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Class III Malocclusion treatment effect on Head Position and Pharyngeal Airway Space: A Systematic Review

Master’s Thesis

Kaunas, 2019

Supervisor
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Class III Malocclusion treatment effect on Head Position and Pharyngeal Airway Space: A Systematic Review

Master’s Thesis

The thesis was done

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(degree, name, surname)

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(day/month)

 Kaunas ,2019
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1. ABSTRACT

Objectives: The aim of this systematic review was to find and evaluate the current available publications regarding the effects surgical correction of Class III malocclusion has on subjects’ head posture and pharyngeal airway space.

Material and methods: Publications relevant to our aim were identified by conducting a search in MEDLINE (PubMed) database. Studies published in English language, performed on humans, controlled and non-controlled prospective and retrospective studies published from January 1st 2010 to November 15th 2019. The keywords used for the search were: Mandibular Setback Surgery, Posture and Bimaxillary Surgery. The selected studies were assessed for their quality and methodology.

Results: The search yielded a total of 32 results out of which 1 duplicated title was excluded. The preliminary exclusion was done by topic relevance. From the remaining, 16 were beyond date limits. 15 full text articles were assessed for eligibility. Finally, 7 articles that met the predefined criteria were included in the systematic review. Cranio-cervical angulation was found to be increased following mandibular setback surgery, and a decrease was observed in pharyngeal airway space after mandibular setback surgery and bimaxillary surgery procedures.

Conclusion: Mandibular setback surgery was found to cause head extension and reduce pharyngeal airway space. However, insignificant changes in cranio-cervical angulation and pharyngeal airway space were observed in patients who underwent bimaxillary surgery.

Keywords: Mandibular Setback Surgery, Bimaxillary Surgery, Posture.
2. INTRODUCTION

The treatment of Class III malocclusion was proven to be a challenging endeavor throughout the history of orthodontic treatment. Records dating back to 1802 show implementation of techniques such as a chin strap to treat mandibular prognathism by a German dentist (Kniesel) [1]. Modern versions of such techniques in accordance with other appliances are widely used nowadays. However, the introduction of the sagittal split ramus osteotomy procedure in 1957 represents the beginning of the modern era of orthodontics- it allowed treatment of rather severe cases of mandibular prognathism [2].

Two main surgical techniques are currently utilized for the correction of skeletal Class III malocclusion – (1) Bilateral sagittal split osteotomy (BSSO) -a procedure performed on the mandible to allow posterior repositioning (2) Bimaxillary surgery-a procedure which combines BSSO along with LeFort I osteotomy in order to move the maxilla forward. Both approaches have been shown to improve dental occlusion and lower facial aesthetics [3, 4]. Class III skeletal malocclusion can be caused by mandibular prognathism, maxillary deficiency, or both. In contrast to past years, in which mandibular setback surgery was the standard, bimaxillary surgery is recently gaining popularity among practitioners due to advancements in techniques and knowledge. In the last decade, mandibular setback surgery has declined in frequency to less than 10% of Class III patients, but maxillary advancement is used in 45% to 55% of Class III patients. [5,6,7].

It has been previously reported that patients with mandibular prognathism presented a decreased cranio-cervical angle, while patients with mandibular retrognathism showed an increased cranio-cervical angle [8]. That means that theoretically, following orthognathic mandibular surgery, changes should be observed in head posture [9]. Measurements of cranio-cervical angle accurately and reproducibly reflect head posture associated with craniofacial morphology [8].

It is important to note that the terms “Natural Head Position” (NHP) and “Natural Head Posture” are not identical. While Natural Head Position indicates a standard procedure applied to all subjects for the analysis of dentofacial morphology, “Natural Head Posture” is an individual characteristic used to assess the relation between posture and morphological parameters [10].

One of the major challenges in studies related to posture changes is choosing a proper method to achieve representation of the patients’ natural posture. The method has to be applicable and to produce consistent results. There are 2 main techniques to achieve NHP for radiographs. The first is defined as “Self-Balance Position”- a method which uses the patient’s own sensation of achieving natural head balance, lacking a use of any external reference point–resulting in a final head position
which is based on proprioceptive information from ligaments and muscles. The second method utilizes visual cues as external references - for example placing a mirror in front of the patient and instructing him to look into the reflection of their eyes in the mirror [10, 11]. Some consider the second method to be inferior to the first, claiming that the position determined by an external reference may be different from the habitual position [12].

Lateral cephalograms are still accepted by most authors as the most practical and accurate way to record head and cervical posture [10, 13]. Furthermore, lateral cephalograms taken in NHP represent the individual’s true life appearance, making it an essential parameter for achieving realistic orthodontic and orthognathic results [14]. Liukkonen et al. [15] has reported a significant increase in cranio-cervical angulation 1 year after mandibular setback surgery, suggesting head extension. Cranio-cervical angle was shown to correlate with extension of the head. Similar results were presented by Achilleos et al.[16], showing head extension following mandibular setback surgery.

The mandible, base of the tongue, hyoid bone, and pharyngeal airway are intimately associated to each other by surrounding muscles and ligaments. Therefore, it is safe to assume a manipulation of mandibular morphology will have an effect on the pharyngeal airway space. In addition, multiple studies have reported a decrease in pharyngeal airway space after mandibular setback procedures. [17, 18, 19]

This review was aimed at evaluating the effect different surgical correction procedures for Class III malocclusion had on patients head posture, and pharyngeal airway space. The review also focused on comparing the effects of abovementioned surgical procedures on the parameters we investigated.

Our tasks were:

1. To evaluate the effect different surgical correction procedures for class III malocclusion had on patients’ head posture.
2. To evaluate the effect different surgical correction procedures for class III malocclusion had on patients’ pharyngeal airway space.
3. To compare the changes seen in patients after mandibular setback surgery versus bimaxillary surgery.
3. SELECTION CRITERIA OF THE STUDIES. SEARCH METHODS AND STRATEGY

3.1. Protocol
This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement [20]. The literature review was done by conducting a search of “MEDLINE” (PubMed) online database, using google Chrome web browser. The key words and their combinations which were used in the search: Mandibular Setback Surgery AND Posture, Bimaxillary Surgery AND Posture. The available literature was analysed to decide which studies will be included in the literature review. The included studies were in English language, studies performed on humans only and publications dating from January 1st 2010 to November 15th 2019. In total 32 publications were identified when searching by the keywords. Titles and abstracts were screened for eligibility, to exclude irrelevant publications. Full texts of remaining articles were assessed and those related to the topic of the review were qualified and included in the study.

3.2. Inclusion criteria for the selection were the following:
- Publications written in English language.
- Studies performed on humans only.
- Studies published from January 1st 2010 to November 15th 2019.
- Controlled and non-controlled prospective clinical studies, retrospective clinical studies.

3.3 Exclusion criteria were the following:
- Publications older than 10 years.
- Publications in languages other than English.
- Case reports, systematic reviews, Meta-Analyses.
- Studies performed on animals.

Table 1. PICOS

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Patients with Dental Class III malocclusion, treated with surgical or conservative manner</td>
</tr>
<tr>
<td>Intervention</td>
<td>BSSO, MSS, Face Mask therapy procedures.</td>
</tr>
<tr>
<td>Comparison</td>
<td>Binaxillary procedure and Mandibular set back surgery.</td>
</tr>
<tr>
<td>Outcome</td>
<td>Increase in crano-cervical angle, reduction in pharyngeal airway space.</td>
</tr>
<tr>
<td>Study Design</td>
<td>Controlled and non-controlled retrospective and prospective clinical trials.</td>
</tr>
</tbody>
</table>
4. SYSTEMATIZATION AND ANALYSIS OF DATA

4.1. Study selection

Article review and data extraction were performed according to the PRISMA flow diagram (Figure 1) [20]. The initial database search identified a total of 32 results from which 1 duplicated title was excluded. The preliminary exclusion was done by topic relevance. From the remaining, 16 were beyond date limits. 15 full-text articles were assessed for eligibility. Finally, 7 articles that met the predefined criteria were included in the systematic review.

Figure 1. PRISMA flow chart.
4.2 Assessment of methodological quality

The process of assessing the quality of the included studies was based on the Cochrane hand book for assessing risk of bias [21]. It was used to assess bias across the studies to identify flaws in methodology and other parameters. Based on the data available in each study, potential risk of bias can be classified to: (+) low risk of bias, (?) unclear risk of bias, or (-) high risk of bias (table 2). The assessment revealed an unclear risk of bias for all studies included in this review. However, most of the criteria this method uses to evaluate risk of bias are not applicable or practical when conducting the type of studies included in this review. In addition, Methodological Index for non-randomized Studies (MINORS) tool for methodological assessment was used to examine the quality of included studies [22] (annex no. 1).

Table 2. Assessment of Risk of Bias

<table>
<thead>
<tr>
<th>Author</th>
<th>Allocation Concealment</th>
<th>Random Sequence generation</th>
<th>Blinding of Participant(s) and personnel</th>
<th>Blinding of outcome assessment</th>
<th>Incompleteness outcome data addressed</th>
<th>Selective Reporting</th>
<th>Other Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dohyun Cho et al., 2015</td>
<td>?</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Gülnaz Marşan et al., 2010</td>
<td>?</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ahmet Yagci et al., 2011</td>
<td>?</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Chun-Ming Chen et al., 2015</td>
<td>?</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Min-Ah Kim et al., 2013</td>
<td>?</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fernando Andriola et al., 2018</td>
<td>?</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ruchengiz Efendiyeva et al., 2014</td>
<td>?</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
The studies included in this review discuss the effects surgical correction of Class III malocclusion has on patients' head posture and pharyngeal airway space, as well as the inter-relation between these parameters. 7 studies were included in this review, 3 out of those studies analyze both the changes in pharyngeal airway space and the changes observed in head posture following surgery [23, 4, 24], and 3 focus solely on analysis of changes in head posture following the procedure [25, 26, 27]. 1 study was included in which a non-surgical approach was used to correct Class III malocclusion (Face Mask Therapy), this study was used to compare the different effects surgical and conservative methods had on head posture and pharyngeal airway space [28].

The studies can be divided into 2 main groups, based on the type of procedure that was investigated: 1st group is comprised of studies in which Mandibular Setback Surgery (MSS) was performed [25, 26], while the 2nd group included studies in which Bimaxillary surgery was performed [27, 23, 4, 24]. The characteristics of those studies are described in Table 3.

Table 3. Characteristics of included studies

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Study Type</th>
<th>Sample Size</th>
<th>Mean Age</th>
<th>Investigatio n Method</th>
<th>Intervention</th>
<th>Angle Class</th>
<th>Parameters Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dohyun Cho et al., 2015</strong></td>
<td>RS</td>
<td>20</td>
<td>21.6</td>
<td>CR, LFP</td>
<td>MSS</td>
<td>III</td>
<td>+</td>
</tr>
<tr>
<td><strong>Gülnaz Marşan et al., 2010</strong></td>
<td>RS</td>
<td>42</td>
<td>25.4±1.2</td>
<td>CR</td>
<td>MSS</td>
<td>III</td>
<td>+</td>
</tr>
<tr>
<td><strong>Ahmet Yagci et al., 2011</strong></td>
<td>PCT</td>
<td>30</td>
<td>9.7±1.2</td>
<td>CR</td>
<td>Face Mask Therapy</td>
<td>III</td>
<td>+</td>
</tr>
<tr>
<td><strong>Chun-Ming Chen et al., 2015</strong></td>
<td>RS</td>
<td>37</td>
<td>20.8</td>
<td>CR</td>
<td>IVRO</td>
<td>III</td>
<td>+</td>
</tr>
<tr>
<td><strong>Min-Ah Kim et al., 2013</strong></td>
<td>RS</td>
<td>25</td>
<td>30.0±13.0</td>
<td>CBCT</td>
<td>BSSO+ Le Fort I Osteotomy</td>
<td>III</td>
<td>+</td>
</tr>
<tr>
<td><strong>Fernando Andriola et al., 2018</strong></td>
<td>PCT</td>
<td>25</td>
<td>29.28±8.23</td>
<td>CR</td>
<td>BSSO+ Le Fort I Osteotomy</td>
<td>III</td>
<td>+</td>
</tr>
<tr>
<td><strong>Ruchengiz Efendiyeva et al., 2014</strong></td>
<td>RS</td>
<td>26</td>
<td>24.1</td>
<td>CR</td>
<td>BSSO+ Le Fort I Osteotomy</td>
<td>III</td>
<td>+</td>
</tr>
</tbody>
</table>

RS-Retrospective Study, PCT- Prospective Clinical trial, CR- Cephalometric Radiograph, CBCT- Cone Beam Computed Tomography, LFP- Lateral Facial Photographs, MSS- Mandibular Setback Surgery, BSSO- Bilateral Sagittal Split Osteotomy, IVRO- Intraoral Vertical Ramus Osteotomy, PAS- Pharyngeal Airway Space
4.3. Evaluation of the effects of surgical intervention on head posture and pharyngeal airway space

4.3.1. Effect of Mandibular Setback Surgery on Posture

Dohyun Cho et al., [25] in 2015, have evaluated the changes in natural head position (NHP) after orthognathic surgery. Pre and post treatment lateral cephalometric radiographs were taken, along with pre and post treatment lateral facial photographs. All data was recorded in NHP. 20 patients, aged 15.8-41.5 years (mean age 21.6± 5.7 years) with class III malocclusion were selected for the tested group. 20 Class I patients were selected for the control group; aged 16.7-37.3 (mean age 22.2 ± 4.5 years). Patients who had temporomandibular disorders, tonsillar hypertrophy, mouth breathing or anterior crossbite or open bite –were not included in the control group. Mean duration of postsurgical orthodontic treatment for the tested group was 10.4 month. Subjects were instructed to stand in natural head position, stare at their own eyes reflected in a mirror (60X90 cm) 1 meter in front of them, and to occlude in maximum intercuspation with relaxed lips, in order to achieve accurate lateral facial photographs. A pendulum hanging on a metal chain was attached to the background to show true vertical plane in the photographs. The angle formed between the metal chain and E-line was measured, later to be transferred to the cephalometric tracing to draw the True Vertical Line (TVL). All patients had their lateral cephalograms taken in habitual occlusion, relaxed lips, and the rest of the instructions were the same as in the lateral facial photographs.

To evaluate NHP, the angles between True Vertical Line (TVL) and Sella-Nasion(SN) plane and between TVL and Frankfurt Horizontal Plane (FH) were investigated. Head flexion or extension in NHP were defined as an increase or decrease in TVL/SN and TVL/FH angles, respectively.

2 weeks later, one examiner randomly selected 10 facial photographs and cephalometric radiographs, and repeated the process of TVL transferring and the cephalometric measurements, to determine the method error. Dahlberg’s formula [29] was used to calculate method error, resulting in 0.4° maximum method error in TVL/FH measurements.

At T1, Class III group showed mandibular prognathism, concave profiles, and reverse overjets, unlike the control group. The mean TVL/FH and TVL/SN measurements in the Class III group were 91.8° and 83.1°, respectively. In the control group, the same values were significantly lower (TVL/FH-88.3°, TVL/SN-79.5°).

As a result of orthognathic surgery, TVL/SN and TVL/FH angles both decreased by 3.1° in the Class III group, while no changes were seen in the control group. 19 out of 20 Class I patients showed minimal or no change while 6 out of 20 Class III patients (30%) showed over 4.5° head
extension. In total, 14 patients from the class III group showed head extension, ranging from 1.5° to 13.5°, 4 showed head flexion (1.5°-4.5°) and 2 showed no significant changes.

The second study used in this review to evaluate the effect of mandibular setback surgery was done by Gülnaz Marşan et al.,[26] in 2010. The changes in head posture and hyoid bone position were investigated. Lateral cephalograms of 42 turkish class III patients (mean age- 25.4 ± 1.2 years) were evaluated. 1.2 ± 0.6 , 2.3 ± 0.8 and 4.2 ± 0.9 years following the MSS procedure. All participants were adults who have completed growth. The protocol for recording head posture was based on Solow and Tallgren [30] – “orthoposition” was achieved by letting the subject walk around, then to stand in a relaxed manner – “self-balance position”. To reproduce accurate radiographs, a fluid level device was attached to the side of the head using a double sided tape square. This provided a horizontal reference on the patient that could be compared with gravity defined vertical reference (a weighted chain mounted on the left-hand margin of the x-ray cassette. The patient was then asked to flex and extend the neck until he felt that a natural balance head position was achieved. Subjects were also asked to occlude teeth and contact lips lightly.

To measure changes in head position, the following angles were used: The angle between Nasion Sella Line (NSL) and the odontoid process tangent(OPT)- NSL/OPT. And the angle between NSL and the cervical vertebrae tangent (CVT) – NSL/CVT. Two weeks after the initial measurements, 30 cephalograms were randomly selected, re-measured and a correlation analysis was applied to the first and second measurements by the same investigator. The interclass correlation coefficient (R) was used to calculate the method error between the replicate tracings. It ranged from 85.7% to 99.8% for all variables, therefore the difference between the first and the second measurements were deemed insignificant.

The results were an increase in cranio-cervical angulation (NSL/CVT, NSL/OPT angles) in the long term measurements, suggesting cranial extension.

### 4.3.2. Effect of Bimaxillary surgery on Posture

In a recent study done in 2018 by Fernando Andriola et al., [27] cervical lordosis and head posture changes following bimaxillary orthognathic surgery were evaluated in 25 (10 men, 15 women, mean age, 29.28 ± 8.23) patients with skeletal Class III malocclusion. Lateral cephalographs were taken in NHP (Natural Head Position) before treatment (2 weeks) and after treatment (6 months). The surgical procedure consisted of a Bilateral Sagittal Split Osteotomy along with a Le Fort I osteotomy for maxillary advancement. The subjects in this study did not have any craniofacial anomalies, cleft lip, cleft palate, musculoskeletal sequels, or history of trauma. To acquire accurate lateral cephalographs which include all structures from NSL (Nasion-Sella line) to
the 7th cervical vertebra (CV7), a modified technique was applied- no ear rods were used, to enable the possibility of moving the field of view down. The ear rods were adjusted to patients’ neck instead. The subjects were standing in orthoposition, while being barefoot. To improve reproducibility, subjects were asked to walk on the spot, then stand in relaxed manner and move their head forward and backwards to achieve self-balance position. When self-balance position was achieved, patients were asked to look into their own eyes in a mirror which was placed in front of them. Prior to the cephalometric analysis, the patients’ data was blinded. The radiographs were traced and analysed by one operator. The measurements were repeated 3 times at 2 week intervals, and the average values of all 3 measurements were used in the final analysis.

Head posture and cervical lordosis measurements were assessed, as well as other cephalometric values. Following the surgical procedure, an insignificant decrease was observed in cranio-cervical and cranio-vertical angles. However, a slight tendency for head extension was observed.

A study conducted by Chung Min-Chen et al., [23] in 2015, wished to determine the correlation between pharyngeal airway space and head posture after mandibular setback surgery. 37 patients with a mean age of 20.8 years (26 women and 11 men) who presented Angle Class III malocclusion and underwent modified bilateral intraoral vertical ramus osteotomy (IVRO) were recruited to the study. Cephalometric radiographs were done to evaluate changes in head position and pharyngeal airway space. The radiographs were evaluated twice by the author, and if the difference between the first and the second value exceeded 0.5mm or 1°, the angle or point were re-measured for a third time. To control head posture of each patient, the laser of the panorex machine was used. The cranio-cervical angle was found to be increased 1 year after surgery, along with a significant shortening of upper and lower oropharyngeal airway space, suggesting a compensatory head extension.

Min-Ah Kim et al.,[4] in 2012 used 3D imaging to evaluate head posture and pharyngeal volume changes following bimaxillary surgery. In total, 25 Skeletal Class III patients (14 men, 11 women, mean age 30 ± 13.08) who underwent bimaxillary surgery were selected. Cone beam computed tomography (CBCT) scans were obtained before the procedure (T1) and 6 months after the procedure(T2). All subjects were asked to sit in a chair, maintaining natural head position using the mirror method, while keeping jaws in maximum intercuspation with lips and tongue in a resting position. In addition, subjects were asked not to swallow or breathe. The head posture measurements were found to differ significantly between T1 and T2. At T2, mean cranio-cervical angle significantly increased (1.89 ± 2.09°). However, although pharyngeal airway volume decreased in the post-operative measurements, the change was insignificant. Another study done by Ruchingez Efendiyeva et al.[23] in 2014, aimed to determine the effect bimaxillary surgery had on
pharyngeal airway and cranio-cervical posture in Class III patients. It also compared short and long term results. Lateral cephalometric films of 26 adult patients (16 women, mean age- 21.4 ± 3.61 years, 10 men, mean age- 23.12 ± 3.32) were analyzed. While acquiring the cephalometric radiographs, patients were told to maintain natural head position and to not swallow. A line going 7° to the sella-nasion plane through sella point was used a horizontal plane of reference, and a line perpendicular to that plane going through sella point was defined as the vertical reference line. The tracings and measurements of points and angles were repeated on 35 randomly selected radiographs. For those measurements correlation coefficient was calculated ($r^2$) to eliminate errors in measurements. All values measured on the cephalograms were measured three times by the same investigator and calculated into an average to eliminate measuring errors. The results showed no significant reductions in pharyngeal airway space, and no significant changes in cranio-cervical angulations.

4.4. Evaluation of the effects of non-surgical treatment on head posture and pharyngeal airway space

Ahmet Yagci et al.,[28] in 2011, assessed the effects of conventional and modified facemask therapy on the dynamic measurement of natural head position (NHP) and orofacial airway dimensions of Class III patients compared with an untreated study group. The study sample was comprised of the dynamic natural head position records of 45 Class III patients who presented maxillary retrusion. The sample was divided into 3 groups – (1) Conventional facemask group – 15 patients (8 girls, 7 boys; mean age 9.6 ± 1.3 years) (2) Modified facemask group – 15 patients (7 girls, 8 boys; mean age 9.5 ± 1.5 years) and (3) Control group- 15 patients (7 girls, 8 boys; mean age 9.8 ± 1.6 years) on which no treatment was performed. All measurements were done by the author, and then reviewed twice by a second investigator. To check for errors in the cephalometric measurements, 10 radiographs were selected at random 8 weeks after first measurements and the tracings were repeated. The differences between the first and second measurements were found to be insignificant. Compared to the control group, sagittal pitch measurement values in both conventional and modified facemask group showed significant changes after treatment, showing cranial flexion. Moreover, measurements of total areas of airways were significantly different in both test groups compared to control group – increases of total area of oropharyngeal airway were observed.
Table 4 presents a summary of the treatment outcomes observed in the studies we reviewed.

**Table 4. Treatment outcomes**

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Intervention</th>
<th>Treatment Outcomes</th>
<th>Changes in Pharyngeal Airway Space</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dohyun Cho et al., 2015 [25]</strong></td>
<td>Mandibular Setback Surgery</td>
<td>TVL/SN and TVL/FH angles both decreased by 3.1° in the Class III group&lt;br&gt;Head extension was found in 14 out of 20 patients, (6 patients showed 4.5° or more of head extension)</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Gülنز Marşan et al., 2010 [26]</strong></td>
<td>Mandibular Setback Surgery</td>
<td>Increase of cranio-cervical angle (NSL/CVT, NSL/OPT) after 4.2±0.9 years suggesting head extension</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Ahmet Yagci et al., 2011, [28]</strong></td>
<td>Face Mask Therapy</td>
<td>Cranial flexion was recorded in the tested group</td>
<td>Total area of oropharyngeal airway space increased</td>
</tr>
<tr>
<td><strong>Chun-Ming Chen et al., 2015, [29]</strong></td>
<td>Intraoral Vertical Ramus Osteotomy</td>
<td>An increase in cranio-cervical angle was observed 1 year after treatment</td>
<td>Significant shortening of upper and lower oropharyngeal airway space</td>
</tr>
<tr>
<td><strong>Min-Ah Kim et al., 2013 [4]</strong></td>
<td>Bimaxillary Surgery</td>
<td>Cranio-cervical angle increased by 1.89±2.09°</td>
<td>Insignificant decrease in pharyngeal airway volume</td>
</tr>
<tr>
<td><strong>Fernando Andriola et al., 2018 [27]</strong></td>
<td>Bimaxillary Surgery</td>
<td>Cranio-cervical angle decreased. A tendency to head extension was observed</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Ruchengiz Efendiyeva et al., 2014 [24]</strong></td>
<td>Bimaxillary Surgery</td>
<td>No significant changes were found</td>
<td>No significant changes were found</td>
</tr>
</tbody>
</table>

NA- Not assessed
5. DISCUSSION

This systematic review discussed the effects of orthognathic surgery on natural head posture and pharyngeal airway space. Due to the apparent heterogeneity of the studies included in this review, no meta-analysis of the findings could be implemented. The studies analysed in this review varied in the methods which were used to evaluate the changes in NHP and pharyngeal airway space, as well as in the protocols used for achieving natural head position while producing radiographic records. Nevertheless, correlations between the results could be drawn, explaining the mechanisms which may have caused the observed changes.

In our review, similar results to those found by Achilleos et al. and Liukkonnen et al. [16, 15] were observed- mandibular setback surgery caused an extension of over 4.5° in 6 out of 20 Class III malocclusion patients [25]. Another study found an increase in cranio-cervical angulation (NSL/CVT, NSL/OPT angles) after MSS in class III malocclusion patients, suggesting head extension [26]. Kim et al [4] have found that bimaxillary surgery resulted mean increase of cranio-cervical angle 6 months after surgery, demonstrating head extension as well. However, Efendiyeva et al., [24] in a long term evaluation, have not observed any significant changes following bimaxillary surgery, other than a slight decrease in cranio-cervical angle. Marşan et al., [26] found a decrease of the upper cervical curvature, along with an increase of cranio-cervical angle after surgically correcting Class III malocclusion, also showing head extension. Results were different when analyzing the effects non-surgical treatment had on Class III patients. Following Face Mask therapy for correction of deficient maxilla, cranial flexion was observed [28]- suggesting that the change in the mandibular morphology is the causative factor of the commonly observed cranial extension, which is also supported by Savjani et al., [9] who reported a significant correlation between head posture and mandibular morphology after orthognathic surgery.

Regarding changes in pharyngeal airway space after orthognathic surgery, one study have found a significant shortening of upper and lower oropharyngeal space 1 year after Intraoral vertical ramus osteotomy [23]. In addition, Min-Ah Kim et al. [4] found a slight decrease in pharyngeal airway volume using cone beam computed tomography, but deemed them insignificant. Similar results were presented by Ruchingez Efendiyeva et al., in long term measurements following bimaxillary surgery [24]. On the contrary, rather noticeable changes were presented by Muto et al., showing a decrease in pharyngeal airway space in the retropalatal, retroglossal regions, of 2.6 and 4.0 mm, respectively, after bilateral sagittal split osteotomy[31]. Tselnik et al. [17], reported that a mean mandibular setback of 9.7mm resulted in 12.8% decrease in pharyngeal airway space. Additional previous reports demonstrated that the post-operative pharyngeal airway volume decreased after conducting mandibular setback surgery. This decrease was less pronounced in those who underwent
surgery which involved the maxilla as well (Bimaxillary surgery) [3, 32]. A potential reason for such findings is that in Bimaxillary surgery the amount of setback of mandible was less than in mandibular setback surgery. Another possible reason is the effect of advancement that LeFort I osteotomy has on the velopharyngeal muscle [37]. Findings of a decreased pharyngeal airway space after mandibular setback were presented by Achilleos et al. [16] along with head extension. A non-surgical approach to correction of Class III malocclusion which was conducted by Yagci et al., [28] showed an increase in pharyngeal airway space- implying that the reasons behind the changes observed in abovementioned studies are exclusive to surgical correction of Class III.

The correlations between these two phenomena (the reduction in pharyngeal airway space and head extension) has been previously explained by various approaches: Wenzel et al. [33] suggested that an increase in cranio-cervical angle could be related to psychosocial factors- the patients tend to lift their head after surgery, due to increased confidence in their appearance. Another approach proposed that an increase in cranio-cervical angulation after mandibular setback surgery is a compensatory mechanism aimed at maintaining adequate pharyngeal airway volume, in which the cranial extension serves to lift away the soft palate and the base of the tongue from the posterior pharyngeal wall [16]. Chen et al. [23] suggested a similar relationship, in which the extension of the head is a manifestation of natural physiological regulation to compensate for the postoperative airway narrowing. Identical patterns of head extension are observed in mouth breathers [34, 35]. Intriguing observations were made by Vig et al. [36] - total nasal obstruction resulted in progressive head extension, while removal of the nasal obstruction caused the return of the head position to the baseline values.

Although not many recent studies were conducted on the topic, an interesting relationship can be observed between surgical correction of Class III and the subjects’ head posture- the procedure causes a reduction in airway space which seems to be later compensated by cranial extension. Nevertheless, more substantial evidence is required to state the exact effects of such procedures on patients’ posture and airway dimensions. The difficulty in reducing the evidence available to us into a single conclusion stems from the challenging nature of conducting such studies. The methods currently used to analyze the factors evaluated in our study vary greatly. Different radiographic methods, postural assessment methods and approaches to surgical correction of Class III are available- resulting in widely dissimilar studies. In addition, most of the studies on the subject did not include a control group, lowering the quality and reliability of results.
6. CONCLUSION

1. Our findings revealed an increase in cranio-cervical angulation and a tendency of cranial extension in patients who underwent orthognathic surgery for correction of Class III malocclusion.

2. A decrease in pharyngeal airway space can be expected following surgical correction of Class III malocclusion.

3. Compared to mandibular setback surgery procedure, bimaxillary surgery showed favourable results regarding reduction in airway space volume.
7. PRACTICAL RECOMMENDATIONS

As mentioned in our discussion, the posterior displacement of mandible is responsible for most of the adverse effects caused by mandibular setback surgery procedures. Posterior movement of mandible corresponds with a reduction in pharyngeal airway space, which might in turn cause extension of the head. In light of these findings, we would recommend to perform bimaxillary surgery when possible. Although it is a rather complicated procedure, it reduces the amount of mandibular setback required to correct Class III malocclusion, which could produce more favourable results.
8. REFERENCES


28. Ahmet Yagci,a Tancan Uysal,b Serdar Usumez,c and Metin Orhand Effects of modified and conventional facemask therapies with expansion on dynamic measurement of natural head position in Class III patients Am J Orthod Dentofacial Orthop 2011;140:223-231


According to the MINORS tool, a score of 16 points is ideal for non-comparative studies while 24 is the ideal score for comparative studies. Thus, it is safe to say the studies included in this review have adequate methodologies.