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A three-dimensional comparison of the pharyngeal airway after mandibular distraction osteogenesis and bilateral sagittal split osteotomy

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ABSTRACT

Purpose: The goal of this retrospective study was to examine the radiological changes in the pharyngeal airway following mandibular distraction osteogenesis (DO) and bilateral sagittal split osteotomy (BSSO).
Material and methods: Between 2005 and 2009, a total of 41 nonsyndromic patients underwent a mandibular osteotomy ($n_{DO} = 23$; $n_{BSSO} = 18$). Digital volume tomography images were created for preoperative and postoperative evaluations of both groups. The Dolphin 3D program was used for comparative analysis of the pharyngeal airways.
Results: After DO, the airway volumes (VOL) improved by 6.8 mL. In comparison, an improvement of 5.9 mL was observed as result of BSSO. The minimum axial areas (AREA) of the enlargements increased by 109.1 mm^2 with DO and 103.1 mm^2 with BSSO. The airway areas (SA) increased by 193.8 mm^2 with DO and 185.2 mm^2 with BSSO. There were no significant differences between two surgical procedures in terms of the parameters describe above ($p_{VOL} = 0.358$; $p_{AREA} = 0.752$; $p_{SA} = 0.777$). However, the initial preoperative values ($p_{VOL} = 0.020$; $p_{AREA} = 0.005$) and the patients' ages ($p_{AREA} = 0.042$; $p_{SA} = 0.007$) did have significant effects on the postoperative values.
Conclusion: Both DO and BSSO expanded the pharyngeal airways of all nonsyndromic patients.

1. Introduction

In orthognathic surgery, it is generally accepted that the forward motion of the mandible has an advantageous effect on the expansion of the airway in the pharyngeal area (Lee et al., 2014). Bilateral sagittal split osteotomy (BSSO) is an accepted treatment option for the advancement of mandible (Geha et al., 2006; Monson, 2013). However, some studies have reported complications, such as impairment of the inferior alveolar nerve (Mensink et al., 2012; Al-Nawas et al., 2014; Baas et al., 2015), the possibility of growth disabilities, as well as postoperative relapse (Gassmann et al., 1990; Schreuder et al., 2007; Ow and Cheung, 2010a). The cause of the relatively high rate of relapse seems to be the acute stretching of soft tissue, including muscles and tendons (van Strijen et al., 2004; Vos et al., 2009). Mandibular distraction osteogenesis (DO) is an alternative procedure to BSSO. DO was first mentioned in the medical literature in the beginning of the 20th century. The Russian Ilizarov is credited with its popularization as early as the 1950s; he established the method for the extension of the extremities (Ilizarov, 1989). In the following decade, the initial experimental animal studies focused on the extension of the mandible. In 1992, McCarthy et al. performed the first mandibular distraction osteogenesis in a human patient (McCarthy et al., 1992). The gentler, gradual stretching of the soft tissue appears to be an advantage of DO (Schreuder et al., 2007). With DO, longer distances of gradual movement are also possible. Additionally, high levels of stability with precise settings of the occlusion are possible when the patient is awake (Schreuder et al., 2007). The medical literature describes

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another possible advantage of DO, namely, the reduced possibility of nerve damage (Ow and Cheung, 2010a,b). Distraction is also possible for child patients (Baas et al., 2010; Abramson et al., 2013).

Both surgical methods lead to improvements in occlusion, chewing functions, and facial aesthetics. Since 1979, the enlargement of the pharyngeal airway has been accepted as a result of BSSO (Kuo et al., 1979; Agbaje et al., 2014). This result is relevant because mandibular retrognathia is usually associated with small, irregularly formed airways (El and Palomo, 2011). This condition significantly increases patient morbidity and mortality (Kim et al., 2010; Okushi et al., 2011; Abramson et al., 2013). Mandibular distraction osteogenesis has subsequently become an accepted alternative to tracheostomy and to BSSO or maxillomandibular advancement (Verse et al., 2009; Ubaldo et al., 2015).

The aim of the present study was to analyze and compare the radiological changes in the pharyngeal airway following bilateral sagittal split osteotomy and mandibular distraction osteogenesis. Secondary aims were an evaluation of the influence of patient gender, age, and initial value on differences between the preoperative and postoperative airway values.

2. Material and methods

Within the scope of this retrospective, noninterventional case–control study, a total of 41 nonsyndromic patients were analyzed between 2005 and 2009. Data were collected case-specifically after the examination of the completeness of the patient's files and a digital body imaging procedure. Inclusion criteria were patients with a mandibular retrognathia who were treated via mandibular orthognathic surgery by DO or BSSO in the Department of Oral and Maxillofacial Surgery at the HELIOS Kliniken Schwerin during the period. Exclusion criteria of this study were as follows: patients with incomplete medical record and missing data from the hospital database; and patients with another treatment or incomplete digital volume tomography images.

The following data were collected from a total of 27 (70.7%) female and 12 (29.3%) male patients. The average age was 31.6 years, and the median was 32.1 years. The minimum patient age was 17.8 years, and the maximum patient age was 52.1 years. Of these patients, 23 (56.1%) were treated with DO, and 18 (43.9%) were treated with BSSO. The average advancement of the BSSO patients was 7.4 mm. The average displacement length of the DO patients was 10.7 mm. Digital volume tomographic images were created for preoperative and postoperative evaluations of both groups. To increase the reproducibility, anatomical radiological landmarks were defined. Additionally, the upper and lower boundaries of the pharyngeal airway were determined. For each patient, the airway volume (VOL) [mL], the sagittal airway area (SA) [mm^2], and the minimum axial area (AREA) [mm^2] were recorded in the data set (Table 1).

The respiratory volume was evaluated using the Dolphin 3D program (Fig. 1). All calculations were made using the statistical program R Version 3.1.0. Significant differences between the improvements in the two surgical procedure groups were statistically tested. The study pursued the following questions: Did the initial values, patient genders, or patient ages affect the differences between the two groups? Linear regressions were calculated based on the differences between the two measurement points (dependent variable) and the grouping variables of the patient gender, age, and the initial value (independent variable).

3. Results

3.1. Comparison of measurements before and after mandibular distraction osteogenesis and bilateral sagittal split osteotomy

The preoperative average values of the airway volumes were 16.1 mL (median 14.6 mL) for the DO group and 14.3 mL (median 11.8 mL) for the BSSO group. The postoperative average values were 22.9 mL (median 21.2 mL) for the DO group and the 20.2 mL (median 17.7 mL) for the BSSO group. The average improvements in the airway volumes were 6.8 mL for the DO group and 5.9 mL for the BSSO group. The difference was 0.87 mL (confidence interval [CI] = −1.02–2.76). Therefore, there was no significant difference ($p = 0.358$) (Table 2, Fig. 2).

The average initial value for the minimal axial areas for the DO group was 150.9 mm^2 (median 142.3 mm^2). The average value before surgery for the BSSO group was 147.9 mm^2 (median 144.8 mm^2). The postoperative averages were 260.1 mm^2 (median 265.0 mm^2) for the DO group and 250.9 mm^2 (median 252.9 mm^2) for the BSSO group. The minimum axial areas improved by an average of 109.1 mm^2 for the DO group and an average of 103.1 mm^2 for the BSSO group. The difference of 6.05 mm^2 (CI = −32.42–44.52) between the two groups was not significant ($p = 0.752$) (Table 3; Fig. 3).

The preoperative average values for the airway areas were 553.2 mm^2 (median 573.7 mm^2) for the DO group and 551.2 mm^2 (median 526.5 mm^2) for the BSSO group. The DO group reached a postoperative average airway area value of 747.0 mm^2 (median 763.2 mm^2), whereas the BSSO group reached an average value of 736.4 mm^2 (median 689.4 mm^2). The airway area of the DO group improved by an average of 193.8 mm^2. The average improvement of the BSSO group was 185.2 mm^2. The difference of 8.61 mm^2 (CI = −52.39–69.61) was not significant ($p = 0.777$) (Table 4, Fig. 4).

3.2. Influence of initial preoperative value and patient gender and age

A linear regression model was calculated to simultaneously examine the effects of group, preoperative value, gender, and age

Table 1
Defined limiting points, determined limits of the pharyngeal airway to be measured, and the determined parameters in the data set.

Boundary points	
Boundary points/Determined parameters	**Definition**
BA (Basion)	The furthest lying posterior-inferior point in front of the foramen magnum
PNS (Posterior nasal spine)	The furthest posterior point of the hard (bony) palate
C_3	The furthest anterior-inferior point of the third cervical vertebra
V (Vallecula)	The cross-section of the epiglottis and the base of the tongue
BA − PNS	The upper boundary of the pharyngeal airway to be measured
C_3 − V	The lower boundary of the pharyngeal airway to be measured
Airway volume (VOL) [mL]	The total airway volume between the upper and lower boundary
Airway area (SA) [mm^2]	The sagittal airway area between the upper and lower boundary
Minimum axial area (AREA) [mm^2]	Calculated by the software

Modified from Valladares-Neto et al., 2013.