Influence of surgical tongue reduction on pressure from the tongue on the teeth

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In previous articles, we have reported: a) the effect of surgical tongue reduction on the rest position of the tongue and the mandible,[1] and b) measurements of the pressure from the tongue on the teeth in a group of young adults with normal occlusion.[2,3] Surgical reduction of the tongue in a group of 27 adolescents and young adults with a clinical diagnosis of macroglossia had no adverse effects on oral stereognosis or motor ability as revealed by performance tests.[1] The reduced tongue size resulted in an increase in the distance between the dorsum of the tongue and the palate in the rest position and a decrease in the freeway space of the mandible. After the operation, the tongue did not fill the oral cavity as much as it had before surgery, which could explain the decreased freeway space.

Macroglossia is blamed by some orthodontists for causing or maintaining openbite, bimaxillary protrusion or spacing. The subjects studied by Ingervall and Schmoker[1] were referred for tongue reduction because they had one or more of these problems. A too-large tongue, by exerting an expansive force on the dental arches or by being interposed between the arches, is thought to constitute an important etiologic factor for the malocclusions mentioned.

Abstract

Pressures from the tongue on the teeth were recorded in 21 children and adolescents before and after surgical reduction of the tongue. The recordings were made before surgery, and 6 and 12 months after the operation. Simultaneous measurements were made at the lingual surfaces of the maxillary and mandibular central incisors and at the left first molar, in the rest position and during chewing and swallowing. The method had been used in a previous study of normal cases, which served as a reference.

Presurgical pressures recorded in the rest position at the maxillary incisors agreed with measurements recorded in the same location in the reference sample. Measurements recorded during rest in the other locations were somewhat higher than those of the reference group. Pressures recorded before the surgery during chewing and swallowing varied from similar measurements made in the reference group. At the recording 6 months after surgery, resting pressures at the molars were lower than they had been presurgically. No significant differences were found for pressures during chewing. A lower pressure was recorded in one location during swallowing. At the recordings made 12 months after surgery none of the pressures differed significantly from the presurgical values. Resting pressures were, however, lower than they had been before surgery and were closer to those of the reference sample.

Key Words

Tongue pressure • Macroglossia • Tongue surgery

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Figure 1A

Figure 1B

Figure 1A-B
Incision lines on upper (a) and lower (b) tongue surface

The expansive effect of the tongue was substantiated recently by Tamari et al.,[4] who found a positive correlation between the volume of the tongue and the size of the mandibular arch. This expansive effect of the tongue could manifest itself as high pressure on the lingual surfaces of the teeth; pressure that would, presumably, decrease when the size of the tongue is surgically reduced. Whether or not the pressure from the tongue on the teeth actually changes after tongue reduction is not known, however, the effect of surgery on the position of the tongue in the oral cavity, found in a previous study,[1] makes effects on the tongue's pressure on the teeth conceivable.

The method we developed to measure pressure from the tongue on the teeth[3] is suitable for the evaluation of such pressures before and after surgical tongue reduction. From previous studies using this method, reference values for pressures in a group with normal occlusion and tongue size are available for comparison. The aim of the present investigation was therefore to study pressure from the tongue on the teeth during various natural functions in individuals with enlarged tongues. Measurements were made before and after surgical reduction of the tongue and the pressures recorded were compared with values of a reference sample.

Material and methods

Subjects

Eleven boys and 10 girls, 9 years 7 months to 19 years 5 months old (median age 15 years 3 months) participated in the study. Each subject's Angle classification was evaluated from dental casts; eleven subjects were Class I, two were Class II and eight were Class III. Twelve subjects had anterior openbite and seven had posterior openbite. Unilateral or bilateral posterior lingual crossbite was found in 14 subjects and anterior crossbite was found in two subjects. Space anomalies — the surplus or lack of 2 mm or more — were recorded in the canine-premolar and incisor segments. In the maxilla, spacing was found in one incisor segment (due to congenitally missing lateral incisors) while crowding was found in four canine-premolar segments. In the mandible, spacing was recorded in four canine-premolar segments (due to congenitally missing or extracted premolars) and crowding in two canine premolar segments and one incisor segment. Four premolars had been extracted in three subjects.

The subjects had been referred to the maxillofacial surgeon by orthodontists. All partial tongue resections were performed by the same surgeon (R.S.) on the grounds of the morphologic malocclusions mentioned and a diagnosis of macroglossia. The diagnosis of macroglossia was based on the clinical observation of a discrepancy between the size of the tongue and the size of the oral cavity. This diagnosis was made primarily by the referring orthodontist, who in most cases had observed or treated the patient for some time, and was confirmed by the surgeon at his examination. The surgical procedure for the reduction of the tongue is described in detail in an earlier report.[5] The incision lines are shown in Figure 1. After the operation, the volume and weight of the part removed were determined. On average, 14 ml (range, 8 to 20 ml) weighing 14 g (range, 9 to 22 g) was removed.

Tongue pressures were recorded on two occasions before surgery. The first recording was made in all subjects 183 - 1 day (median time 27 days) before surgery. The second recordings were made in 15 subjects 6 - 1 day (median 1 day) before the operation. Six subjects were excluded from the second presurgical recording due to technical difficulties in three cases and the presence of a palatal appliance in three subjects. The first series of postsurgical recording was made in 19 subjects 155 - 254 (median 190) days after the operation. This recording could not be done in two subjects because of palatal appliances. A second postsurgical set of recordings was made in 17 subjects 344 - 484 (median 380) days after the operation. Four subjects were excluded from the second postsurgical recording because maxillo-facial surgery had been perfomed. Three subjects had maxillary and mandibular multibanded orthodontic appliances at one or both of the presurgical recordings. Eleven subjects had such appliances at the first and 10 at the second postsurgical recording sessions. None

of the subjects had palatal or lingual arches at the time of the pressure recordings.

Measurement of the pressure from the tongue on the teeth

Pressure from the tongue on the lingual surfaces of the teeth was measured simultaneously:

1) in the interdental space between the maxillary central incisors (maxillary incisor);

2) in the interdental space between the mandibular central incisors (mandibular incisor);

3) in the interdental space between the maxillary left second premolar and first molar (maxillary molar); and

4) in the interdental space between the mandibular left second premolar and first molar (mandibular molar).

In each of these positions an open cannula, embedded in a small custom-made acrylic shield (mouthpiece), was attached (Figure 2A-D). The other end of the cannula was connected via a flexible tube to an extra-oral measuring system consisting of a bottle of water and compressed air, a pressure transducer and a flow-limiting valve. The pressure caused a small, constant stream of water to escape through the cannula. When the tip of the cannula was covered by the tongue, resistance was offered to the escape of the water. This increased the pressure in the water system and the increase was recorded by the pressure transducer. The recordings reflect pressure from the tongue on the mouthpiece. The same method of recording pressure from the tongue on the teeth has been used in a previous study[3] and details of the system, including the calibration procedure, are described in an article by Thüer et al.[6]

Pressure from the tongue on the teeth was measured:

1) with the mandible and the tongue in the rest position;

2) during two acts of swallowing water (on command);

3) in the rest position once again; and

4) during two acts of swallowing 7 cm^2 of crispbread.

Electromyographic recordings

Simultaneous with the pressure registrations, activities of the right anterior temporal muscle and the muscles of the floor of the mouth were recorded electromyographically as described earlier.[2] Temporal muscle activity was recorded to evaluate the phase of the chewing cycle and to identify the act of swallowing. Activity of the muscles of the floor of the mouth was recorded to monitor the rest position of the tongue; rest position was attained after a command swallow. The electromyographic signal of the muscles of the floor of the mouth was displayed on an oscilloscope, which was placed in front of the subject who could then follow the activity of the muscles of the floor of the mouth (including the muscles of the tongue) and better keep the tongue at rest for the pressure recording.

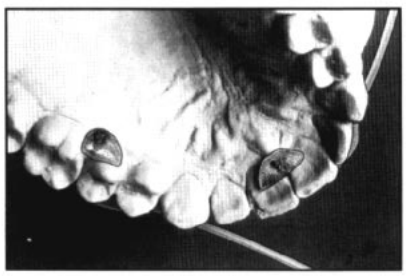

Figure 2A

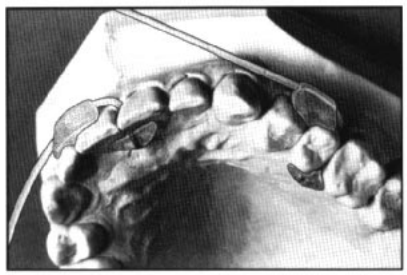

Figure 2B

Figure 2C

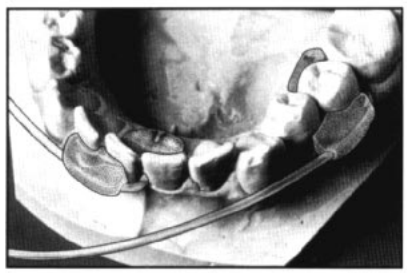

Figure 2D

Figure 2A-D Mouthpieces for the measurement of the pressures in the maxilla and mandible

Analysis of the pressure recordings

Signals from the pressure transducers and the electromyographic device were recorded on an electrostatic writer (GOULD ES 1000) and analyzed on the paper strip of the writer. The characteristic level of pressure at rest was established when the recording showed a constant pressure level with simultaneous minimal activity of the muscles of the floor of the mouth for at least 5 seconds. The measurements from the two recordings at rest were averaged. The maximum pressures during two acts of swallowing were measured and averaged. The maximum pressures during four chewing cycles in the middle of each of two acts of chewing were measured and averaged.

Statistical methods

Systematic differences between repeated recordings were evaluated with Wilcoxon's matched-pairs signed-ranks test and accidental errors, si, (standard deviation of the single observation) calculated with the formula

$$s_i = \sqrt{\frac{Sd^2}{2n}}$$

where d is the difference between the duplicate measurements. Differences between distributions were tested at the 5% level with Wilcoxon's matched-pairs signed-ranks test adjusted according to Bonferroni-Holm.[7] Correlations between

Table 1
Accidental errors of the method (s_i) in g/cm² for duplicate recordings of tongue pressure in 15 subjects and s_i-value in percent of pooled standard deviation for the two series of recordings.

	S_i	S_i in %
Rest position		
Maxillary incisor	5.22	70
Mandibular incisor	8.40	54
Maxillary molar	4.51	48
Mandibular molar	7.05	57
Chewing		
Maxillary incisor	8.24	54
Mandibular incisor	40.03	58
Maxillary molar	28.94	42
Mandibular molar	43.05	51
Swallowing		
Maxillary incisor	174.07	93
Mandibular incisor	113.69	72
Maxillary molar	154.03	99
Mandibular molar	148.40	83

variables were tested with Spearman's rank-correlation. In the text and in the tables, a probability of $0.01 < P < 0.05$ is designated *, a probability of $0.001 < P < 0.01$ **, and a probability of $P < 0.001$ ***.

Results

Reproducibility of the pressure recordings

The errors of the method were evaluated from the duplicate recordings made before surgery. Only one variable differed significantly between the two recordings: the swallowing pressure at the maxillary incisor was larger at the second recording than at the first ($0.01 < P < 0.05$). The accidental errors of the method (including the intra-individual variation) were great (Table 1). Relative to the inter-individual variation (s_i in per cent), the intra-individual variation seemed to be somewhat greater for the pressure recording during swallowing than for the other two functions.

Average pressure values

The median values and the range of variation for the pressures recorded are given in Table 2. The presurgical values are based on the mean of the two presurgical recordings. The pressures found during all functions studied (rest, chewing and swallowing) were characterized by a large range of variation. The median pressures in the rest position were small and, on all three occasions, negative at the maxillary incisor. On all occasions, many individuals had negative readings, especially at the maxillary incisor.

At the presurgical recording, pressure in the rest position at the maxillary incisors was significantly lower than at the other locations and pressure at the maxillary molar was lower than at the mandibular molar. At the recording 6 months after surgery, there were no significant differences between the resting pressures recorded in the four locations. Twelve months after surgery, resting pressure was lower at the maxillary incisors than at the molars.

Chewing pressure at the presurgical recording was significantly lower at the maxillary incisors than at other locations, while pressure at the mandibular molar was larger. Recordings made 6 months after surgery show that chewing pressure was significantly lower at the maxillary incisor than at the mandibular molar. At 12 months, chewing pressure at the maxillary incisor was lower than at the mandibular incisor and molar. Pressures during swallowing did not differ significantly among the four locations of measurement on any of the three occasions. Negative pressures during chewing and swallowing were rare.

Pressure recorded during rest at the molars decreased significantly from the presurgical to the 6 months postsurgical recordings, but there were no significant differences when the presurgical and the 12 month postsurgical recordings were compared. Pressures recorded during chewing did not change significantly during the period of observation. Pressure at the maxillary incisor during swallowing decreased significantly from the presurgical to the 6 months postsurgical recording, but was not significantly different when the recordings before and 12 months after surgery were compared. Thus, none of the pressures found at the 12 month postsurgical recording differed significantly from the presurgical pressures.

Pressures recorded before surgery were not significantly correlated to pressures found in the same location and during the same function at the recording 12 months after surgery, with one exception. Thus, there was a positive correlation between the presurgical chewing pressure at the maxillary molar and the pressure found at the 12-month postsurgical recording (rho= 0.46*). There were no significant correlations between the size (volume, weight, length or width) of the removed part of the tongue and the change of the pressures recorded before and 12 months after the operation.

Correlations between the presurgical pressures recorded in four locations

Pressure in the rest position at the maxillary incisor recorded before surgery was not significantly correlated to the resting pressures in the other locations on the same occasion. Resting

Table 2
Median and range of variation (in g/cm²) of the pressures recorded in the different positions on each occasion and the number of individuals with a negative pressure value.

	Before surgery (n = 21)			6 months after surgery (n = 19)			12 months after surgery			
	Median	Range	Negatives**	Median	Range	Negatives	n	Median	Range	Negatives
Rest position										
1. Max incisor	-1.0	-13.9 - 20.3	14	-1.0	-14.9 - 45.9	12	17	-3.7	-13.0 - 4.3	13
2. Mand incisor	3.8	-8.3 - 70.7	5	0.4	-7.0 - 26.9	7	17	0.7	-12.4 - 19.4	6
3. Max Molar	3.0	-2.4 - 32.7	4	-0.8*	-5.1 - 8.6	12	17	1.8	-3.2 - 21.3	6
4. Mand molar	8.2	-12.3 - 40.8	3	-0.1*	-4.6 - 16.6	10	17	0.5	-3.1 - 26.7	7
Significant difference 1-2	3-4							1-3		
1-3								1-4		
1-4										
Chewing										
1. Max incisor	6.9	-3.7 - 58.7	2	10.9	-10.0 - 93.0	1	15	15.9	0.8 - 63.8	0
2. Mand incisor	40.4	0.3 - 321.2	0	21.4	3.0 - 150.2	0	15	50.0	7.1 - 240.8	0
3. Max molar	37.6	0.0 - 254.8	0	20.3	-1.4 - 251.8	1	15	39.4	1.0 - 199.7	0
4. Mand molar	111.1	8.1 - 317.9	0	73.1	0.7 - 297.7	0	15	116.5	4.7 - 416.1	0
Significant differences 1-2	2-4			1-4				1-2		
1-3	3-4							1-4		
1-4										
Swallowing										
1. Max incisor	128.3	-0.7 - 493.3	1	107.8*	0.0 - 509.0	0	17	123.5	-20.1 - 482.6	1
2. Mand incisor	212.7	3.4 - 558.9	0	181.9	-18.9 - 644.4	1	17	214.7	52.7 - 404.3	0
3. Max molar	172.3	2.0 - 516.5	0	183.9	10.1 - 485.0	0	17	191.3	2.7 - 557.1	0
4. Mand molar	241.0	44.6 - 670.6	0	107.3	10.9 - 555.5	0	17	245.0	23.0 - 568.4	0

* indicates significant difference from the presurgical recording
** Number of individuals with a negative value

pressure at the mandibular incisor, on the other hand, was positively correlated to the maxillary and mandibular molar pressures (rho = 0.60** and 0.62**, respectively). There was also a correlation between the maxillary and mandibular molar resting pressures (rho = 0.82***).

The significant coefficients of correlation between the presurgical pressures recorded in the four locations during chewing and swallowing, respectively, are given in Table 3. Swallowing pressures recorded in the four locations were all positively intercorrelated. This was also the case for pressures recorded during chewing except that no significant correlation was found between chewing pressure at the maxillary incisor and at the mandibular incisor and molar.

Correlations between presurgical pressures recorded in the same location during different functions

There were no significant correlations between pressures recorded at the maxillary incisor during

Table 3
Coefficients of correlation between the pressures recorded in the four locations during chewing and during swallowing (*italics*)

	Maxillary incisor	Mandibular incisor	Maxillary molar	Mandibular molar
Maxillary incisor				
Mandibular incisor	*0.56***			
Maxillary molar	0.52**	0.45*		
	*0.81****	*0.54***		
Mandibular molar		0.46*	0.53**	
	*0.55***	*0.40**	*0.73****	

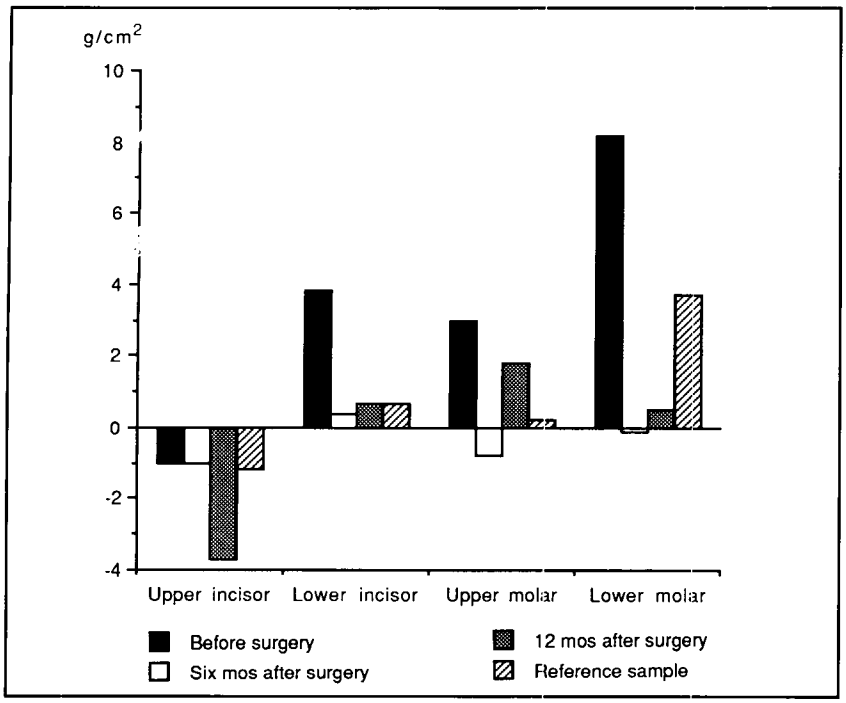

Figure 3
Median pressures in the rest position on the three occasions of recording as well as the pressures in the reference sample of Fröhlich et al.[3]

the three functions studied. Pressures recorded at the mandibular incisor at rest and during chewing and swallowing were all positively correlated (rho = 0.56** - 0.72***). The same was true for pressures recorded at the mandibular molar (rho = 0.66** - 0.71***). Pressures recorded at the maxillary molar at rest and during chewing were positively correlated (rho= 0.79***) while no significant correlations were found between resting and swallowing pressures or between chewing and swallowing pressures.

Discussion

In the present study it was not possible to evaluate the clinical effects of the partial glossectomy. This would have been highly interesting but was impossible because of the heterogeneity of the material. Thus all three Angle Classes were represented among the subjects, some of whom had anterior openbite, others posterior openbite, and still others no such malocclusion. Furthermore, some individuals wore multibanded appliances at the time of the presurgical recordings and about half of the subjects did so by the postsurgical recordings. It would have been impossible to differentiate between the effects of the tongue reduction and the mechanotherapy. Instead we took the opportunity to study the effect of this surgical procedure, partial glossectomy, on the actual pressures from the tongue on the teeth.

Pressures were recorded with the same method used in an earlier study of 20 dental students (18 men and 2 women) aged 23-35 years, median age 26 years.[3] The dental students had clinically normal occlusion and tongue size. When comparing the results, it should be kept in mind that the subjects in the present study were younger and that the sex distribution was even. It is not known whether sex and age (in the range of this and the previous study) have an influence on the pressures recorded. It is clear, however, that the method of pressure recording influences the results considerably. Thus, for example, the projection of the point of measurement above the tooth surface and the ability of the system to record negative pressure are important factors.[2] We know of no other system for the measurement of pressures on the teeth that can record negative pressure at the point of measurement.

The accidental errors of the method in the recordings in the rest position were somewhat greater in this study than in the study on dental students. No great differences between the two investigations in the reproducibility of the recordings during chewing were found. The accidental errors in the recordings during swallowing were, however, considerably greater in this investigation than in the study on dental students.

When the median presurgical pressures in the rest position are compared with those of the previous investigation,[3] very good agreement is found for pressure at the maxillary incisor. Pressures in the other locations, however, are larger than those in the reference sample (Figure 3). Also, a considerably greater range of variation was noted in this study for the pressures recorded at all points of measurement. Comparable proportions of individuals with negative resting pressures were found in both investigations. The relationship between the resting pressures recorded at the four different points of measurement before surgery was the same in this sample of individuals with macroglossia as in subjects with normal tongue size.[3] Thus, in both studies, the lowest resting pressure was found at the maxillary incisor and the highest at the mandibular molar.

The median presurgical pressures recorded during chewing were very similar to those in the study on dental students except for the very low value recorded at the maxillary incisor in this investigation. The reason for this exception is not known but it may be a result of the morphological deviations of the dentitions of the present subjects. As in the previous study on dental students, the highest chewing pressure was found at the mandibular molar. The presurgical median pressures during swallowing were lower at the maxillary incisor, similar at the maxillary molar and higher at the mandibular incisor and molar than

in the study on dental students. Both for chewing and swallowing, the ranges of variation in the present sample were generally greater than in the reference group while the groups were similar regarding the rare occurrence of a negative pressure.

The patterns of correlation between the presurgical pressures recorded at the four points of measurement in the rest position and during swallowing, respectively, were identical and those during chewing were very similar in this study and in the investigation on dental students. The correlations between the pressures recorded at a point of measurement during various functions were only partly the same as in the previous study. Thus, in this investigation no correlations were found between the chewing and swallowing pressures at the maxillary incisor and molar while, on the other hand, the pressures recorded in the mandible were all intercorrelated, which was not the case in the previous study.

At the recording 6 months after surgery, 9 of the 12 median pressures were numerically smaller than before the operation. A significant difference was, however, found for only three variables (the resting pressure at the maxillary and mandibular molars and the swallowing pressure at the maxillary incisor). At the recording 12 months after surgery, however, none of the pressures was significantly different from the presurgical values. In fact, the median pressures during chewing and swallowing were astonishingly similar to the presurgical values. Twelve months after surgery, lower resting pressures were found at the maxillary incisor and mandibular molar than in the reference sample. At the mandibular incisor, the same median resting pressure was noted as in the study on dental students while the resting pressure at the maxillary molar was somewhat higher but closer to the value in the group of students than before surgery. Although no significant differences in resting pressures were found after 12 months compared to the presurgical pressures, there was a tendency to "normalize" these pressures.

Pressure from the tongue on the teeth in the rest position is considered more important for the position of the teeth than pressure during chewing and swallowing.[8] The reason is the much greater duration of resting pressure during the day and night. From the results of the present study, it is difficult to say whether surgical reduction of the tongue is meaningful regarding the pressures from the tongue on the teeth. Before the operation, resting pressures from the tongue were higher than in the reference sample of individuals with normal occlusion and tongue size, but not substantially so. This may be an expression for an equilibrium between the pressure from a clinically diagnosed enlarged tongue and the effect of this enlargement over time, i.e. the dentition has adapted to the volume of the tongue. The surgical procedure tended to "normalize" the pressure but the effect was small and not signficant. Whether the small reduction of the pressure is clinically significant is unknown. One year after the operation, there was also a wide range of variation in resting pressure, but the variation was smaller than it had been before surgery. It is possible that in individual cases the pressure difference as a result of the operation may have consequences for the dentition.

Clinical studies demonstrating the effect of surgical tongue reduction are lacking with the exception of an investigation by Steiner and Gebauer[9] on a limited number of openbite cases. During the first year after the operation, these authors found a beneficial effect on the overbite, which is consistent with the reduced pressures we found at the 6-month postsurgical recording. After one year, there was a tendency to a decrease of the overbite again in some of the few cases that could be followed for a longer period. Our study did not evaluate the clinical consequences of the operation. This was impossible because of the different types of malocclusions of the subjects and the fact that many were undergoing orthodontic treatment. It would be of great interest to investigate the influence of the procedure in individuals who are still growing. Studies of the unimpaired bite development over a longer time-span after surgery are, however, difficult to perform. Subjects undergoing the operation generally also need orthodontic and orthognathic surgery, procedures which for ethical reasons cannot be postponed.

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