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"The impact of orthognathic surgery on articulation proficiency and speech intelligibility in skeletal Class III malocclusion: 18 months follow up"

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A R T I C L E I N F O

Keywords:
Articulation errors
Speech intelligibility
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Orthognathic surgery
Lefort 1 maxillary advancement
Mandibular setback surgery

A B S T R A C T

Introduction: Orthognathic surgery results in the positional change of the maxilla and mandible that may affect speech. The present study evaluated the effect of combined maxillary advancement and mandibular setback surgery on articulation proficiency and speech intelligibility in patients with non-syndromic skeletal Class III malocclusion.

Methods: In this prospective study, twenty-five patients with skeletal class III malocclusion and consecutively treated with Lefort-1 maxillary advancement and mandibular setback (BSSO) orthognathic surgery were included in this study. The speech sample was recorded with a digital audio tape recorder one day before surgery and at 3, 6, 9, 12 and 18 months after surgery. Three qualified and experienced speech and language pathologists evaluated articulation errors and intelligibility of speech samples. Repeated One-way analysis of variance was used to compare articulation proficiency and speech intelligibility at different time intervals.

Results: The substitution, omission, distortion and addition errors showed no significant changes at 3 months and 6 months. The total articulation errors decreased to zero at 9 months and no significant increase was observed till 18 months ($P < 0.05$). Speech intelligibility showed statistically non-significant improvement at any time interval. Cephalometric skeletal parameters SNA and N ⊥ A°. were significantly correlated with addition and total articulation errors at 18 months follow up.

Conclusions: The ortho-surgical treatment improves speech (decreases. articulation errors) in most of the patients usually 6–9 months post-surgery. Speech intelligibility is not affected by bimaxillary orthognathic surgery in skeletal class III patients. The articulation errors were correlated to changes in position of maxilla.

1. Introduction

Speech is a dynamic and complex process produced by the vocal apparatus, which involves respiration, resonation, articulation, and neuromuscular integrity.[1] The quality of speech may be affected by any change in vocal apparatus due to craniofacial surgical procedure.[2] Orthognathic surgeries are performed in patients to correct skeletal deformities to achieve good aesthetics and occlusal function. The articulating structures viz. tongue, cheeks, teeth, and alveolus coordinate the airflow for speech formation and articulation of the consonants.[3] Several studies have shown an association between skeletal and dental malocclusion and articulation in speech. Subjects with Class III malocclusion tend to have difficulty producing linguo-alveolar consonants that require approximation of tongue tip to alveolar ridge.[4–6] Lathrop-Marshal et al. (2022)[7] showed a higher prevalence of articulation errors in skeletal class III deformities compared to controls with Class I occlusion and skeletal bases. Ninety percent of skeletal Class III subjects suffer speech distortions.[8] Witzel observed a direct correlation between the severity of malocclusion and the number of articulation errors.[2]

Orthognathic surgery results in the positional change of the maxilla and mandible or both to improve dentofacial disharmony. This

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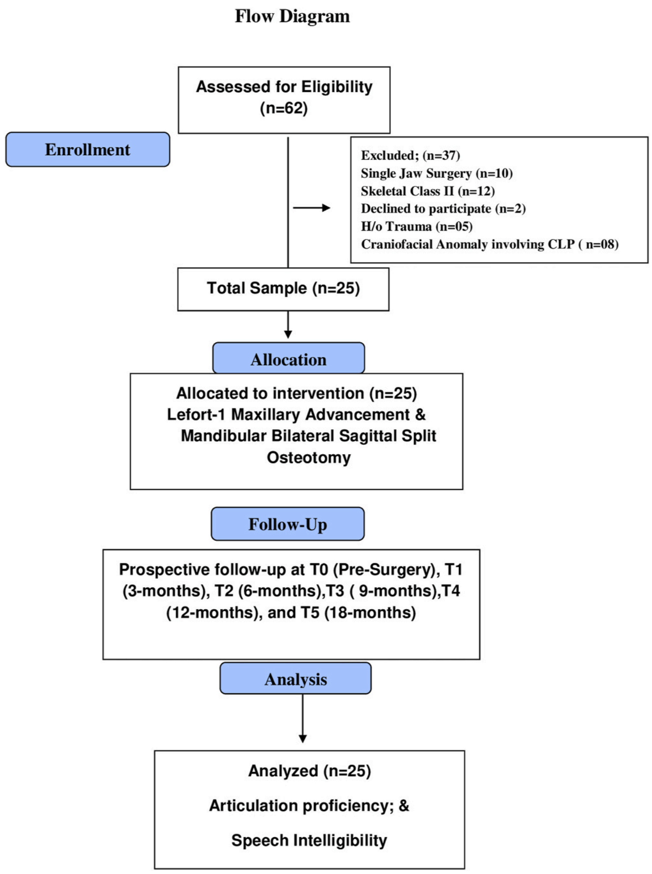

Fig. 1. Flowchart of the study.

procedure brings perceptible changes in the spatial position of the jaws, hyoid bone and larynx that may influence the patient's speech.[9] Various speech characteristics such as articulation, resonance and voice quality can be affected to varying degrees according to the surgery performed.[2]Dalston and Vig (1984)[9] suggested significant changes in nasal-oral acoustic coupling and nasal resistance; however, they observed no effects on articulation proficiency after orthognathic surgeries. A few studies have investigated the effects of mandibular setback surgery on speech characteristics and found improvement in articulation errors.[4,10,11] There is no impact of mandibular advancement on articulation errors whereas maxillary advancement in cleft patients showed an improvement in articulation errors.[12,13] Most of the previous studies did not give any consideration to type of malocclusion and orthognathic surgery during speech evaluation.[5,9] A recent systematic review evaluated the effect of orthognathic surgery on voice and speech and reported that it surgery does not affect vowel production. The most prevalent articulation errors prior to surgery were fricative sounds, mainly/s/and/z/.[14]

Several authors[2,14] evaluated different speech parameters and reported no changes in the speech following orthognathic surgery. In contrast, some authors[9,15–17] have reported articulation errors of speech immediately after orthognathic surgery and found that the errors were reduced over 6–8 months after surgery. A few studies reported improvement in speech after orthognathic surgery.[5,18,19] The previous studies were primarily conducted on small and heterogeneous samples and were followed up for not more than six months. However, the only study by Ghaemi et al. (2021)[20] evaluated the articulation errors, nasalance and speech intelligibility on a homogenous sample of skeletal class III patients and treated by similar bimaxillary surgeries (mandibular setback and maxillary advancement) but the patients were followed up for six months only. There is still no consensus regarding the long term impact of orthognathic surgeries on speech parameters in non-syndromic patients.

Terminology	**Definition**
Substitution	**One sound is replaced by another (e.g., rat for cat)**
Omission	**Sound is omitted from the word (e.g., _at for cat)**
Distortion	**Sound is not produced in appropriate manner but is still recognizable to the listener.**
Addition	**one or more extra sounds are added or inserted into a word (e.g., buhlack for black)**
Speech intelligibility	**how clearly a person speaks so that his or her speech is comprehensible to a listener**

Fig. 2. Definitions of terminologies related to specch

Thus, the objective of this longitudinal study was to evaluate the effect of combined maxillary advancement and mandibular setback surgery on articulation proficiency and speech intelligibility in patients with non-syndromic skeletal Class III malocclusion at 3,6,9,12- and 18-months post-surgery.

2. Material and methods

This longitudinal study evaluated articulation proficiency and speech intelligibility among 25 consecutively treated Skeletal Class III patients of North Indian origin, before and at different time intervals after orthognathic surgery for 18 months. The study was conducted after the ethical clearance from the Institute's ethical committee (NK/3751/MDS/984) and was conducted following the recommendations of the Declaration of Helsinki. The sample size was calculated according to the study by Ghaemi et al. (2021)[20] using mean difference of articulation errors with an effect size of 1.64. The estimated sample size was 24 at power of 90 %. All the patients signed informed and written consent to participate in the study. The inclusion criterion were adult patients with Skeletal Class III bases (a combination of maxillary retrusion and mandibular prognathism) and planned for bimaxillary surgery (Maxillary LeFort I advancement and mandibular BSSO setback). The patients with Skeletal Class III malocclusion were selected based on measurement of parameters ANB angle <0° and Wits < -2 mm on Lateral cephalogram and requiring combined maxillo-mandibular movement of 9–12 mm for surgical correction. The exclusion criteria were patients with cleft lip and palate, history of trauma, craniofacial syndromes, any history of speech therapy and those who cannot read Hindi or English. The same surgeon (VR) operated on all the patients for orthognathic surgeries. The North Indian natives predominantly speak Hindi. A provision was made to include English speaking subjects also in the study by selecting both English and Hindi passages for recording. Since all the subjects could read and speak Hindi, all speech samples were recorded in Hindi. Fig. 1 shows the flow diagram of this study.

2.1. Assessment of speech sample for articulation proficiency and overall speech intelligibility

A Hindi speech sample which was developed and standardized at All India Institute of Speech and Hearing (AIISH), Mysore was used for the purpose of analysis. (Annexure 1)Each subject was made to read 60 words and 20 short sentences. Before the actual recording, the subject was made to read the passage to make him familiar and reduce the factor of fear and anxiety. A single operator recorded speech sample of all the patients in a sound-attenuated room with a digital audio tape recorder (Yamaha Corporation, POCKETTRAK PR, China) kept at a fixed distance of 10 cm. The speech sample for assessment of articulation proficiency and speech intelligibility was recorded one day before surgery (T0), 3 months (T1), 6 months (T2), 9 months (T3), 12 months (T4), and 18 months (T5) after surgery. The speech recording started at presurgical stage and the patient had labial appliances at all stages of evaluation.

Score

0=Normal
1=Can be understood without difficulty however feels that speech isn't normal
2=Can be understood with little effort occasionally need to ask for repetitions
3=Can be understood with concentration and effort by sympathetic listeners. Requires a minimum of repetitions
4=Can be understood with difficulty and concentration especially by family members but not by others
5=Can be understood with effort if the content is known
6=Can't be understood at all if content is known

Fig. 3. 7-point speech intelligibility rating scale by Ali Yavar Jung National Institute for Hearing Handicapped.

Table 1
Sample distribution according to Age and Gender.

	Male Age (years)			Female Age (years)			Total Age (years)		
	N	Range	Mean ± SD	N	Range	Mean ± SD	N	Range	Mean ± SD
Sample (n = 25)	15	17–30	20.46 ± 3.50	10	16–25	20.00 ± 3.00	25	16–30	20.30 ± 3.26

Table 2
Cephalometric Ortho-surgical changes at T0-T2 interval.

Variables	T0	T2	Mean difference (T0-T2)	95 % Confidence Interval		p value
	Mean ± SD	Mean ± SD		Lower	Upper	
SNA°	79.21 ± 6.07	82.56 ± 6.07	−3.36	−4.0425	−2.6695	<0.001***
SNB°	84.11 ± 6.18	81.02 ± 5.63	3.09	2.2545	3.9215	<0.001***
ANB°	−4.90 ± 2.92	1.54 ± 2.28	−6.44	−7.4065	−5.4815	<0.001***
WITS APPRAISAL (mm)	−11.51 ± 4.52	−1.33 ± 2.96	−10.18	−11.6647	−8.6873	<0.001***
N ⊥ A (mm)	−3.37 ± 6.07	−0.37 ± 5.94	−3.00	−4.0091	−1.9909	<0.001***
N ⊥ B (mm)	1.93 ± 10.40	−3.25 ± 9.54	5.18	3.6723	6.6877	<0.001***
N ⊥ Pog (mm)	3.73 ± 11.57	−0.33 ± 10.81	4.06	2.5426	5.5774	<0.001***
FMA°	24.48 ± 6.32	24.67 ± 5.46	−0.20	−1.8449	1.4529	>0.05
SN-MP°	33.37 ± 6.92	33.05 ± 6.47	0.32	−0.8898	1.5218	>0.05

p-value- >0.05- NS=Non-Significant; p-value-(<0.05) = * Significant.

Three qualified and experienced speech pathologists from the Speech and Hearing Unit subjectively evaluated articulation errors and intelligibility of speech samples. The judges were fluent in speaking Hindi. The speech samples were presented in random order for blinded perceptual analysis. The speech sample was analyzed independently for omissions, additions, substitution, or distortions to evaluate the articulation errors (Fig. 2). The number of occurrences of articulation errors was counted. When the ratings of the three judges differed, a consensus rating was established. The average ratings of the three judges for intelligibility were used for evaluation at different time intervals. Ali Yavar Jung National Institute for the Hearing Handicapped (AYJNIHH) 7-point intelligibility rating scale was used to assess overall speech

Table 3
Comparison of mean ± SD changes in articulation errors of Skeletal Class III (n = 25) subjects at different time intervals.

Time interval	Mean ± SD	Substitution	Omission	Distortion	Addition	Total Errors
T0	X±SD	1.41 ± 1.82	0.61 ± 1.43	1.68 ± 3.86	1.73 ± 4.83	5.43 ± 9.44
T1	X±SD	2.13 ± 3.95	1.25 ± 4.2	1 ± 2.45	0.53 ± 1.67	4.91 ± 11.67
T2	X±SD	2.28 ± 4.38	1.20 ± 2.62	1.08 ± 2.16	1.57 ± 3.36	6.03 ± 11.56
T3	X±SD	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T4	X±SD	0.22 ± 0.67	0.00 ± 0.00	0.2 ± 0.62	0.00 ± 0.00	0.42 ± 1.28
T5	X±SD	0.00 ± 0.00	0.13 ± 0.60	0.42 ± 1.41	0.00 ± 0.00	0.55 ± 1.41
T0-T1	MD	−0.73 ± 0.74	−0.64 ± 0.66	0.68 ± 0.59	1.2 ± 1.05	0.51 ± 1.81
	p-value	1.000	1.000	1.000	1.000	1.000
	CI	−3.20–1.75	−2.87–1.59	−1.30–2.65	−2.31–4.71	−3.20–4.71
T0-T2	MD	−0.87 ± 0.71	0.59 ± 0.34	0.59 ± 0.56	0.16 ± 0.66	−0.61 ± 1.13
	p-value	1.000	1.000	1.000	1.000	1.000
	CI	−3.30–1.51	−1.74–0.55	−1.30–2.48	−2.05–2.37	−3.30–2.48
T0-T3	MD	1.41 ± 0.41	0.61 ± 0.32	1.68 ± 0.86	1.73 ± 1.08	5.42 ± 2.11
	p-value	0.055	1.000	1.000	1.000	**0.04***
	CI	0.04–2.77	−0.46–1.68	−1.22–4.57	−1.90–5.35	−1.90–5.35
T0-T4	MD	1.19 ± 0.44	0.61 ± 0.32	1.48 ± 0.89	1.73 ± 1.08	5 ± 2.17
	p-value	0.302	1.000	1.000	1.000	**0.047***
	CI	−0.29–2.67	−0.46–1.68	−1.50–4.45	−1.90–5.35	−1.90–5.35
T0-T5	MD	1.41 ± 0.41	0.48 ± 0.36	1.26 ± 0.95	1.73 ± 1.08	5 ± 1.96
	p-value	0.055	1.000	1.000	1.000	**0.041***
	CI	0.04–2.77	−0.73–1.68	−1.93–4.44	−1.90–5.35	−1.93–5.35

p-value- >0.05- NS = non-Significant; p-value-(<0.05) = * Significant.
CI – Confidence Intervals.

Table 4
Gender-wise comparison of articulation errors of Skeletal Class III (n = 25) subjects at different time intervals.

	T0			T1			T2			T3			T4			T5		
	Mean ± SD			Mean ± SD			Mean ± SD			Mean ± SD			Mean ± SD			Mean ± SD		
	Male	Female	P value	Male	Female	P value	Male	Female	P value	Male	Female	P value	Male	Female	P value	Male	Female	P value
Substitution	0.0 ± 1.93	0.86 ± 1.46	0.29	2.62 ± 4.63	1.29 ± 2.36	0.64	3.23 ± 5.34	0.71 ± 1.25	0.49	0 ± 0	0 ± 0	1.00	0.15 ± 0.56	0.29 ± 0.76	0.65	0 ± 0	0 ± 0	1.00
Omission	0.85 ± 1.82	0.14 ± 0.38	−0.53	1.85 ± 5.13	0 ± 0	0.29	1.77 ± 3.14	0 ± 0	0.07	0 ± 0	0 ± 0	1.00	0 ± 0	0 ± 0	1.00	0 ± 0	0 ± 0	1.00
Distortion	2.15 ± 4.79	0.71 ± 0.95	0.66	1.38 ± 2.99	0.14 ± 0.38	0.53	1.38 ± 2.66	0 ± 0	0.11	0 ± 0	0 ± 0	1.00	0.15 ± 0.56	0.29 ± 0.76	0.65	0.62 ± 1.71	0 ± 0	0.29
Addition	2.46 ± 5.78	0.29 ± 0.76	0.53	0.77 ± 1.92	0 ± 0	0.29	2.15 ± 3.96	0.29 ± 0.76	0.35	0 ± 0	0 ± 0	1.00	0 ± 0	0 ± 0	1.00	0 ± 0	0 ± 0	1.00
Total Errors	7.15 ± 11.5	1.86 ± 2.19	0.68	6.83 ± 14.2	1.33 ± 2.35	0.36	8.65 ± 13.7	1.14 ± 2.14	0.11	0 ± 0	0 ± 0	1.00	0.33 ± 1.2	0.57 ± 1.51	0.70	0.62 ± 1.71	0 ± 0	0.29

p-value- >0.05- NS = non-Significant; p-value-(<0.05) = * Significant.
CI – Confidence Intervals.

Table 5
Mean ± SD changes in Speech Intelligibility of Skeletal Class III (n = 25) subjects at different time intervals.

Time interval	Mean ± SD	P-value	Confidence intervals	
			Upper	Lower
T0	0.29 ± 0.47	–	–	–
T1	0.23 ± 0.42	–	–	–
T2	0.12 ± 0.31	–	–	–
T3	0.00 ± 0.00	–	–	–
T4	0.10 ± 0.31	–	–	–
T5	0.05 ± 0.16	–	–	–
T0-T1	0.06 ± 0.49	1.000	−0.31	0.43
T0-T2	0.18 ± 0.34	1.000	−0.08	0.43
T0-T3	0.29 ± 0.47	1.000	−0.06	0.65
T0-T4	0.19 ± 0.61	1.000	−0.27	0.65
T0-T5	0.24 ± 0.40	1.000	−0.16	0.64
T1-T2	0.12 ± 0.29	1.000	−0.10	0.34
T2-T3	0.12 ± 0.31	1.000	−0.12	0.35
T3-T4	−0.10 ± 0.31	1.000	−0.33	0.13
T4-T5	0.05 ± 0.36	1.000	−0.14	0.24

p-value- >0.05- NS=Non-Significant; p-value-(<0.05) = * Significant.

intelligibility.[21](Fig. 3).

2.2. Intra and inter-rater reliability

The internal consistency of judgment among speech pathologists was evaluated by duplicating the eight random recordings and assessed after three weeks interval without the knowledge of judges. The intra and inter-class correlation coefficient was between 0.792 and 0.990, indicating a good to excellent agreement among the three judges.

The investigator was calibrated for registration, landmark identification and measurements on lateral cephalogram. The intra-examiner reliability was assessed by repeating the measurement of selected parameters on 10 % of the all the lateral cephalogram selected randomly after and interval of three weeks. The ICC ranged from 0.938 to 0.999 which indicated excellent reliability.

2.3. Statistical analysis

Statistical Package for Social Sciences version 25 (IBM SPSS statistics) for Windows software was used for statistical analysis. Descriptive statistics, including means and standard deviations, were calculated. Repeated One-way analysis of variance was used to compare articulation proficiency and speech intelligibility. The level of significance was set at $P < 0.05$.

3. Results

The age range of the total sample was 16–30 years with a mean age of 20.30 ± 3.26 years (Table 1). Gender distribution showed 15 males and 10 females participated in the study. Table 2 shows the cephalometric skeletal changes at 6 months post-surgery. Table 3 shows the changes in articulation errors at T1, T2, T3, T4 and T5 of follow up. There was an initial increase in substitution and omission errors at 3 months of surgery followed by a gradual decrease to zero at 9 months of follow up. The substitution, omission, distortion and addition showed no significant changes at T1 and T2. The errors decreased to zero at T3 and the decrease was maintained at T4 and T5 of follow up. The total articulation errors showed no significant differences at T1 and T2. The total articulation errors decreased to 0 at T3, and the decrease in the total articulation errors was significant at a time interval (T0-T3), presurgical to T3 (Table 3). The decrease in articulation errors was maintained at T4 and T5 of follow up. Table 4 shows the gender wise comparison of articulation errors and no significant differences were found. Table 5 showed a regular improvement in speech intelligibility from T0 to T3 but the differences were non-significant at all time intervals. Table 6

Table 6
Correlation between Articulation Errors and Ortho-surgical cephalometric changes following bimaxillary surgery.

Skeletal parameters		Substitution (T0-T5)	Omission (T0-T5)	Distortion (T0-T5)	Addition (T0-T5)	Total (T0-T5)
SNA ° (T0 -T1)	Pearson Correlation ρ	0.185	0.324	0.215	**0.525***	**0.465***
	P value	0.435	0.164	0.362	**0.018**	**0.039**
SNB° (T0 -T1)	Pearson Correlation ρ	0.252	0.228	0.272	0.067	0.233
	P value	0.284	0.334	0.247	0.780	0.323
N⊥A (T0 -T1)	Pearson Correlation ρ	0.306	0.334	0.186	**0.466***	**0.448***
	P value	0.189	0.150	0.432	**0.038**	**0.048**
N⊥B (T0 -T1)	Pearson Correlation ρ	0.286	0.294	0.281	0.080	0.262
	P value	0.221	0.208	0.231	0.736	0.265
N⊥Pog (T0 -T1)	Pearson Correlation ρ	0.331	0.315	0.281	0.082	0.275
	P value	0.154	0.177	0.230	0.732	0.240

p-value- >0.05- NS = non-Significant; p-value-(<0.05) = * Significant.

shows the correlations between the cephalometric skeletal changes and the articulation errors. Cephalometric skeletal parameters SNA and N ⊥ A°. were significantly correlated with addition and total articulation errors at 18 months follow up.

4. Discussion

In the present study, the articulation errors and speech intelligibility were evaluated with long term follow up of 18 months on a homogenous sample of skeletal Class III patients treated with bimaxillary surgery. The earlier studies showed increased articulation errors in patients with anterior-posterior jaw discrepancies similar to the present study.[7,22] The total articulation errors and all the individual errors (Substitution, Omission, Distortion and Addition) decreased significantly post-surgically at 9, 12, 18 months of follow up. Ghaemi et al. (2021)[20] showed a decrease in articulatory errors after orthognathic surgery similar to the observations of the present study. The sample had similar malocclusion but the mean maxillo-mandibular discrepancy was in range of 4–8 mm whereas it was 9–12 mm in the present study. An important finding in the present study different from previous studies was that there was an initial increase in substitution and omission errors at 3 months of surgery followed by a gradual decrease to zero at 9 months of follow up. The initial increase may be due to the sudden change in spatial position of the maxilla and mandible and neuromuscular adaptation of the surrounding tissues with time must have improved the articulation errors.

Lee et al. (2002)[19] **and** Glass et al. (1977)[16] found improvement in articulation errors after mandibular setback in skeletal Class III patients on a sample of five patients. The results of these studies cannot be compared because of smaller sample size and different surgeries. **Though,** Ruscello et al. (1986),[5] Geffen (1978)[23] **and** Vallino (1990)[18] showed a decrease in articulation errors post surgically but the sample included in the study was small and heterogeneous with various malocclusion. Dalston and Vig (1984)[9] on 6–8 months follow up showed that the surgery had no long-term effects on articulation proficiency but the sample had heterogeneous malocclusion and different types of surgeries were conducted whereas the present study included homogenous sample and with same surgeries.

Goodstein et al. (1974)[15] showed non-significant changes in articulation errors after the correction of mandibular prognathism with mandibular osteotomy. The follow up period of 8-weeks was very short for the soft tissue adaptation and responsible for no significant changes, whereas significant improvement of articulation errors was observed after 9 months in the present study. Ward et al. (2002)[24] showed improvement in Articulatory precision and intelligibility in one patient out of 5 patients but the sample size was very small and included heterogeneous malocclusion, thus the results are difficult to be accepted and compared.

In the present study, there was an improvement in speech intelligibility corresponding to the improvement in the articulation errors though the level of improvement was not statistically significant. The results are similar to the previous studies by Ghaemi et al. (2021)[20] and Vallino (1990)[18] who also showed an improvement in speech intelligibility.

The present study observed an improvement of articulation errors at 9 months after surgery that was stable at follow up of 18 months.

4.1. Clinical implications

The ortho-surgical treatment may decrease the articulation errors and improve speech intelligibility in most of the patients usually 6–9 months after surgery.

4.2. Limitations and future perspectives

The speech assessment was subjective in the present study. The subtle changes in articulation not perceptible manually may be assessed objectively by acoustic analysis. The present study was conducted on only patients treated for skeletal Class III malocclusion. The reduced number of participants may have contributed to the absence of some significant results. The future studies may evaluate speech in other malocclusions viz open bite, skeletal Class II. The speech assessment was done along with orthodontic appliances which can be a confounder in articulation proficiency.

5. Conclusions

The ortho-surgical treatment improves speech (decreases. articulation errors) in most of the patients usually 6–9 months post-surgery. Speech intelligibility is not affected by bimaxillary orthognathic surgery in skeletal class III patients. The articulation proficiency is affected by change in spatial position of maxilla due to surgery.

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Declaration of competing interest

There is no conflict of Interest.

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