Original Article

Evaluation of volume change in oral cavity proper before and after mandibular advancement: *A retrospective volumetric study*

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ABSTRACT

Objectives: To evaluate the tongue and oral cavity proper volume in pre- and post-bilateral sagittal split osteotomy (BSSO) patients, and to establish whether there was a correlation between them.

Materials and Methods: A retrospective study that evaluated 12 patients' pre- and post-surgical computed tomography records satisfying the inclusion criteria. Borders were defined for measurement of tongue and oral cavity proper volume. The volume assessment was carried out using 3D slice software.

Results: The mean difference of tongue volume was 5.7 $\pm$ 1.7 cm^3, which showed high statistical significance. The mean difference of oral cavity proper volume (OCVP) was 6.9 $\pm$ 3.4 cm^3 and indicated high statistical significance. A very strong positive correlation existed between pre- and post-surgical tongue volume. Positive correlation was also evident between pre and post - surgical OCVP. Medium positive correlation was noted when the difference between pre- and post-surgical tongue and OCVP were assessed.

Conclusions: There was a significant change in volume of tongue and oral cavity proper after BSSO advancement surgery. The space around the tongue, position of tongue, and maxillary and mandibular relationship influence the volume of tongue and oral cavity proper. (*Angle Orthod.* 2021;91:81–87.)

KEY WORDS: Bilateral sagittal split osteotomy (BSSO); Tongue volume (TV); Oral cavity proper volume (OCVP)

INTRODUCTION

The teeth are aligned in arch forms, which follow a parabolic curve remaining in the neutral zone. The force exerted by the tongue lingually and the cheek muscles buccally created this zone.[1] According to the equilibrium theory, "The tongue in resting posture exerts a light force over a long duration, significantly influencing the tooth position and the dental arch form."[2,3] The force exerted by the tongue was determined by its volume. Hence, the volume of the tongue has pronounced influence on the alignment and occlusion.

Though a debatable topic, there was evidence supporting that volumetric disturbances have caused few malocclusions. For example, in Beckwith-Wiedemann syndrome, patients have macroglossia and acromegaly patients have anterior or lateral open bite,[2,4] whereas the effect of tongue volume in mandibular prognathism was rejected.[5] To maintain the ideal occlusion and arch form, there exists a certain proportion between the tongue volume and oral cavity.[6]

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The continuing dilemma about the adaptation of tongue to its surrounding morphology and structure led to the need for its precise volumetric assessment.

In the late 1960s, the tongue and oral cavity volume were first evaluated. The various methods employed were alginate impressions, dental casts,[7,8] lateral cephalograms,[3,9] cone beam computed tomography,[10] computed tomography,[11,12] magnetic resonance imaging (MRI),[13,14] ultrasound,[6] and new devices were invented and used for assessment in few studies.[15]

In 1983, Lowe et al. reconstructed the tongue from CT and evaluated the tongue volume in an obstructive sleep apnea patient.[12] CT provides images of thin slices with variable thickness. Hence, in this study, CT was used to evaluate the volume change of the oral cavity proper and tongue in patients pre- and post-surgery who underwent BSSO advancement.

Skeletal Class II malocclusion due to mandibular retrognathism in adults is best treated with BSSO with or without genioplasty.[16] According to Proffit et al., advancement of the mandible was considered to be a highly stable orthognathic surgical procedure.[17] Hence, the success of BSSO advancement was mainly determined by the post-surgical stability. According to the literature, between 1 and 5 years post-surgical healing, a decrease in mandibular length was seen in 20% of the patients.[17] There is limited research correlating the tongue volume with oral cavity proper and their volume differences between pre and post-surgical BSSO advancement patients, which could influence post-surgical stability.

The main purpose of this study was to fill this void by analyzing the volume change in the tongue, in correlation to intraoral cavity proper among patients pre- and post-BSSO advancement.

MATERIALS AND METHODS

Subjects

This retrospective study was carried out after approval from the Ethics Committee of the institutional board of Meenakshi Ammal Dental College, MAHER, Chennai (protocol number MADC/IRB-XVI/2017/307).

The patient details comprised of demographic details: name, age, sex, date of birth, height and weight, and medical history were retrieved from a database. All the patients were treated in the same center. Pre- and post-surgical records were reviewed from 2010 to 2017 and 15 CTs were collected. CTs included were required to meet the following inclusion criteria: records with adequate data, age 18–25 years, without any craniofacial abnormality, body mass index normal (18.5–24.9), male patients, single jaw surgery: Bilateral sagittal split osteotomy advancement without genioplasty, and 3-month follow-up post-surgical CT records.

Sample Size Calculation

A pilot study was carried out with five patients' pre- and post-surgical records. The sample size was determined with nMaster software version 2.0 (Department of Biostatistics, CMC, Vellore, India). The calculated sample size was 12 records, with the power of study being 90%. A total of 12 adult male patients with a mean age of 22.1 $\pm$ 3.2 years were included in this study.

CT Scans

The 12 CT scans were taken before and 3 months after mandibular advancement surgery using the same SIEMENS CT (Siemens Healthineers AG, Mumbai, India) scan machine performed in AARTHI Scan Center, Chennai, India with the following settings: 120 kVp, 200 ma, axial image was 3.0 mm, and table speed of 6 mm per second. Pre-surgical and post-surgical scans were taken with the condyle in centric relation (the patient was awake and in a reclined position). The patients were instructed not to swallow and not to move the tongue during the scanning.

Segmentation and Measurement

Each participant's Digital Imaging and Communications in Medicine data were uploaded into 3D slicer (free access) software, providing 512 image slices of 1-mm thickness (Figure 1).

Boundaries for Oral Cavity Proper Volume Analysis

- The superior border formed by the palatal plane that extended from ANS to PNS, which was perpendicular to the mid-sagittal plane.
- The anterior and lateral borders were formed by teeth.
- The posterior border was extended to the oropharynx.
- The inferior border was formed by the anterior margin of the lingual frenulum, parallel to the palatal plane or 8 mm below the mandibular lower incisor.

The oral cavity proper would include the space between the dorsum of the tongue and the palate, ventral surface of the tongue and the floor of mouth, and other minimal residual space, if present.

Boundaries for Tongue Volume Analysis

- The borders of the tongue were defined by adjusting the contrast of the CT image.
- The tongue volume was measured either superior to the attachment point of the lingual frenulum or the

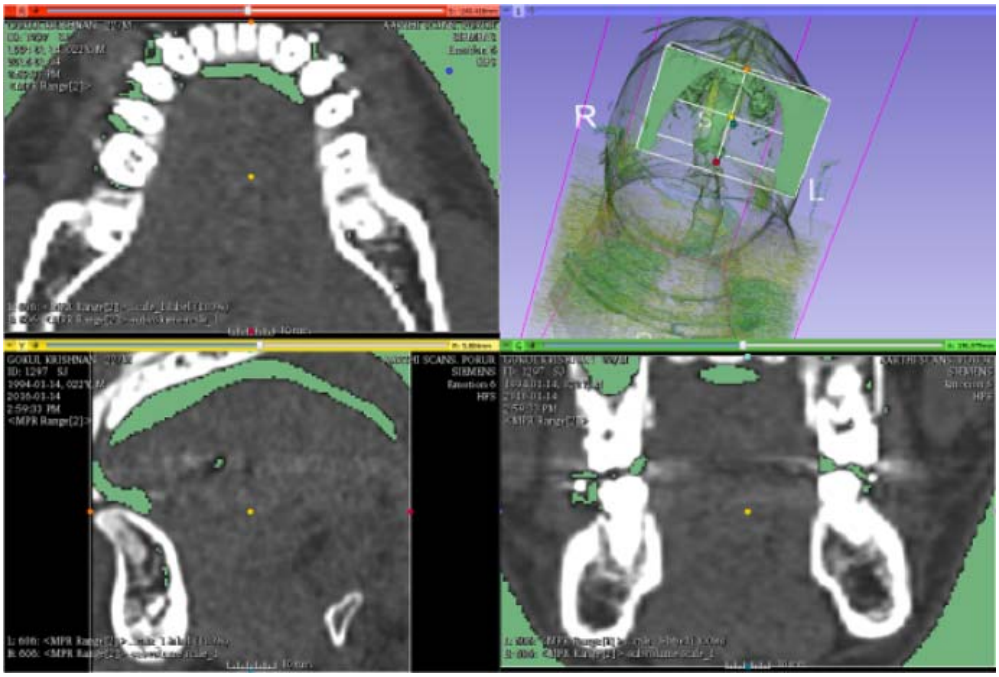

Figure 1. Segmentation of oral cavity proper using 3D slice software.

volume that was within 8 mm from the mandibular lower incisor.
- The posterior border of tongue to the area of the oropharynx.

The outline of the tongue and oral cavity proper volume were traced manually on each slide. The difficult part in assessment of tongue volume with CT was to differentiate lateral surfaces of the tongue from the lingual mucosa of the lower dental arch. Lauder et al. expressed the same difficulty even with MRI.[18] To overcome this difficulty, the following steps were taken:

- Borders were defined using a manual method and by adjusting contrast.
- A constructed plane was at level of the anterior margin of the lingual frenulum parallel to the palatal plane.
- In cases with difficulty in identifying the lingual frenulum, 8 mm below the mandibular incisor edge was used as a reference plane.[19]

Statistical Analysis

To evaluate error of the method, intraobserver reliability and sensitivity were checked using intraclass correlation (ICC) value. In all 12 cases, post-surgical tongue and oral cavity proper volume were measured by the first author and checked by the second author. To avoid bias, the cases were randomly allocated to the first investigator for remeasurement. The agreement between the two measurements was checked by the second investigator. A value of 0.8 and above 0.8 were considered as high level of agreement. A paired-sample *t*-test was used to evaluate the mean difference and *P* value of tongue and oral cavity proper volume (OCVP) proper volume pre and post-surgery. Pearson's correlation coefficient test was used to analyze the correlation among pre- and post-tongue volume, pre- and post-OCVP, and mean difference of tongue and oral cavity volume. *P* values less than .05 were considered statically significant. All the analyses were carried out using SPSS statistical software (version 13.0, SPSS Inc., Chicago, IL, USA).

RESULTS

The 12 patients' records of pre- and post-tongue and oral cavity proper volume are shown in Table 1. The ICC for intraobserver reliability of all the samples were more than 0.8 and *P* value of $<.001$ was found. This indicated that the intraobserver reliability was high (Figure 2).

The mean OCVP before and after mandibular advancement surgery was 3.0 ± 1.1 cm^3 and 8.7 ± 2.7 cm^3, respectively (Figures 3 and 4). The mean difference was 5.7 ± 1.7 cm^3 and this difference was found to be statistically significant. ($P < .001$) (Table 2). The mean tongue volume before and after mandibular advancement surgery was 34.3 ± 6.6 cm^3 and 41.1 ± 7.0 cm^3 (Figures 5 and 6). The mean difference was 6.9 ± 3.4 cm^3 and this difference was found to be statistically significant ($P < .001$) (Table 2).

Table 1. 12 Case Records With Pre- and Post-Tongue and Oral Cavity Proper Volume[a]

Case Number	Oral Cavity Vol Pre, cm³	Oral Cavity Vol Post, cm³	Difference, cm³	Tongue Vol Pre, cm³	Tongue Vol Post, cm³	Differences, cm³
1	4.9	13	8.1	34.4	48.9	14.5
2	2.9	7.5	4.6	45.9	49.9	4
3	3.4	11.7	8.3	28.5	34.9	6.4
4	0.8	4.7	3.9	37.8	41.9	4.1
5	1.8	4.7	2.9	24.7	30	5.3
6	2	6.1	4.1	38.9	43.1	4.2
7	3.6	10.5	6.9	28.9	33.9	5
8	3.8	9.7	5.9	40.7	46.0	5.3
9	3.4	9.4	6.0	40.2	46.5	6.3
10	4.4	11.2	6.8	34.9	47.9	13
11	2.3	8.4	6.1	30.0	36.3	6.3
12	3.4	8	4.6	26.4	33.3	6.9

[a] Vol indicates volume.

Pearson's Correlation Coefficient Among Different Parameters (Figure 7)

There was a strong positive correlation between OCVP before and after mandibular advancement surgery (0.909); the correlation was found to be statistically significant ($P < .05$). There was a strong positive correlation between tongue volume before and after surgery (0.875); the correlation was found to be statistically significant ($P < .05$). There was a positive correlation ($r = 0.588$) between the mean difference in OCVP and tongue volume before and after mandibular advancement surgery; the correlation was found to be moderately significant at the 0.05 level. No significant correlation ($r = 0.002$) between OCVP and tongue volume before mandibular advancement surgery was found ($P = .995$). No significant correlation ($r = 0.293$) between OCVP and tongue volume was found post mandibular advancement surgery ($P = .355$).

DISCUSSION

The term "oral cavity volume" is a combination of oral cavity proper volume and tongue volume.[11] Oral cavity proper volume is the space between the dorsum of the tongue and hard palate with the space between the ventral surface of the tongue and the floor of the mouth and residual space that includes space between the tongue and teeth. Tongue volume is defined as the portion of the tongue that is present between the palate and the upper and lower dental arches. The boundaries defined for oral cavity proper and tongue volume measurement in this study were almost the same as the boundaries defined by Ding et al.[10]

In this study, the mean post-surgical tongue volume was 41.1 ± 7.0 cm³, which was increased compared to the pre-surgical tongue volume of 34.3 ± 6.6 cm³. There was a positive significant correlation between pre- and post-tongue volume after the BSSO surgical procedure. This increase in tongue volume was due to mandibular advancement for the correction of skeletal Class II. The mean post-surgical tongue volume obtained in this study was almost equal to the value reported by Ding et al in Class I malocclusion.[10] The mean tongue volume reported by Usyal et al.[20] was smaller (31.0 ± 9.8 cm³) compared to the post-surgical tongue volume in the current study. The boundaries

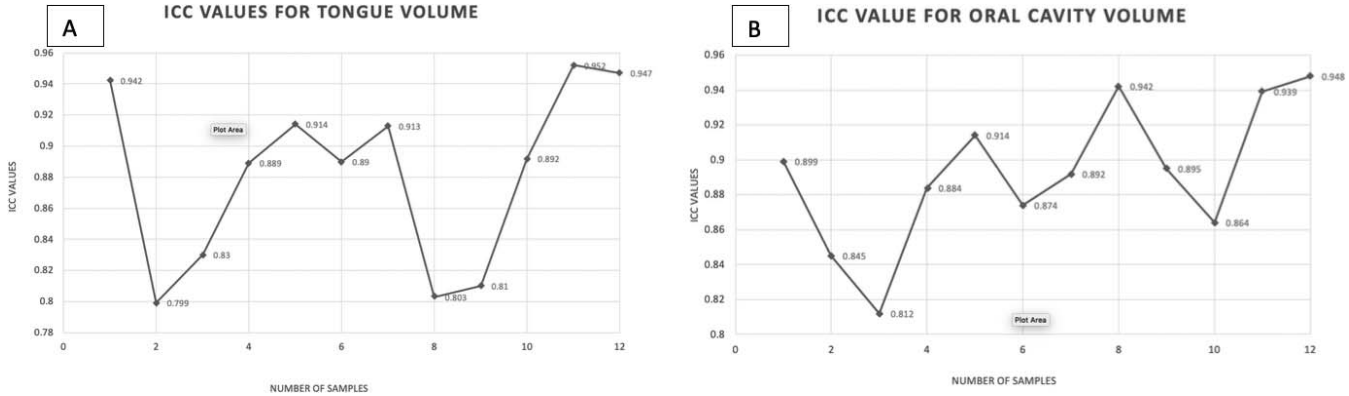

Figure 2. ICC value of: (A) tongue volume; (B) oral cavity proper volume.

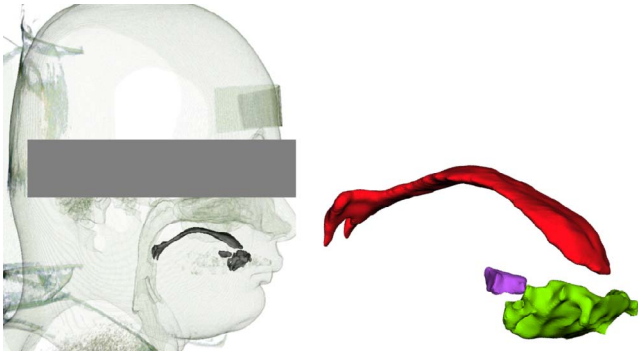

Figure 3. Presurgical OCPV.

defined by Usyal et al.[20] were more superior and anterior, resulting in reduced tongue volume. The tongue volume measured by Humbert et al.[21] using MRI was relatively high (63.3 ± 8.2 cm^3) because they included extrinsic and intrinsic muscles of the tongue, eg, styloglossus and hyoglossus. The tongue, being a soft tissue structure with flexibility in its shape and position, presents difficulty in defining a particular region of the tongue, owing to the intrinsic muscles.

In this study, the mean post-surgical OCVP was 8.7 ± 2.7 cm^3, which was increased almost twice compared to pre-surgical OCPV of 3.0 ± 1.1cm^3. The reason for significant increase in volume in this study was due to the forward positioning of the tongue post-surgically. According to Brown et al., the tongue is a muscular hydrostat and changes in the tongue base influence the whole tongue position.[22] After mandibular advancement, the elongation of the posterior aspect of the tongue would cause superoinferior compression, with the tongue acting as a muscular hydrostat. The forward positioning of the tongue caused an increase in the tongue to palate distance, which in turn resulted in increased OCVP. According to Fatima and Fida, the tongue to palate distance was reduced in skeletal Class II, which was in agreement with the results of this study.[23] A positive correlation between the oral cavity proper volume pre- and post-surgically was observed in this study. In most studies, there was a wide

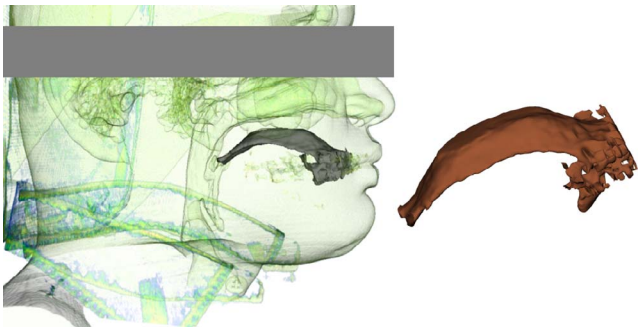

Figure 4. Post-surgical OCPV.

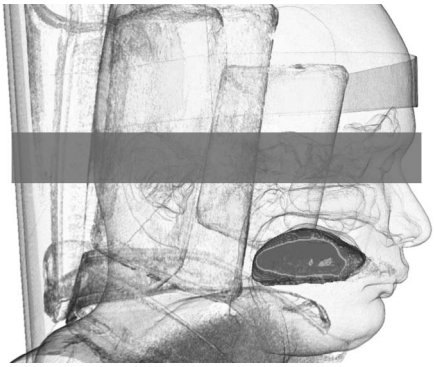

Figure 5. Presurgical tongue volume.

variation seen in the oral cavity proper ranging from 0.42 ± 0.80 to 12.13 cm^3. This large variation could have been due to habitual tongue positioning,[24–26] and the shape and position[25] of the mandible.

Lauder and Muhl[18] evaluated tongue and oral cavity volume with MRI but used different boundaries. They considered the inferior border of the tongue was constructed from the genial tubercle to the hyoid bone; posterior border of the tongue was constructed from the hyoid bone to the vallecula, and oral cavity volume was measured inclusive of tongue volume and the oropharynx. They reported that the ratio of tongue volume to oral cavity capacity was 91% and a correlation existed between the tongue volume and the oral cavity, ie, when the tongue was large, the oral cavity was also expected to be large as well. However, in the current study, the pre- and post-surgical OCVP was evaluated as a space not inclusive of the tongue. In this study, there was no statistically significant correlation between the pre-oral cavity proper and pre-tongue volumes. Similarly, no correlation existed between post-surgical oral cavity proper and post-surgical tongue volumes. Ding et al. also reported that there was no significant correlation between the oral cavity proper volume and tongue volume.[10]

There was a statistically significant, positive correlation between the difference in tongue volume and OCVP volume between pre- and post-surgical values.

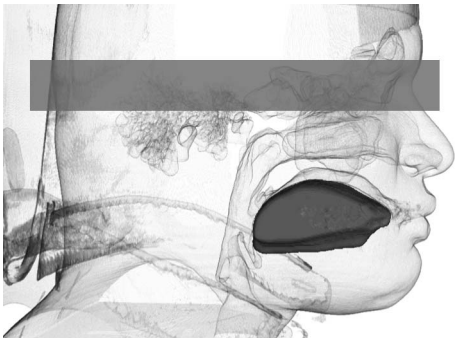

Figure 6. Post-surgical tongue volume.

Table 2. Comparison of Tongue and Oral Cavity Volume Proper Before and After Mandibular Advancement Surgery

Parameter	Presurgery, Mean ± SD	Post-surgery, Mean ± SD	Mean difference	*P* Value
Oral Cavity Volume	3.0 ± 1.1	8.7 ± 2.7	5.7 ± 1.7	<.001***
Tongue Volume	34.3 ± 6.6	41.1 ± 7.0	6.9 ± 3.4	<.001***

* *P* value < .05 is statistically significant; ** *P* value < .01 is statistically highly significant; *** *P* value < .001 is statistically very highly significant.

Presurgically, patients were in skeletal Class II skeletal relation and were corrected to skeletal Class I post surgically. This implied that that tongue volume and OCVP depended on the relative position of the maxilla and mandible.[27]

The null hypothesis was rejected, and there was a significant increase in tongue and oral cavity proper volume in post-surgical BSSO patients.

This volume assessment method would be clinically helpful in:

- Estimating the degree of tongue movement pre- and post-surgically.
- Assessing "in-mouth air cavity" and tongue volume, which is associated with low oxygen saturation level[28] and its management post-surgically.
- Evaluating the degree of tongue enlargement (macroglossia) in patients with acromegaly or Beckwith-Wiedemann syndrome.
- Treatment planning for glossectomy ie, amount of the tongue that needs to be excised, to achieve an ideal oral cavity and tongue volume.

The shortcomings of this study should be mentioned. A radiocontrast agent could have been used for better definition of boundaries. The reproducibility of independent scans is difficult to assess due to the dynamic nature of the tongue and an inability to standardize its position in the oral cavity. However, to overcome the radiation risk, further studies may be conducted by assessing multiple MRI scans to find the mean volume changes.

CONCLUSIONS

- Significant increase in post-surgical tongue and OCVP post-surgery volumes were in accordance with the normative values.
- There was a highly significant positive correlation between pre- and post-tongue volume.

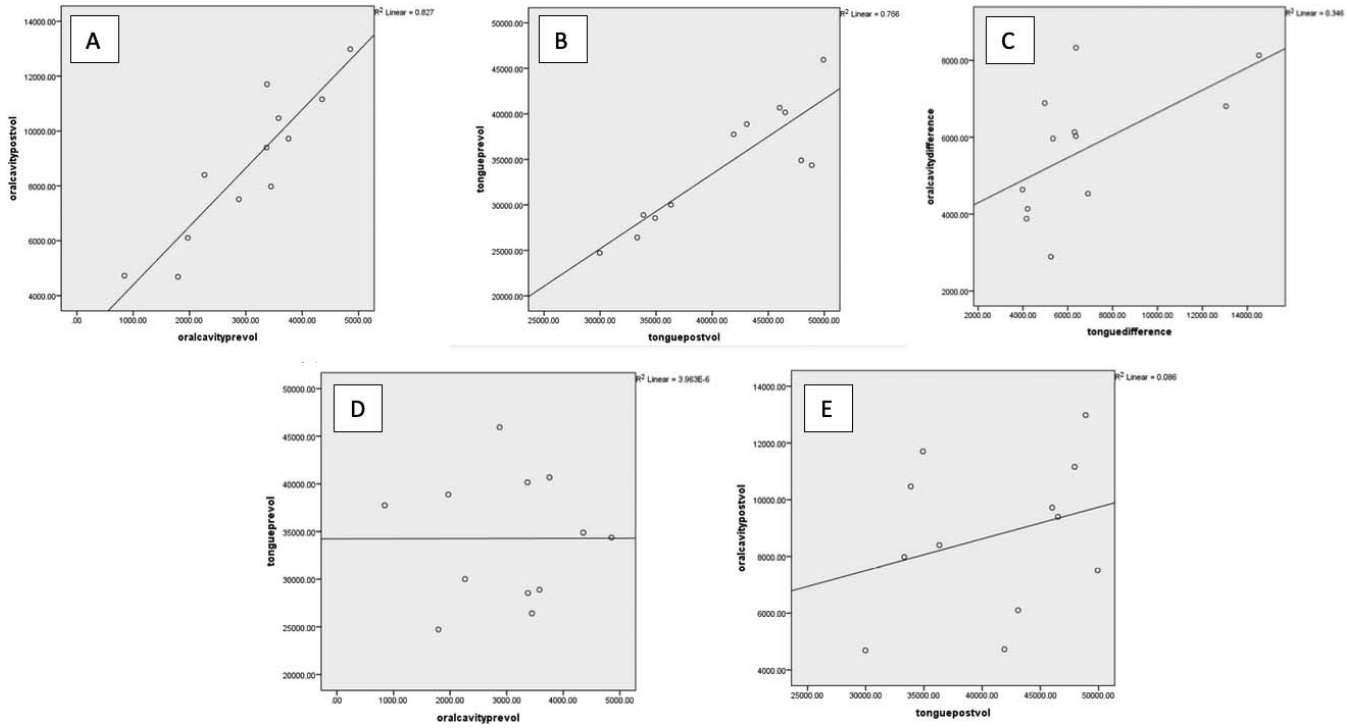

Figure 7. Pearson's correlation coefficients among: (A) OCVP before and after surgery, (B) tongue volume before and after surgery, (C) difference in OCVP and tongue volume before and after mandibular advancement surgery, (D) OCVP and tongue volume before surgery, (E) OCVP and tongue volume after surgery.

- There was a highly significant positive correlation between pre- and post-OCVP.
- There was a positive correlation in the tongue and oral cavity proper volume difference between the pre- and post-surgical values.
- This volume depends on the tongue posture, space around the tongue, and relative position of the maxillary and mandibular skeletal bases.

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