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Recurrence of the Anterior Open Bite After Orthognathic Surgery: 3D Analysis of Dental, Soft Tissue, Skeletal and Airway Changes in Unravelling the Aetiology of Relapse

Suttorp CM[1]*, Camardella LT[2], Desmedt DJS[3], Baan F[1], Maal TJJ[1] and Breuning KH[1]

[1]*Department of Orthodontics and Craniofacial Biology, Radboud University Medical Centre, Nijmegen, The Netherlands*
[2]*Department of Orthodontics, Federal Fluminense University Dental School, Brazil*
[3]*Department of Orthodontics, Private Practice in Diksmuide, Belgium*

Abstract

Several treatment approaches have been used to correct anterior open bites, but high relapse rates are reported. This report shows the orthognathic surgical correction of a severe anterior open bite of a 23 years old woman with a mouth breathing habit. Although the treatment outcome was regarded as successful, progressive recurrence of the anterior open bite was found during 2 years retention. Digital dental models, 3D facial scans and CBCT were superimposed to analyse the dental, soft tissue, skeletal and airway volume changes during treatment and 2 years retention in three dimensions (3D). The Ortho Gnathic Analyser software tool was used to analyse in detail the skeletal dimensional changes (translations and rotations) of the maxilla and mandible in 3D. Relapse of the upper arch expansion was found in the posterior region. The impaction, advancement and clockwise pitch of the maxilla by the Le Fort 1 osteotomy were very unstable. The mandibular advancement and counter-clockwise pitch by the BSSO showed significant relapse. During retention a counter-clockwise roll of the maxilla was noticed, and considered as an adaptation to the relapse. The upper airway volume was reduced and the improvement of the soft tissue profile appeared to be unstable. 3D superimpositions made it possible to relate the oropharyngeal airway volume changes to the stability of the corrections of the dentition, maxilla and mandible and soft tissues. The orthognathic surgical treatment had reduced the upper airway volume, which maintained the mouth breathing habit, suggesting that this was the major cause of the dental, soft tissue and skeletal relapse. It is mandatory to collecting more 3D data on stability of hard and soft tissue and airway volume changes in unravelling the aetiology of relapse after orthognathic surgical correction of anterior open bites.

Keywords: 3-Dimensional evaluation; Orthodontics; Orthognathic surgery; Relapse; Habit; Open bite

Introduction

An anterior open bite is diagnosed when there is a lack of vertical overlap of the incisors compromising speech, swallowing and mastication and facial aesthetics [1]. The aetiology of the anterior open bite is multi-factorial as both hereditary and environmental factors as: unfavourable growth patterns [1], enlarged lymphatic tissue [1], oral habits and mouth breathing [2], are included. Several treatment approaches have been performed to correct this malocclusion, but high relapse rates are reported [3] (Figure 1). This report shows the orthognathic surgical correction of a severe anterior open bite of a 23 years old woman with a mouth breathing habit. Although the treatment outcome was regarded as successful, progressive recurrence of the anterior open bite was found during 2 years retention. The mouth breathing habit had not been corrected into nose breathing at rest. The improvement of the soft tissue profile showed significant relapse during retention, and a counter-clockwise cant of the occlusal plane was noticed. In literature, relapse after orthognathic surgery is mainly measured on cephalograms, only containing data from the anatomy in the sagittal plane (translations and pitch rotation). A disadvantage is that no data are available from relapse in the frontal plane (translations and roll rotation) and the transverse plane, (translations and yaw rotation), and changes in the airway volume. To better understand the relapse it was decided to collect detailed information about the 3 dimensional (3D) changes of the hard and soft tissues and oropharyngeal airway volume. Digital dental models, 3D facial scans and CBCT were superimposed to analyse the dental, soft tissue, skeletal and airway volume changes during treatment and retention. By using the semi-automated Ortho Gnathic Analyser software tool [4,5], detailed information of the dimensional changes (translations, and pitch, roll and yaw rotations) of the maxilla and mandible in 3D were obtained. The methods used to perform the 3-D superimpositions will be described in this article. The purpose of this case report is to illustrate the advantage of 3-D analysis of hard and soft tissues and airway volumes in unravelling the aetiology of relapse after orthognathic surgical correction of anterior open bites.

Aetiology and Diagnosis

During childhood (between 12 and 14 years of age) the patient was treated at our department with full fixed appliances. Class II elastic traction was used to correct the discrepancy in the interact relationship, but elastic traction did not completely correct the anterior open bite (Table 1). Due to poor compliance and bad oral hygiene it was decided to finish the treatment prematurely, and the poor result was accepted by the patient. The written status, copies of extra and intraoral photographs (Figure 2) and the dental plaster models made at the start and finish of this orthodontic treatment were available. Nine years after the end of the orthodontic treatment, at the age of 23 years, the patient returned to the orthodontic department because of functional

***Corresponding author:** Suttorp CM, Department of Orthodontics and Craniofacial Biology, Radboud University Medical Centre, Nijmegen, The Netherlands, Tel: +31-24-3614005, E-mail: Maarten.Suttorp@radboudumc.nl

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complaints, such as difficulties with mastication due to the severe open bite and incompetent lip closure. She also mentioned some aesthetic complaints: an open mouth posture and in her opinion a "long face". During clinical evaluation the patient demonstrated an open mouth posture with a mouth breathing habit at rest, although there was no evident nose obstruction detected. A traditional set of photographs (Figure 3A), impressions, and a cone beam computed tomography (CBCT) scan and a 3D facial scan were made. The Class II jaw relation and Class II malocclusion corresponded with the tapered dental arch form in the maxilla. It can be speculated that a combination of the open mouth posture together with the mouth breathing habit resulted in an excessive vertical growth of the maxilla, Class II jaw relation, low tongue position, a narrow maxillary dental arch, a reversed curve of Spee in the mandibular dental arch and a severe anterior open bite.

Treatment objectives and alternative treatment plans

Treatment objectives for this patient were: closure of the severe anterior open bite and reduction of the overjet, modification of the tapered arch form in the maxilla, correction of the Class II cuspid occlusion, correction of the midline shift of the upper arch, correction of the reversed curve of Spee in the lower arch, achievement of a competent lip closure, reduction of the anterior lower face height, increase of the chin prominence, improvement of the profile and smile aesthetics, and correction of the mouth breathing habit into nose breathing at rest. In this case the anterior open bite could might have been closed by intrusion of the posterior teeth of the maxilla and mandible. It has been reported that effective orthodontic intrusion of the upper molars in adult patients can be obtained by using posterior bite-blocks [6], temporary anchorage devices such as zygoma anchors [7], palatal implants [8] or other temporary anchorage devices [9]. A disadvantage of this treatment option is that the narrow maxillary arch will not be corrected, and her long face and Class II profile will only slightly improve. Alternatively, the anterior open bite could have been corrected by a surgical approach [10]. By performing a maxillary anterior segmental osteotomy the anterior open bite could have been closed by downward rotation of the anterior segment [11]. Otherwise, this surgical approach would not improve the increased lower anterior face height and would not correct the lip incompetence. Because of the relapse of the anterior open bite and her aesthetic and functional complaints, an orthognathic surgical treatment plan was proposed. A

Figure 1: (A) Example of a high angle case with mandibular retrusion and anterior open bite treated at our department demonstrating relapse of the orthognathic surgical correction of a severe anterior open bite. (B) Extra and intraoral photographs before orthognathic surgical treatment after orthognathic surgical treatment (C) and 2 years after orthognathic surgical treatment.

Figure 2: (A) Extra and intraoral photographs before (**B**) and after orthodontic treatment.

Figure 3: (A) Extra and intraoral photographs before orthognathic surgical treatment (**B**), and 9 weeks before BIMAX surgery.

Surgically Assisted Rapid Maxillary Expansion (SARME) procedure was planned to widen the maxilla and to improve the dimensions of the nose cavity. Extraction of the second premolars in the mandible was indicated, creating space to correct the reversed curve of Spee and to increase the overjet, necessary for surgical advancement of the mandible. After removal of the Hyrax expander a transpalatal arch (TPA) would be placed in the maxillary arch to retain the expansion. Full fixed appliances in the maxillary and mandibular arch would be used to align the dentition, to close the extraction diastemas and correct the reversed curve of Spee. When both arches are corrected the 0.016" × 0.022" stainless steel wire should be cut between the cuspids and first premolars to evaluate the stability of the dental correction in the incisor region. In case of recurrence of the anterior open bite, an additional maxillary anterior segmental osteotomy should be performed to close the open bite. The long face and the anterior open bite would be corrected by a Le Fort I osteotomy impaction of the maxilla together with a clockwise pitch rotation. The overjet would be corrected by the Bilateral Sagittal Split Osteotomy (BSSO). Finally, a chin advancement osteotomy would be performed to improve the chin prominence. During the pre and post-surgical orthodontic treatment, the patient would be referred to a speech therapist to correct the open mouth posture and mouth breathing habit. Fixed retainers behind the maxillary and mandibular incisors and cuspids (C-C bars) should be placed to retain the tooth position after treatment. A removable clear retainer would be used at night to retain the maxillary arch width.

Treatment progress

A conventional Hyrax with bands on both first premolars and molars was placed one week before the SARME. The SARME procedure was performed under general anaesthesia as previously described [12]. The extractions of the second premolars in the mandible were performed directly after the SARME. Five days after SARME the patient was instructed to activate the device twice a day for 16 days, generating a daily expansion of 0,5 mm. The Hyrax expander was removed 4 months after SARME, and the TPA was placed between the upper first molars to retain the expansion. Pre-adjusted self-ligating brackets (0.018 × 0.025-in slot) with interactive clip (In-Ovation R, Dentsply Sirona, York, USA) were placed in the upper- and lower arch. Extraction diastemas were closed with elastic chains. Eventually, both wires (0.016" × 0.022" stainless steel) were cut between the cuspids and first premolars and the dental correction in the incisor region appeared to be stable during 10 weeks follow-up (Table 1 and Figure 3B). After 8 months *in situ*, and 4 weeks prior to BIMAX, the TPA was removed because of the interference with CBCT imaging. A 3D digital pre-surgical set-up was performed using Maxilim® software (Medicim

Figure 4: (A) Extra and intraoral photographs after orthognathic surgical treatment (**B**), and 2 years after orthognathic surgical treatment.

NV, Mechelen, Belgium) whereof the occlusal wafers were designed and 3D printed. The bi-maxillary surgical procedure (BIMAX); the Le Fort I osteotomy, Bilateral Sagittal Split osteotomy (BSSO) and chin osteotomy procedures were carried out under general anaesthesia, as described elsewhere [4]. The BSSO was performed according to Obwegeser-Dal Pont technique including the Hunsuck modification. The maxilla and the mandibular anterior segment were both positioned using the 3D printed acrylic occlusal wafers according to the virtual surgical planning. The bone segments were fixed with osteosynthesis plates. Two weeks after BIMAX surgery the patient was instructed to wear Class II elastics (¼ in, 3.5 oz). Despite the use of elastic traction relapse of the open bite correction occurred. At the control visit seven weeks after the BIMAX, the reopening of the anterior overbite was still present. It was decided to replace the sectioned wires by continuous stainless steel wires (0.016" × 0.022") in the upper arch to close the anterior open bite. After two months of elastic traction, the vertical position of the incisors was corrected, but relapse of the Class II occlusion had occurred. Inter-arch Class II correction springs (Forsus™ Fatigue Resistant Device, 3M Unitek, USA) were placed to correct the persisting Class II occlusion, and within 10 weeks a Class I cuspid and Class III molar occlusion was achieved. It was then decided to promptly finish the orthodontic treatment.

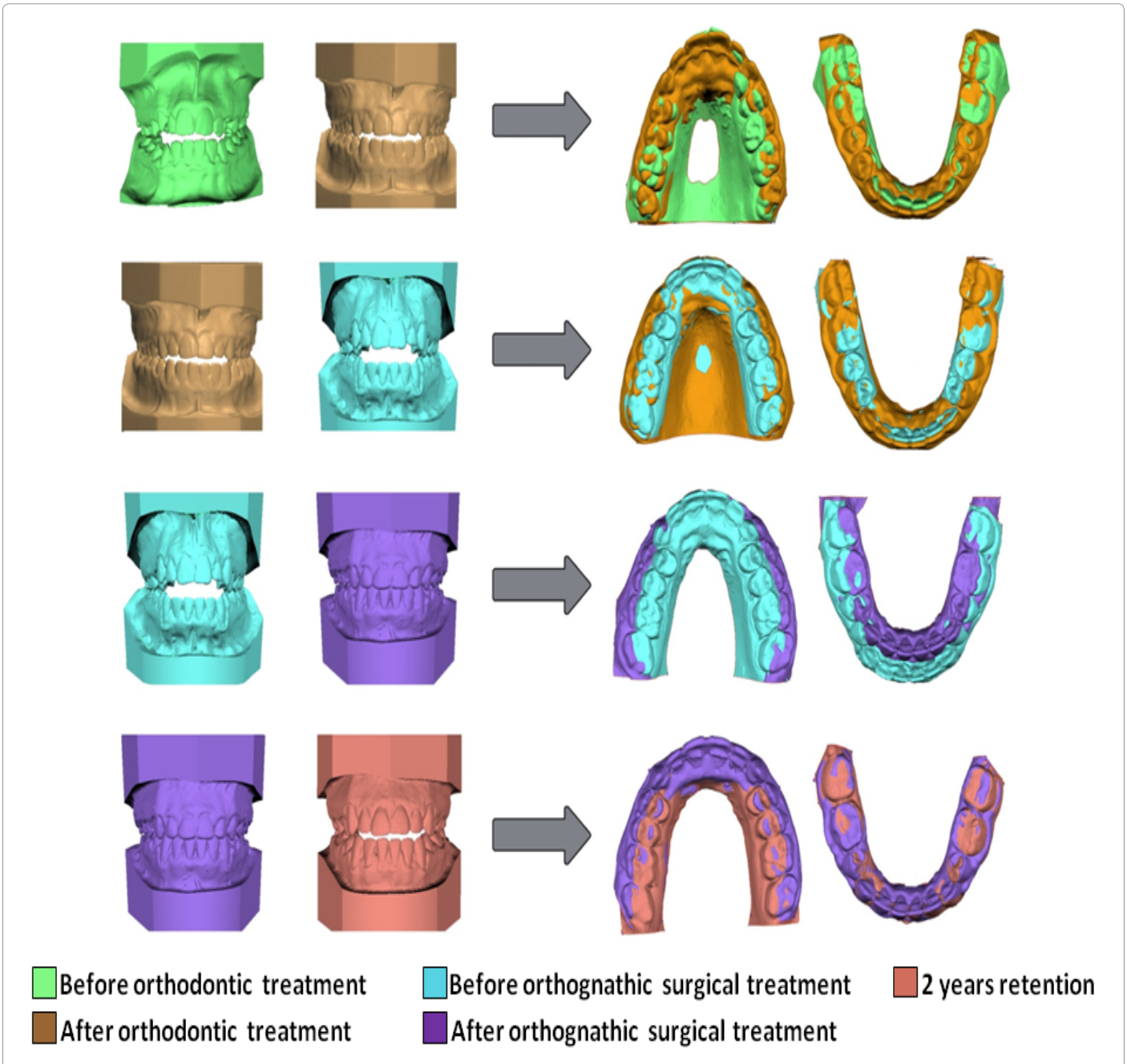

Figure 5: Dental changes visualized with superimpositions of digital dental models in 3D.

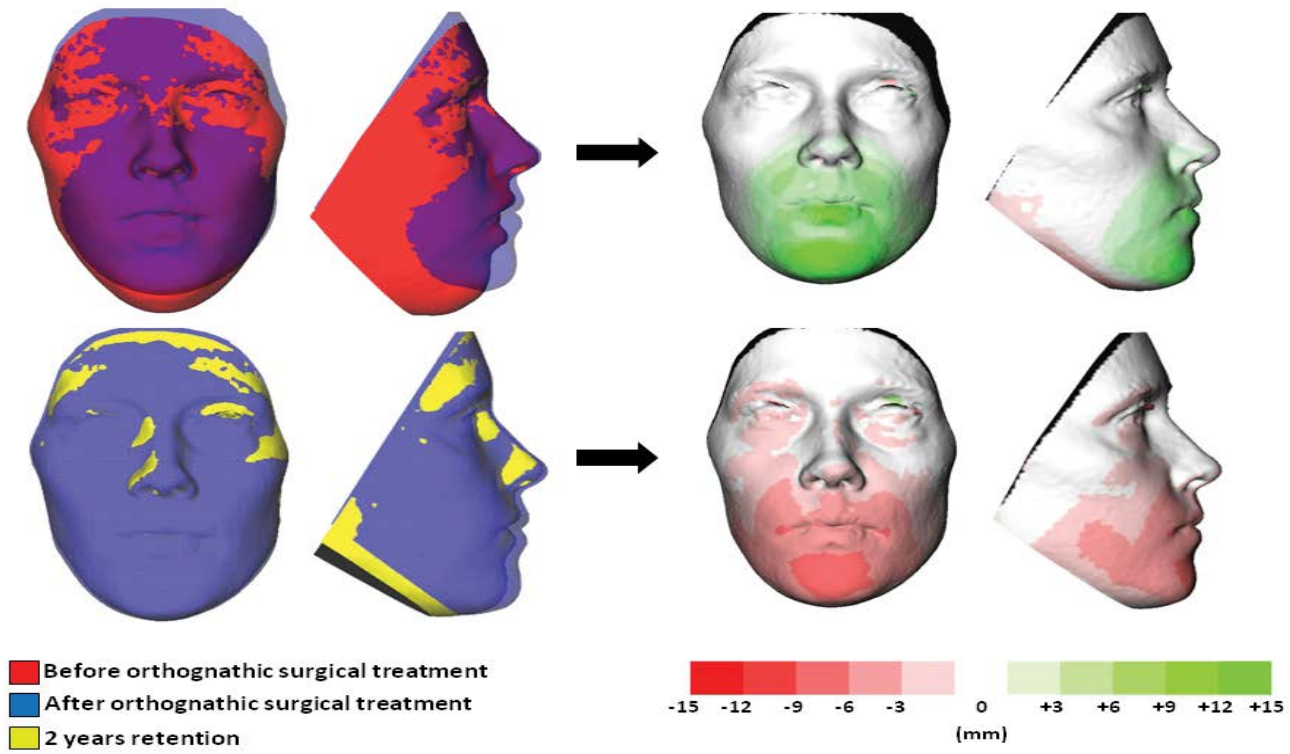

Figure 6: Facial soft tissue surface changes visualized with superimpositions of 3D facial scans.

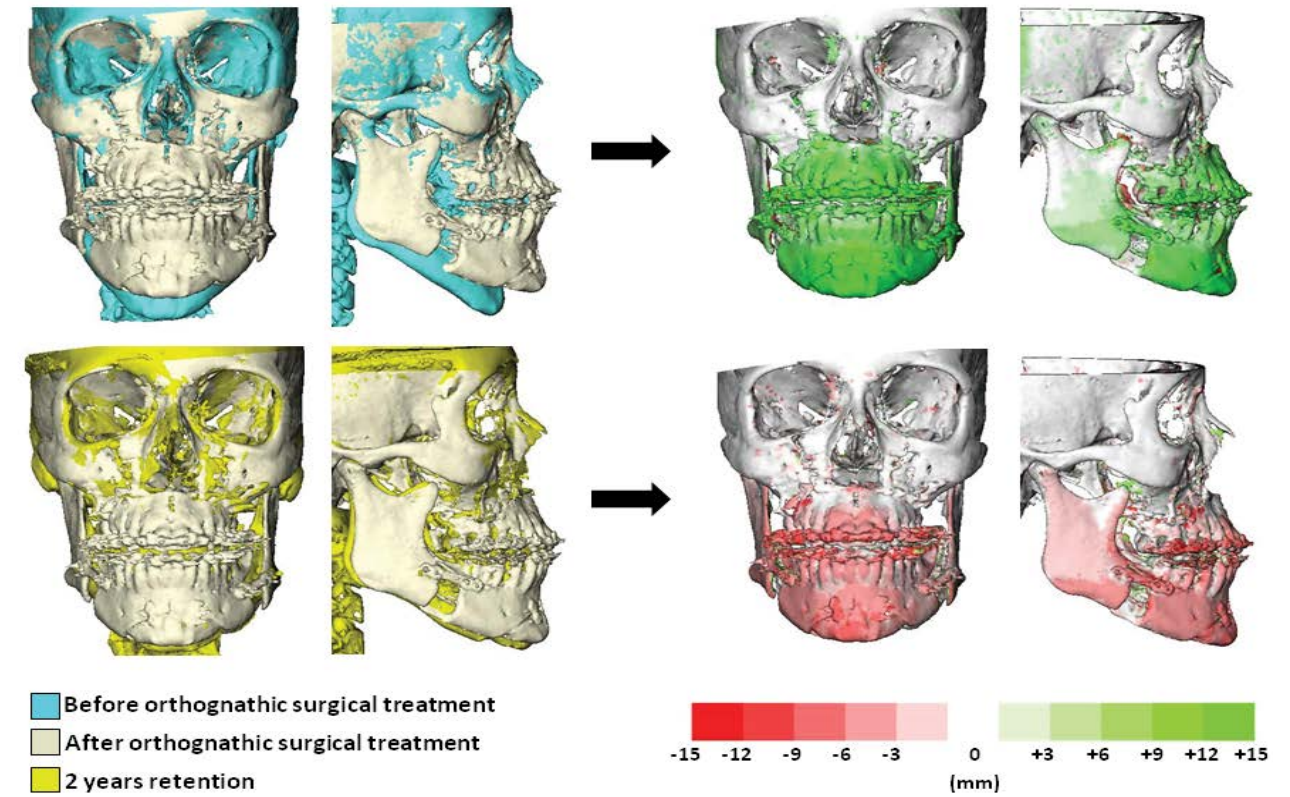

Figure 7: Skeletal changes visualized with superimpositions of the skull in 3D from CBCT images.

Treatment results

The C-C bars were placed and extra and intraoral photographs and dental impressions were taken direct after debonding (Figure 4A). The photographs "en face", at rest and during smiling show balanced facial dimensions, but an asymmetrical smile. The treatment outcome was regarded as very successful by both the practitioner and the patient. For retention of the upper arch width the patient was instructed to wear a removable clear retainer at night. Total treatment time for the orthognathic surgical treatment was 2 years and 1 month.

Case retention

After 6 weeks retention the occlusion appeared to be stable. However, 1 year after treatment an overjet of 4 mm was observed without vertical contact of the incisors. The patient was instructed to gradually reduce wearing the removable clear retainer. At the 2 years retention visit significant relapse of the anterior open bite was found, and a counter-clockwise cant of the occlusal plane was noticed (Figure 4B and Table 1).

Method of Relapse Analysis using 3-D Superimpositions

Obtaining more insight in the relapse of the anterior open bite correction we decided to quantify the dimensional changes of the different facial structures. Therefore, 3D digital dental models, 3D facial scans and CBCT scans collected during orthognathic treatment and 2 years retention were superimposed to analyse the changes of the hard and soft tissues of the face and the oropharyngeal airway volume in 3D. The dental plaster models (orthodontic treatment between 12 and 14 years of age) and the dental impressions (orthognathic surgical treatment and 2 years retention) were digitized with a CT scanner by the Orthoproof company (Nieuwegein, the Netherlands). The digital dental models were constructed from stereolitographic files (STL files) with Ortho Analyzer software (3-Shape, Copenhagen, Denmark). Superimpositions were performed with Geomagic Qualify software (3D Systems, Rock Hill, South Carolina, USA). For superimposition of the upper arch the volume around the palatal rugae was used as a stable reference structure [13]. Superimpositioning of the lower arch was less reliable due to the lack of accurate bony reference structures [14]. By default, the models of the lower arch were superimposed on the two second molars, because both were not bonded during this treatment (Figure 5). Facial soft tissue surface changes were visualized with superimpositions of 3D facial scans (Figure 6). A 3D stereo photogrammetric camera set-up (3dMD face™ System, 3dMD LLC, Atlanta, GA, USA) was used to make facial scans of the head. The facial scans were imported into Maxilim® software and resized to the region of

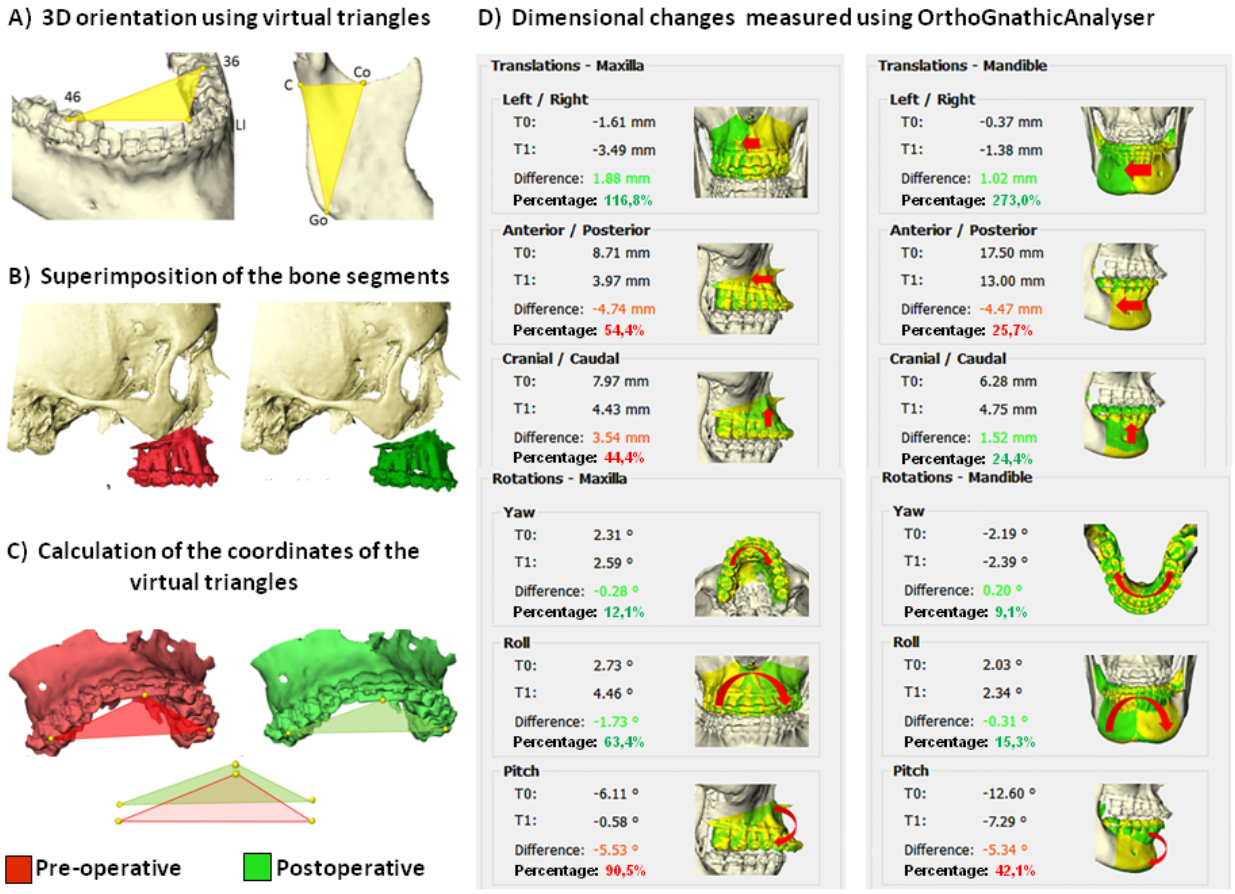

Figure 8: The illustrations explained the method of superimposing of individual maxillary and mandibular bone segments to quantify the dimensional changes in 3D by the BIMAX surgery (T0) and during 2 years retention (T1).

interest. A surface based matching procedure was performed by placing landmarks on the surface of the facial scans, as described elsewhere [15]. Virtual 3D models of the CBCT of the skull were reconstructed and the superimpositions were made with "Maxilim™" software, version 2.2.2.1 (Medicim NV, Mechelen, Belgium). The superimpositions of the 3D skull models were performed using voxel-based registration upon the anterior cranial base [16] (Figure 7). By using the semi-automated OrthoGnathicAnalyser software tool [4,5], detailed information about individual changes in the sagittal plane (translations and pitch rotation), frontal plane (translations and roll rotation) and the transverse plane (translations and yaw rotation), of the maxillary and mandibular segments were obtained by performing superimpositions in multiple steps (Figure 8), as described elsewhere [4]. Cephalometric landmarks were placed at the preoperative maxillary and mandibular bone segments and virtual triangles were constructed which contained information on the preoperative 3D position and orientation (Figure 8A). Pre and postoperative maxillary and mandibular segments were superimposed using the cranial base as a stable reference (Figure 8B). The virtual triangle of each segment was translated from the 3D preoperative position to the postoperative position (Figure 8C). The coordinates of the triangles were imported into OrthoGnathicAnalyser and information about the translations (anterior/posterior, left/right and up/down) as well as the rotations (pitch, roll and yaw) were obtained (Figure 8D). The changes of the individual maxillary and

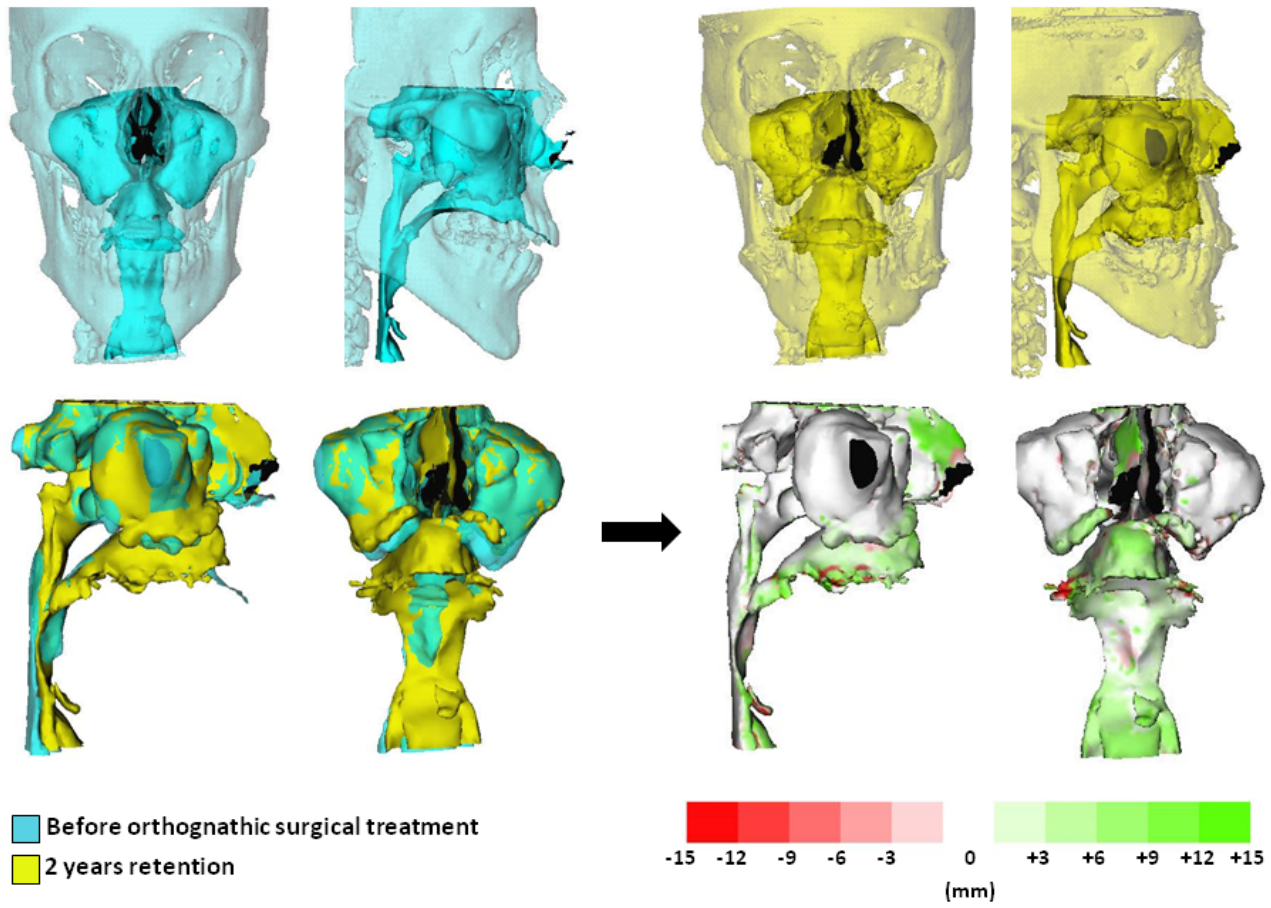

Figure 9: Airway volume changes visualized with superimpositions of CBCT images in 3D.

Stage	Age	Angle occlusion	Molar occlusion right	Molar occlusion left	Overjet	Overbite	Midline shift
Before orthodonic treatment	12	Class II/1	1/4 cusp disto	5/4 cusp disto	6 mm	-3 mm	Maxilla 3 mm to the right
After orthodonic treatment	14	Class II/1	1/4 cusp disto	5/4 cusp disto	7 mm	-4 mm	Maxilla 3 mm to the right
Before Orthognatic surgical treatment	23	Class II/1	1/4 cusp disto	5/4 cusp disto	6 mm	-5 mm	Maxilla 3 mm to the right
Before BIMAX Surgery	24	Class III subdivision right	1/4 cusp disto	neutro	13 mm	0 mm	Maxilla 2 mm to the right
After Orthognatic surgical treatment	25	Class III	1 cusp mesio	1 cusp mesio	2 mm	2 mm	Straight
2 Years retention	27	Class II/1	1/2 cusp disto	1/2 cusp disto	5 mm	-2 mm	Straight

Table 1: Dental characteristics per stage.

mandibular segments as the result of the BIMAX surgery (T0) and 2 years retention (T1) were compared, and the difference between T1 and T0 was calculated. Pharyngeal airway volumes before orthognathic surgical treatment and after 2 years retention were obtained from CBCT data and were visualized and superimposed in 3D. Virtual 3D models of the airway was reconstructed from the CBCT with "Maxilim® software. Superimposition of the airways with the same software was performed using voxel-based registration upon the anterior cranial base (Figure 9).

3-D Analysis Results

The superimposed digital dental models demonstrated significant relapse of the upper dental arch expansion in the posterior region (premolars and molars) after both the orthodontic treatment and orthognathic surgical treatment (Figure 5). Superimpositions of the facial scans demonstrated an increase of the anterior lower face height, a reduction of the prominence of the chin, the upper- and lower lip and the cheek region during 2 years retention (Figure 6). The superimposed 3D skull models demonstrated increase of the anterior lower face height, caudal displacement of the maxillary segment, dorsal displacement of the maxilla and anterior segment of the mandible, and recurrence of the anterior open bite (Figure 7). The OrthoGnathicAnalyser software measured dimensional changes in the opposite direction of the orthognathic surgical correction, which were considered as relapse (difference and percentage displayed in red colour). On the other hand, dimensional changes in the same direction of the orthognathic surgical correction were also found (difference and percentage in green) considered as an adaptation to the relapse (Figure 8D). For the maxilla high relapse rates of the clockwise pitch rotation (90.5%), impaction (44.4%) and advancement (54.4%) were measured. In the frontal plane counter-clockwise roll (63.4%), and in the transverse plane translation (1.88 mm) and yaw (12.1%) were found to be an adaptation. For the mandibular anterior segment relapse of the clockwise pitch (42.1%), and advancement (25.7%) were measured. In the frontal plane the counter-clockwise roll (15.3%), and in the transverse plane the translation (1.02 mm) and yaw (9.1%) were found to be an adaptation. Although the maxilla was expanded by the SARME the upper airway volume was found to be decreased due to the cranial displacement of the floor of the maxillary sinus by the Le Fort 1 osteotomy, even after 2 years retention. The lower pharyngeal airway volume was significantly increased by the orthognathic surgical treatment, and this was stable during 2 years retention (Figure 9).

Discussion

Several treatment approaches are able to correct severe anterior open bites, but high relapse rates are reported during retention [3]. Real success of anterior open bite corrections should thus be measured by its long term stability [17], as demonstrated by this case report. Besides the recurrence of the open bite the orthognathic treatment was also not successful in correcting the mouth breathing habit. For mouth breathers different cephalometric parameters were found, such as mandibular retrusion and posterior rotation, increased anterior face height, anterior open bite and increased maxillary and mandibular dentoalveolar height [18,19]. Notably, all these parameters were present in our case. The oropharyngeal airway appear to smaller subjects with a vertical growth pattern [20] and mandibular retrusion [21]. Moreover, on cephalograms, anteroposterior narrowing of the upper airways, mainly in the nasopharynx and oropharynx, was observed in anterior open bite cases [19]. Therefore, development of more understanding about the relation between the stability of the anterior open bite correction and airway function is mandatory. We need to discuss the individual steps of the orthognathic surgery performed in our case in relation to its influence on the airway volume and the stability of the dental, soft tissue and skeletal changes in the long term. Despite the overexpansion of the upper dental arch after SARME performed in our case, as recommended in literature [22], we found significant relapse in the posterior region after 2 years retention. It has previously been demonstrated that both orthodontic palatal expansion and SARME showed up to 30% decrease in transverse molar width after 3 years follow-up [22]. Orthodontic rapid palatal expansion is mainly performed in patients in the range from 7 to 15 years of age [23]. Even the use of a TPA after SARME does not improve stability in the long term [24]. However, in Class II patients with transverse discrepancies 60% relapse found of the surgical expansion by a 2-piece maxillary osteotomy [25]. Apparently, upper arch expansion by both orthodontics and surgery are prone to relapse in the long term. We presume that the relapse of the upper dental arch expansion affected the occlusion and contributed to the recurrence of the anterior open bite in our case. In literature, relapse was found to occur after both surgical and non-surgical closure of anterior open bites [3,26,27]. Vertical impaction of the maxilla by the Le Fort 1 osteotomy usually provides a stable result in cases with a maxillary facial height excess [28,29]. Otherwise, in anterior open bite cases reopening of the anterior bite after the Le Fort 1 osteotomy was found during long-term follow-up [10]. Long-term skeletal relapse seems even to be more common after bi-maxillary surgery, since relapse of 2-4 mm of the open bite in 7% of the Le Fort 1 osteotomy group and 12% in the BIMAX group was observed [30]. It is known that large surgical advancements (more than 6 to 7 mm) of the mandible are more prone to relapse, explained by the increased soft tissue and muscular tension [31,32]. It was found that especially in high angle cases more horizontal relapse occurred after mandibular lengthening, possibly as a result of the increased muscular tension to the proximal segment to the original inclination [33,34]. Relapse of the counter clockwise pitch rotation of the maxilla-mandibular complex was also found after bi-maxillary surgery [35]. The authors note that alternative orthognathic surgical treatments exists, such as a 3- piece maxillary osteotomy including an additional maxillary anterior segmental osteotomy. According to the literature, it can be supposed that in general vertical impaction of the maxilla and advancement of the mandible are both basically regarded as surgical corrections with a stable outcome, but especially in anterior open bite cases relapse can be expected. Our 3D superimposition of the airway demonstrated that lengthening of the mandible by the BSSO procedure increased the lower pharyngeal airway volume, which was also found by others [36]. On the contrary, the cranial impaction of the floor of the maxillary sinus, as a result of the Le Fort 1 osteotomy, reduced the vertical dimension of the upper airway. After treatment the mouth breathing was still present despite the speech therapy, Therefore, it is tempting to speculate that the upper airway volume reduction maintained at least the mouth breathing habit at rest, probably the major cause of relapse. Detailed information was obtained by analysis of the dimensional changes of the maxillary and mandibular segments using the OrthoGnathicAnalyser software tool [4,5] (Figure 8D). All dimensional changes in the opposite direction of the orthognathic surgical correction were considered as relapse according to its definition [37] the recurrence of the open bite was found to occur as the result of the counter-clockwise pitch and dorsal and caudal translation of the maxilla in the sagittal plane during 2 years retention. The counter-clockwise pitch and dorsal translation of the mandible also contributed to the relapse of the open bite correction. In addition, dimensional changes in the same direction

of the orthognathic surgical correction were also found, regarded as adaptations to the relapse. In the frontal plane the maxilla and mandible demonstrated counter-clockwise roll, and in the transverse plane translation and yaw was found. However, dimensional changes of the maxilla and mandible as the result of relapse and adaptation affected the occlusion and stability of the anterior open bite correction. In conclusion, 3D analysis made it possible to compare oropharyngeal airway changes to the dental, soft tissue and skeletal changes. The changes of the dentition, maxilla and mandible occurred in three dimensions and contributed to the recurrence of the anterior open bite. It should be realized that in most studies on relapse after orthognathic surgical anterior open bite corrections data are mainly obtained from cephalograms, only containing information from the anatomy in the sagittal plane. No data from the anatomical changes in the frontal and transverse plane are then available. Besides, it is not possible to measure the 3D upper airway volume changes on cephalograms. In high angle cases, and especially in anterior open bite cases small airway volumes were found, indicating that vertical impaction of the maxilla is absolutely unfavourable. Recently, a study was performed on the stability of surgical anterior open bite corrections using 3D designed drilling guides and pre-bent titanium plates. Successful closure of the anterior open bites was demonstrated but relapse was just measured 18 months after treatment and no measurements were performed on the oropharyngeal airway changes [38]. In search for more stable treatment outcome it might be reasonable to plan the orthognathic surgery from the upper airway ventilation perspective instead of aesthetics only. More knowledge on relapse might have implications on future diagnosis, treatment planning, treatment outcome and retention protocols for anterior open bite cases.

Conclusion

This report showed the recurrence of the anterior open bite after orthognathic surgery. Digital dental models, 3D facial scans and CBCT were superimposed to analyse the dental, soft tissue, skeletal and airway volume changes during treatment and retention in three dimensions (3D). The upper airway volume was found to be reduced by the orthognathic surgery, and the mouth breathing habit was not corrected. The 3D superimpositions showed that the combination of dimensional changes of the dentition, maxilla and mandible contributed to the recurrence of the anterior open bite. It is tempting to speculate that the upper airway volume reduction as the result of the orthognathic surgery affected the patient's airway ventilation, the major cause of relapse. Collecting more 3D data on stability of hard and soft tissues and airway volumes after orthognathic surgery is essential in unravelling the aetiology of relapse.

Declarations

Ethics approval and consent to participate

This case report was approved by the Committee on Human Research (CMO) of the Radboudumc, Nijmegen, Netherlands.

Consent for publication

Written informed consent was obtained from the patient for publication of this report and accompanying images.

Availability of data and supporting materials

The materials and results obtained in this study belong to the authors and are therefore available only upon request, after approval by the author.

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Not applicable.

Competing Interests

The authors declare that they have no competing interests.

Author's Contributions

CS: Performed the follow-up, analyzed and interpreted data, performed the superimpositions of the CBCT and drafted the manuscript. LC: Performed the superimpositions of the dental models. DD performed the orthodontic treatment and created the superimpositions of the facial scans. FB: Performed the superimpositions of the CBCT scans and designed the Ortho Gnathic Analyser software. TM: designed the Ortho Gnathic Analyser software. KB: Revised the manuscript. All authors read and approved the final manuscript.

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