA. Each of the OAs falls basically into one of two main categories and the diverse variety is simply a variation of a few major themes: the tongue retaining device (TRD) and mandibular repositioning appliance (MRA). The TRD functions by directly holding the tongue in a forward position and securing it with negative pressure in a soft plastic bulb [1]. When the tongue is in an anterior position, the back of the tongue does not collapse and obstruct the airway during sleep. The first patient-series of TRD therapy in OSA management was reported in 1982 [3] and since then it has been demonstrated to reduce the number of upper-airway obstructions in OSA patients. Several studies have examined the initial effect of the TRD on respiratory parameters [4, 5]. Now the TRD is often recommended if there are dental reasons which preclude the construction of a MRA [6], especially for patients with large tongues [7], who have compromised dentitions, who do not tolerate MRAs or are edentulous. The MRAs are commonly used and there are numerous studies on MRA long-term (longer than 5 years) side effects [8–10] but very few were reported for TRDs. Detailed TRD three-dimensional (3D) dental effects have not been quantified.

In the present study, the occlusal alterations of five long-term OA cases were evaluated with a newly developed 3D dental study model analysis system [11]. Model analysis was the primary method for the case evaluation, with additional polysomnographic (PSG) and lateral cephalometric analysis for two of the five cases. The differences between baseline and follow-up study models were calculated and possible mechanisms of the TRD effects were discussed.

Material and methods

Two OA cases (cases 1 and 2) from the University of British Columbia (UBC) Sleep Apnea Dental Clinic and three (cases 3, 4, and 5) from the private clinic of the third author (A.M.S.) were evaluated. In all five cases, a TRD was the current and longest type of OA therapy, while other types have been used occasionally. The average OA treatment duration of the five cases was 6 years and 4 months. Baseline and follow-up PSG studies were completed at the UBC Hospital Respiratory Sleep Laboratory for the two UBC cases. All dental study models were taken at baseline and follow-up. The study models were measured with the UBC MicroScribe-3DX analysis system which consists of a computer (Pentium III with a 1,000 MHz processor and 256 MB of RAM), a mechanical digitizer (MicroScribe-3DX, Immersion Corporation, San Jose, CA, USA) and a graphics software (Rhinoceros NURBS modeling program, version 3.0 SR3c, Robert McNeel & Associates, Seattle, WA, USA). A total of 156 variables were measured as linear distances between points or from points to determined reference planes. The detailed principles have been described and a method error within 0.23 mm identified for this 3D system previously [11].

Definitions of main variables

a) Arch width

Intercanine arch width (AW) was measured by digitizing left and right canine cusp tips. Interpremolar arch width and intermolar arch width were measured by digitizing lingual cusp tips (premolars) or mesiolingual cusp tips (molars) from both sides.

b) Curve of Spee

The curve of Spee was measured as the perpendicular distance from the buccal cusp of each mandibular premolar and molar to the occlusal plane (OP). OP in this study was defined as an imaginary plane made by three points: the midpoint between the two central incisors and the distobuccal cusp tip of the most posterior molar on each side.

c) Overbite and overjet

A computer-aided curve for measuring overbite (OB) and overjet (OJ) of each tooth through the entire arch was formed in the Rhinoceros modeling program by digitizing the mandibular distobuccal, buccal groove, mesiobuccal cusp tips of molars, buccal cusp tips of premolars, labial aspects of canine cusps, and middle points on the labial aspects of incisor edges from one side to the other. This curve was named as the overlap reference curve (ORC) (Fig. 1).

Incisor OB was measured as the perpendicular distance between maxillary incisal middle points to the ORC. OB of canines or premolars was the perpendicular distance from maxillary labial or buccal cusp tips to the ORC. OB of molars was the perpendicular distance from maxillary mesiobuccal and distobuccal cusp tips to the ORC. The measurement of OJ was based on ORC and the same landmarks. The only difference for OJ was that the dimensions were measured as horizontal distances.

d) Anteroposterior (AP) relationship

The AP relationship of the upper and lower arch was based on the same ORC as OB and OJ. It was measured as the mesiodistal distance from the mesiobuccal cusp tips of the upper molars to the buccal groove of the lower counterparts, the buccal cusp tips of upper premolars to the buccal cusp tips of their lower counterparts, or the cusp tips of the upper canine to the cusp tips of the lower canine.

Lateral cephalograms were taken for the UBC cases, both at baseline and follow-up without the TRD appliance in place. Two-dimensional cephalometric analysis was also performed by the MicroScribe-3DX digitizer and measured with a digital program developed at UBC. All model digitization measurements as well as cephalometric tracings and digitization were performed by the first author (H.C.).

Case reports and measurement results

Case 1

A 31-year-old female presenting with chronic loud snoring, witnessed apneas, nocturnal awakenings and mild daytime sleepiness was referred to the UBC Sleep Apnea Dental Clinic for OA treatment. The baseline overnight PSG study

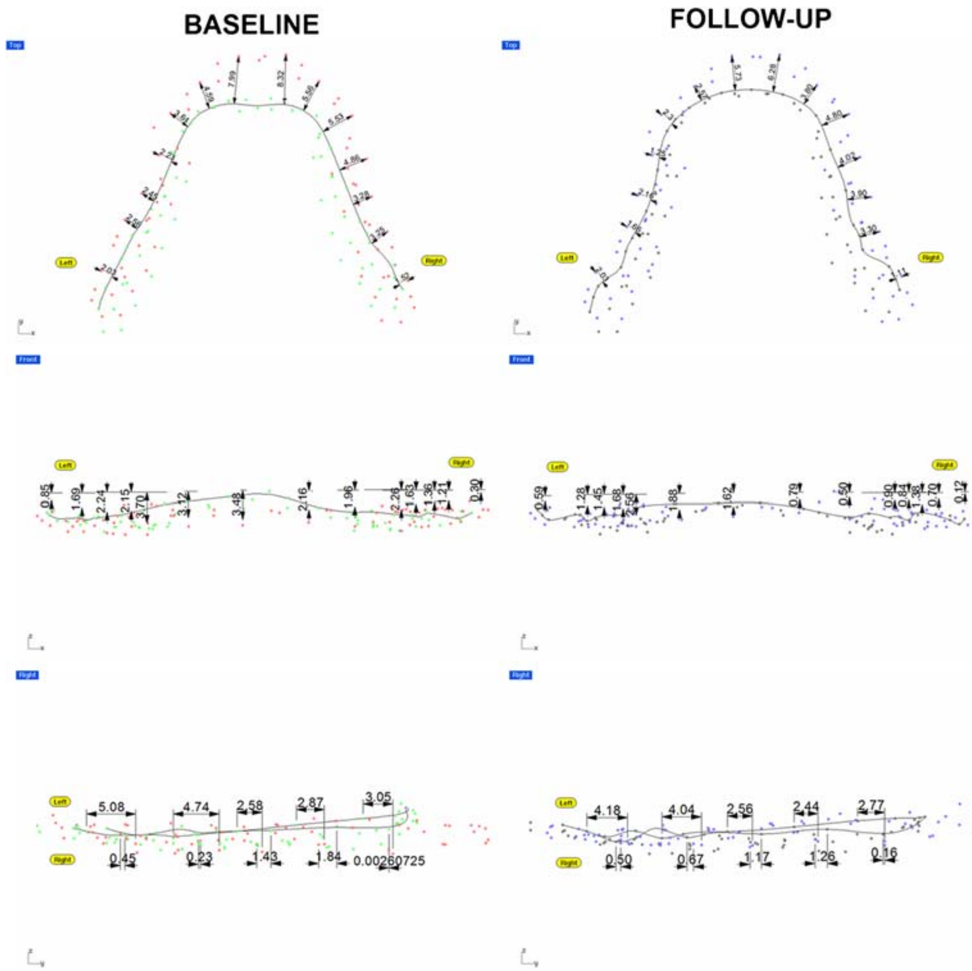

Fig. 1 Dental study model analysis by MicroScribe-3DX system for case 1. The *curve* indicates the overlap reference curve (ORC). *Left column* baseline; *right column* follow-up. Overjet—*top view*; overbite—*front view*; AP relationship—*right view*. *Red points* baseline maxillary landmarks; *green points* baseline mandibular landmarks; *blue points* follow-up maxillary landmarks; *black points* follow-up mandibular landmarks

reported a mild obstructive sleep apnea/hypopnea with associated arterial oxygen desaturation and sleep fragmentation. Her baseline intraoral occlusion was an Angle's class I relationship on the right side and a class II relationship on the left side with a 100% OB and 9 mm OJ in the central incisor region. There was a mild crowding in the lower anterior right arch which resulted in a lingual version of mandibular right central incisor (Fig. 2). The patient reported an improvement in OSA-related symptoms and subsided snoring was also reported by her bed partner right immediately after TRD insertion. The follow-up PSG study was performed with the TRD in place and demonstrated a significant OSA improvement: apnea/hypopnea index (AHI) decreased from 26.4 to 7.8 events per hour and the episodes of desaturation below 90% decreased from 180.0 to 3.0. Five months later, another follow-up PSG was performed with a similar outcome (AHI= 7.1; O_2-desats <90%=21). A summary of the case history is provided in Table 1.

The follow-up intraoral photos, models and lateral cephalograms were taken after 10 years and 1 month of TRD wear.

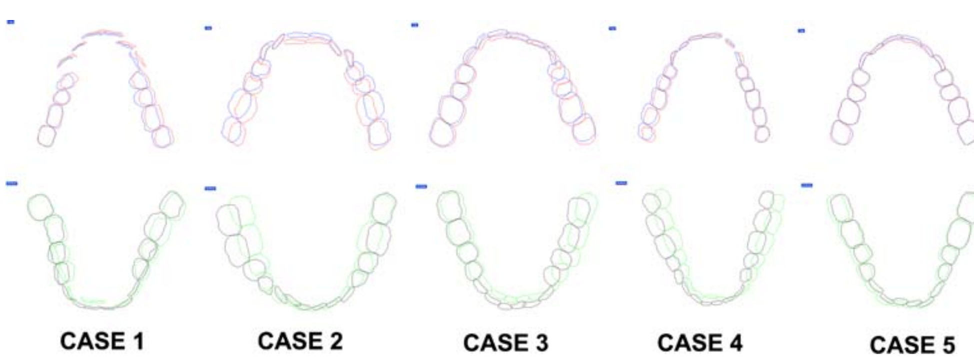

Fig. 2 Dental study models exhibition for case 1. *Upper* baseline; *lower* follow-up

Table 1 Summary of history for five cases

Term	Procedure	Snore score
Case 1		
Initial	PSG and study model and Ceph (baseline) TRD insertion	10/10
4 months	PSG (first follow-up)	0/10
9 months	PSG (second follow-up)	
3 years 6 months	New TRD insertion	1–6/10
10 years 1 month	Study model and Ceph (follow-up)	
Case 2		
Trial	Trail CPAP intolerant	
Initial	PSG and study model and Ceph (baseline) Klearway insertion	10/10
6 months	PSG (follow-up)	1–2/10
7 months	Posterior openbite	
8 months	No Klearway, 80% occlusion closed, continue Klearway Hawley retainer for daily use	
1 year 2 months	TRD insertion with Hawley retainer	0/10
2 years 2 months	Suggested UPPP by E.N.T.	1–6/10
2 years 10 months	Laser UPPP, stop TRD	3–4/10
3 years 2 months	Stopped TRD 4 months; occlusion back to almost normal	
3 years 5 months	Snorex insertion	
9 years 9 months	Study model and Ceph (follow-up)	
Case 3		
Trial	Trial TRD and MRA	NA
Initial	Custom MRA insertion	
2 weeks	TMJ pain	
3 months	MRA tolerant, titration began	
7 months	Bite changing, Switch to trial TRD with “bruxism” bite guard	
9 months	Custom TRD	
11 months	Maxillary central incisors became mobile from nocturnal bruxism	
1 year 11 months	Switch to TAP, Study model (baseline)	
3 years 8 months	Maxillary central incisors mobile again	
3 years 11 months	Back to TRD with “bruxism” bite guard; study model (follow-up)	
Case 4		
Trial	Study model (baseline), trial TRD and MRA	NA
Initial	Custom TRD insertion	
1 year 5 months	Posterior openbite; study model (first follow-up)	
1 year 6 months	Orthodontic treatment with nCPAP	
3 years 11 months	Orthodontic treatment finished; back to TRD with oral exercise; study model (second follow-up)	
Case 5		
Trial	Study model (baseline), trial TRD, and MRA	NA
Initial	MRA insertion	
7 months	Minor bite changes; transient TMJ pain experience	
11 months	Switch to TRD with retainers; oral exercises	
2 years 8 months	Study model (follow-up)	

The snore score was quantified by bed partners by referencing the original snoring sound as “10” and no snoring as “zero”.

Figure 1 provides a 3D representation of the OB, OJ and AP relationship with the MicroScribe-3DX system for baseline and follow-up models for this case. The first column of Fig. 3 shows the occlusal contour superimposition of maxillary and mandibular arch which was accomplished with the MicroScribe-3DX system. The crowding relieved in the lower anterior section with the incisors moved forward. The first column in Fig. 4 exhibits the AW, CS, OB, OJ, and AP changes between baseline and follow-up. The greatest AW changes were noticed in the inter-first molar for both maxilla and mandible. The depth of the CS on both sides became shallower: the more mesial the tooth position, the shallower became. The OB and OJ decreased in almost the entire arch. OB decreased more on anterior teeth than posterior teeth. The same tendency occurred in OJ, which decreased more towards the anterior teeth than posterior teeth.

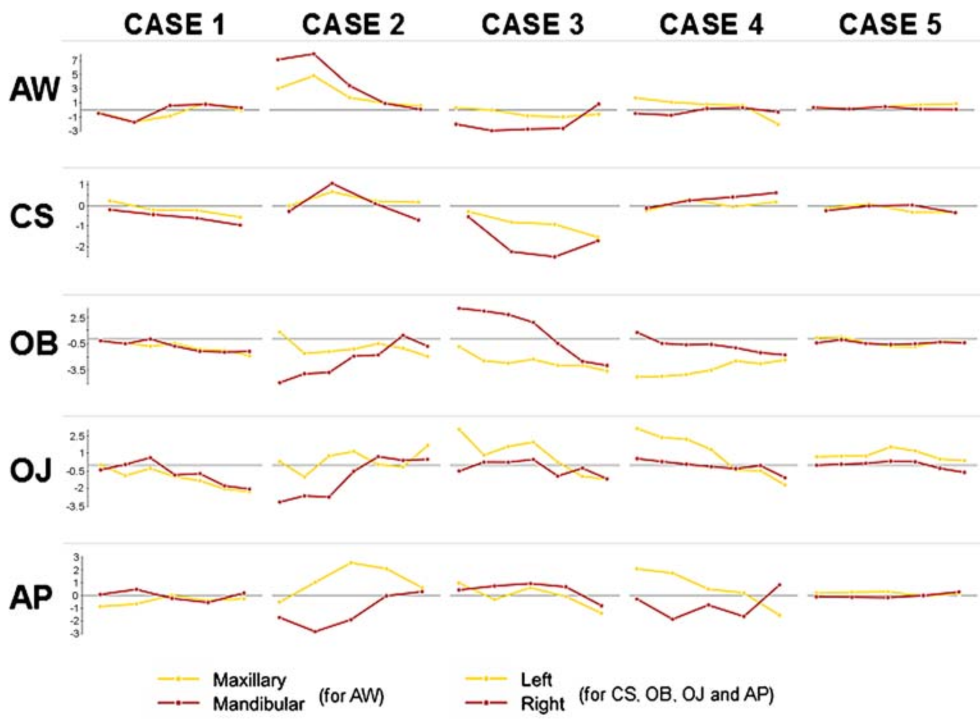

Fig. 3 *Upper row* tooth movements of mandibular model superimpositions (palatal rugae and occlusal contacts as reference points) for five cases. *Green* baseline; *black* follow-up. *Lower row* tooth movements of maxillary model superimposition (palatal rugae as reference points) for five cases. *Red* baseline; *blue* follow-up

Case 2

A 43-year-old female who was unable to tolerate nasal continuous positive airway pressure (CPAP), was referred to the UBC Sleep Apnea Dental Clinic after being diagnosed with a mild degree of obstructive sleep hypopnea with associated arterial oxygen desaturation and sleep fragmentation based on the baseline PSG study. She presented with a history of loud snoring, difficulty maintaining sleep, witnessed apneas, and daytime sleepiness. The baseline intraoral occlusion revealed a normal class I canine and molar relationship with a 50% OB and 2 mm OJ (Fig. 5). An MRA-type of OA (Klearway™) [12] was selected in the initial stage of treatment. The follow-up PSG study was done after 6 months and showed the AHI decreased from 33.3 to 5.8 events per hour and the episodes of desaturation below 90% decreased from 9.0 to 2.0. As a consequence of the posterior openbite related to an MRA use, the patient switched to a TRD 1 year and 2 months later. The TRD had subjectively improved OSA symptoms similar to the previous MRA. A summary of the case history is presented in Table 1.

After 9 years and 9 months of OA treatment, the follow-up intraoral photos, study models and lateral cephalograms were taken. The occlusal view of superimposed upper and lower arch changes is demonstrated in the second column of Fig. 3. It shows a major expansion of the posterior section, with the right side of the mandibular expanded the most. The second column of Fig. 4 illustrates the 3D changes for case 2. The follow-up AW of both arches was wider than at baseline: the more posterior, the greater the AW change.

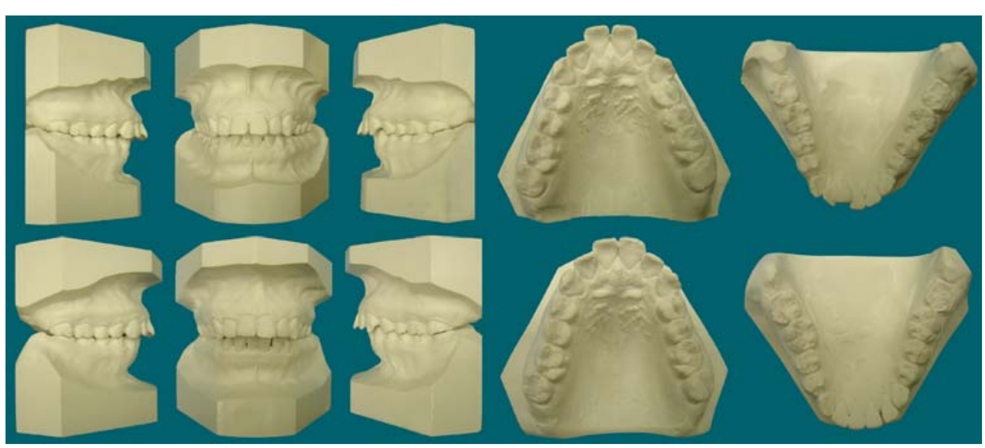

Fig. 4 Occlusal changes (in millimeters) for five cases. *Negative values* indicate decreased variables while *positive values* indicate increased variables. *Dots* represent tooth positions of second molar, first molar, second premolar, first premolar, canine, lateral, and central incisor from left to right. *AW* arch width; *CS* curve of Spee; *OB* overbite; *OJ* overjet; *AP* anteroposterior relationship

Fig. 5 Dental study models exhibition for case 2. *Upper* baseline; *lower* follow-up

There was an openbite of in the posterior right arch, which was more obvious than in the left and the anterior area. The posterior OJ decreased to a crossbite, predominantly on the right side but increased on the left side premolar and anterior areas. The left side mandible moved forward relative to the maxilla, while the right side mandible moved backward relative to the maxilla. These movements were related to a right shift of the mandible resulting in a right shift of the lower midline.

Case 3

A 62-year-old female diagnosed with moderate OSA associated with loud snoring, excessive daytime sleepiness, and increasing forgetfulness was referred for OA therapy. An anterior tongue thrust habit and a history of clenching and bruxism were present before OA treatment. An MRA was indicated as the first choice for OA therapy. After initial temporomandibular joint (TMJ) discomfort, the patient was able to use the appliance for 4 months. However, the MRA did not improve her sleep symptoms significantly and therefore a TRD was prescribed 3 months later. Another 1 year and 2 months later, the patient requested a Thornton Adjustable Positioner (TAP) and it was at this moment that the baseline models were taken. Slight posterior openbite of both sides was observed. The patient had to switch back to the TRD because of the mobility of the maxillary central incisors after 2 months. The follow-up study models were taken after 3 years and 11 months of OA treatment when the left posterior openbite was more noticeable with an edge-to-edge incisor relationship (Fig. 6). A summary of the case history is demonstrated in Table 1.

Larger changes in the left side of the dental arch can be viewed in the third column of Fig. 4. The occlusal changes with contributions from both TRD and TAP are shown in the third column of Fig. 4. The mandibular AW narrowed greater than the maxillary AW. The CS flattened on both right and left sides. There was a decrease in the anterior and posterior left OB while the posterior right OB increased. Posterior OJ changed on both sides, with the greatest change in tooth #27. The anterior OJ decreased. The AP relationship changed a little on both sides and there was no midline shift.

Case 4

A 55-year-old male with a 10 year history of loud snoring was referred for OA therapy by his family physician. The

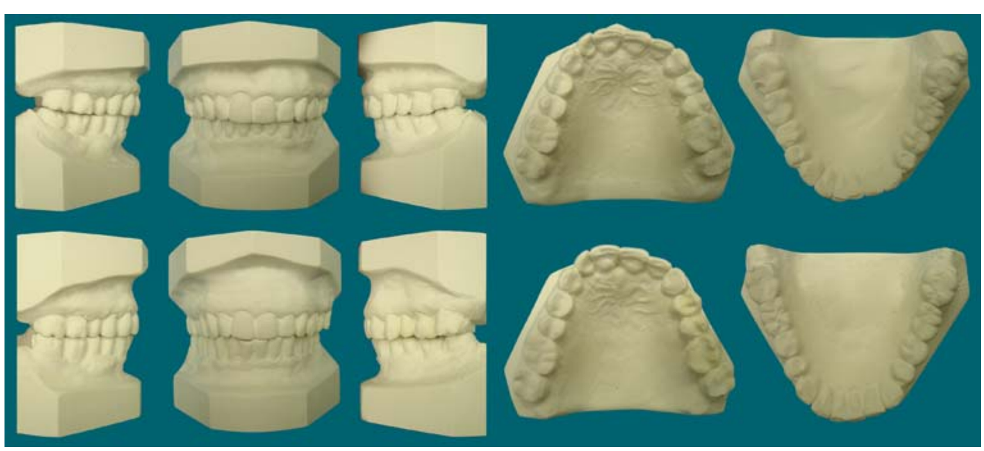

Fig. 6 Dental study models exhibition for case 3. *Upper* baseline; *lower* follow-up

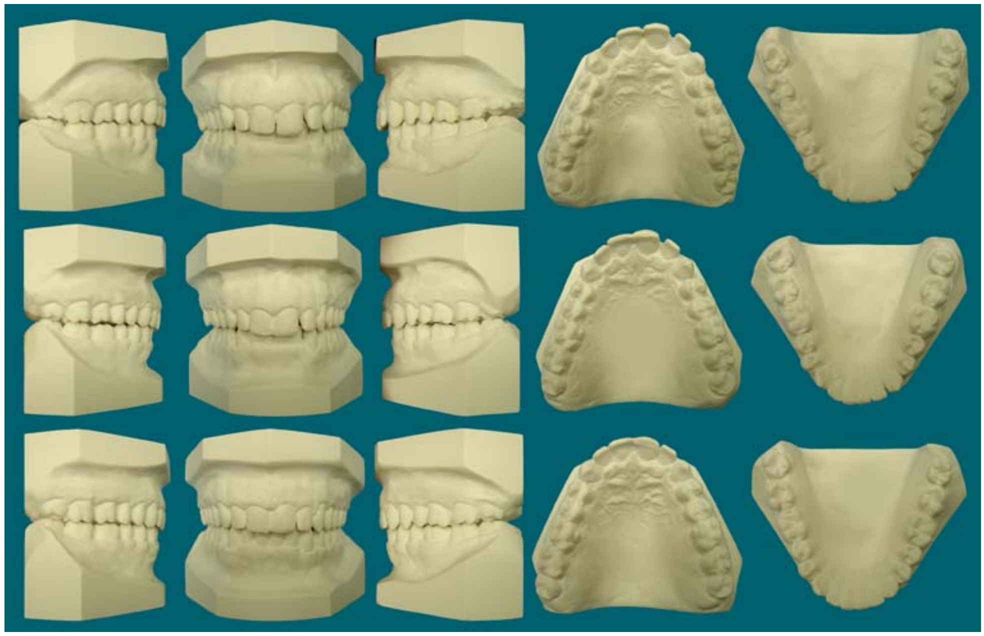

Fig. 7 Dental study models exhibition for case 4. *Upper* baseline; *middle* follow-up; *lower* after orthodontic treatment

baseline study model revealed a class I relationship with 80% OB and 4 mm OJ in the central incisor region. A custom TRD with an extra large length and medium width tongue bulb was inserted and complete elimination of snoring was reported. The patient slept 7.5 h per night with the TRD in place and felt refreshed in the mornings. One year and 5 months after insertion, a significant openbite was observed and the follow-up study models were taken (Fig. 7). A summary of the case history is provided in Table 1.

With the aid of the MicroScribe-3DX system, the 3D occlusal changes were measured and are illustrated in the fourth column of both Figs. 2 and 4. On Fig. 2, the significant right shift of the mandible can be visually viewed which caused the severe left side posterior openbite. The maxillary AWs expanded in the premolar and molar regions whereas the intercanine decreased. The left side OB decreased from the anterior area to the posterior area, resulting in a posterior openbite relationship. The posterior OJ of the left side increased. The right side OB and OJ showed minor changes compared to the left side. The OJ of the central incisors decreased, which was greater than the lateral incisors and canines. On the right side, the mandibular posterior teeth tipped mesially while the left side moved distally relatively to the maxilla.

Case 5

A 40-year-old male with a moderate OSA diagnosis was referred for OA treatment after uvulopalatopharyngoplasty, turbinate resection, and CPAP intervention failed. A history of mild to severe TMJ/muscle pain 2 to 5 years before OA therapy was collected during examination. He had been wearing a bite guard during sleep for approximately 3 years. His baseline occlusion revealed a class I canine and molar relationship with a 40% OB and 1–2 mm OJ of the central incisors (Fig. 8). An MRA was inserted and titrated based on the improvement of sleep apnea symptoms. After 7 months

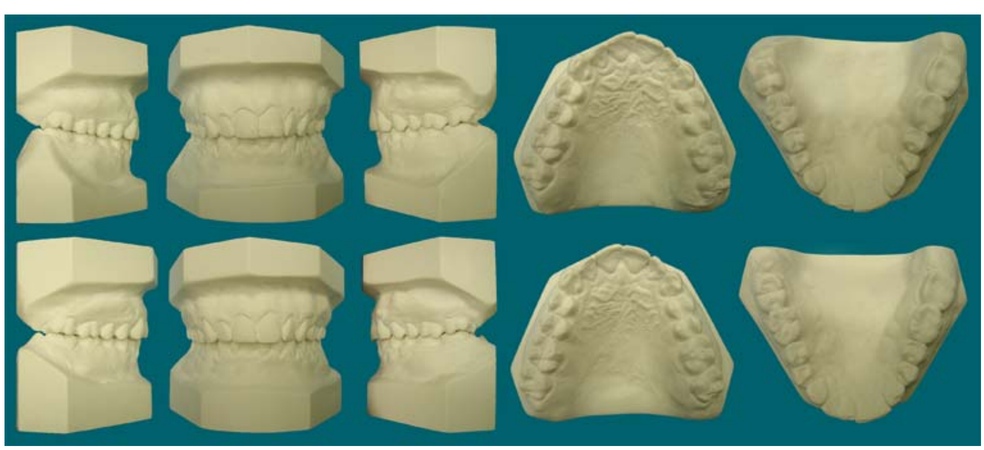

Fig. 8 Dental study models exhibition for case 5. *Upper* baseline; *lower* follow-up

of MRA wear, minor bite changes were noted and the patient was instructed to do some jaw exercises. Despite clenching and stretching exercises accomplished throughout the day, further TMJ pain was experienced. After 2 months without treatment, a medium bulb size TRD was inserted to use over retainers. The follow-up study models were taken 2 years and 8 months after OA use. A summary of the case history is provided in Table 1.

The occlusal changes registered with the MicroScribe-3DX analysis (the fifth column of Fig. 4) shows that the greatest decrease of OB occurred in the left premolars and canines. The most significant OJ increase was also seen on the left premolars and canines. The maxillary AWs of premolars and canines increased the most while the mandibular AWs of premolars and canines showed the smallest changes. The CS, OB, and AP relationship showed minor changes. Clinically, the occlusion demonstrated a slight buccal movement of left maxillary premolars and canines while the molar relationship of both sides remained stable.

Discussion

This is the first study to precisely measure and assess dental side-effects with a 3D study model analysis tool after long term TRD use. The five cases demonstrated that TRDs have different effects on individual dental arches though four of the cases were not restricted to solely TRD usage. Tooth displacements had also been affected by relatively short-term MRA usage. With close dental supervision, acceptable compliance in all cases was confirmed in spite of the dental side effects.

Case section was rather heterogeneous based on the treatment length and various OA use, so the five cases were not readily comparable with statistical analysis. Generally speaking, cases 2, 3, and 4 showed more obvious changes when compared to cases 1 and 5 (Fig. 4).

Cases 1 and 2 were the longest term patients who had been using OA for as long as 9 to 10 years. TRD was the only appliance that case 1 had ever used. She was class II division 1 at baseline (age 31 years) and showed a beneficial effect on crowding and OB/OJ after 10 years of wearing. Case 2 was class I with a shallow OB/OJ at baseline and showed unfavorable dental changes during OA treatment. The dental side effects in cases 3 and 4 were also related to more than one type of OA. They also showed unilateral posterior openbites while the bite on the other side somehow deepened or only mildly decreased which might relate to imbalanced tongue pressure on each side.

TRD and MRA appliances have relatively different mechanisms to improve the airway caliber and respiratory capacity. The TRD maintains lingual protrusion with suction derived from a plastic bulb that is held between the lips and teeth [4]. Tongue protrusion increases the oropharyngeal, velopharyngeal, and hypopharyngeal cross-sectional areas of the upper airway, thereby improving airway patency and function [13]. An MRA, on the other hand, holds the mandible forward in order to open the posterior airway. The capability to increase pharyngeal width at all analyzed levels occurs in both the upright and supine positions [14, 15]. Most of the MRAs have full coverage acrylic to hold the entire arch and transmit forces on the mandible [16].

The different mechanisms differentiate the side effects that TRD and MRA could deliver to the dentition. Both Marklund [8] and Almeida et al. [9] suggested the orthodontic changes might be predictable from the type of device. The presence of side effects related to MRAs has been statistically analyzed [8, 9, 17] based on large group of cases in recent years. As for the TRD, because the tongue is a powerful muscle and has the capability to adapt to the oral size and environment, it would be reasonable to assume that the dental side effects of the TRD are mainly determined by altered tongue pressure, which potentially results in dynamic arch expansion. Takahashi et al. [18] reported that masticatory muscle activity was affected by tongue position by instructing 10 skeletal class I adults to specific tongue positions: rest, superior, and anterior. From the performances of the five subjects in this study, we further hypothesized that the tongue moved in two main directions (forward and laterally) while using a TRD. This hypothesis needs to be evaluated in a well-controlled electromyographic study. We also suspected that the size, position, and suction of the tongue in the bulb could be related to the type and amount of side effects. Custom-made TRDs appear to be preferable when compared to prefabricated ones in term of better suction. An unsuitable bulb could produce less effective and unexpected dental side effects [9, 15, 17, 19–21].

Recently, MRA has merged into a major and first-choice of OA modality for patients. Unfortunately however, case 2 in this study had to stop the initial MRA use after 8 months because of the significant posterior openbite although the follow-up PSG showed a satisfied improvement. The patient switched to the TRD and continued using it for the next 8 years with an acceptable sleep improvement as well. Case 3 was considered as an intractable case because of the complications of TMJ and the bruxism problems. Case 5 exhibited another TMJ disorder with the shortest duration of OA use and consequently showed minor occlusal changes. The patient consequently used three types of OAs: MRA, TRD, TAP, and then had to go back to TRD. These three cases reminded us that not all patients can comply with a specific OA option. Dentists need to be aware that alternative modalities could be helpful for an individual case. The low correlation between the duration of treatment and the amount of side effects emphasizes how different the cases can be. The early awareness of the bite problems and the use of oral exercises are highly recommended.

A number of studies have demonstrated that OAs are well tolerated in spite of the occlusal side effects [16, 22]. All five cases in the present study also showed an acceptable compliance with long-term OA use. Even after the dental side effects were affirmed, all the patients preferred to try another OA rather than switch to CPAP therapy. Although it has been concluded that subjective benefits experienced from OA therapy outweighed these minor inconveniences by far and did not lead to discontinuation of treatment [16], it is desirable to reduce the occlusal side effects. Hoffstein stated that compliance with oral appliances depended strictly on the balance between the perception of benefit and side effects [6]. The reasons for the high compliance of long-term OA use are numerous. Patient convenience is important and another one is sleep improvements. Sleep improvements can be confirmed by PSG study, decrease in daytime sleepiness, and quality of life assessments. Because snoring is one of the common symptoms for most of patients, the reduced snoring frequency and decibel levels during sleep that can be ascertained from the bed partner is also considered as a major motive to encourage OSA patients to continue using the OA.

Currently, the underuse of OA is partly financial as well as the lack of qualified dentists who can utilize OA and effectively control the dental side effects [6]. With professional care of skilled dentists, the initial and follow-up oral examinations together with effective patient education could ensure the eventual success of OA treatment. We consider the first half year of OA usage as the most important stage to predict long-term compliance.

Conclusions

TRD and MRA prevent the collapse of the airway passages through different mechanisms, reflecting various dental side effects. In the present study, five typical cases were discussed exclusively on long term occlusal changes followed by different clinical managements. It was hypothesized that there might be two possible major mechanisms for the TRD induced side effects: one is the forward displacement of the tongue, which affects the anterior dental arch; and the second is the lateral pressure of the tongue affects the posterior arch. Careful clinical management is of considerable importance for the patients to manage occlusal changes effectively. The dental side effects caused by OA therapy were common, though they could lead to beneficial orthodontic changes in specific cases.

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