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Amplitude and speed of masticatory movements in total laryngectomy patients[☆]

Paulo Fernandes Pinheiro Junior^a, Lucas Carvalho Aragão Albuquerque^{b,*},
Cicília Lais de Lima Silva^c, Natália Freira da Silva^c, Daniele Andrade da Cunha^c,
Hilton Justino da Silva^c

^a Department of Pathology, Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

^b Department of Neuropsychiatric, Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

^c Department of Speech, Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil

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Abstract

Introduction: Laryngectomy is a surgical procedure that aims to remove the hyoid bone and the larynx and its muscles; it is inferred that a destabilization of the hyoid-mandibular axis will occur, consequently changing chewing.

Objective: To characterize the amplitude and speed of chewing in laryngectomies and to compare them with two groups of non-laryngectomized individuals differentiated by age.

Method: 72 volunteers were divided into three groups: (A) 32 volunteers, mean age 22.3 years, 17 females; (B) 20 volunteers, mean age 53.2 years, 10 females, and (C) 20 volunteers who underwent total laryngectomy, mean age 61.5 years, one female. Electroglyphography, a method that tracks and measures millimeter jaw movements, was used for evaluation.

Results: Significant differences were observed between groups A and C in masticatory amplitude and speed.

Conclusion: Age, and adaptive and compensatory changes appear to explain chewing better than factors related to total laryngectomy.

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Amplitude e velocidade dos movimentos mastigatórios em indivíduos laringectomizados totais

Resumo

Introdução: A laringectomia é um procedimento que objetiva a retirada do osso hióide, da laringe e seus músculos, e, com isso acredita-se que ocorra uma desestabilização do eixo hióideo-mandibular, com consequente alteração na mastigação.

Objetivo: Caracterizar a amplitude e a velocidade mastigatória em laringectomizados e compará-las com dois grupos de indivíduos não laringectomizados, de acordo com a faixa etária.

Método: Participaram do estudo 72 voluntários, que foram divididos em três grupos: (A) 32 voluntários, não laringectomizados com idade média de 22,3 anos, sendo 17 do sexo feminino; (B) 20 voluntários não laringectomizados, idade média de 53,2 anos, dos quais 10 eram do sexo

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* Corresponding author.

E-mail: fono_lucas@hotmail.com (L.C.A. Albuquerque).

feminino; e (C) 20 voluntários submetidos à laringectomia total, idade média de 61,5 anos, sendo um do sexo feminino. Para a avaliação foi utilizada a eletrognatografia, que é um método objetivo e não invasivo que rastreia e mensura milimetricamente os movimentos mandibulares. **Resultados:** Foram encontradas grandes diferenças entre os grupos A e C na velocidade e amplitude mastigatória, e essas diferenças foram significativas.

Conclusão: Fatores etários, adaptativos e compensatórios parecem explicar melhor as alterações mastigatórias do que fatores relacionados à laringectomia total.

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Introduction

Total laryngectomy is a method for the surgical treatment of laryngeal cancer. The procedure is characterized by a complete larynx removal, from the base of the tongue to the trachea, including the hyoid bone and the pre-epiglottic space,¹⁻³ implying the mutilation of various systems and consequent alteration of their functional characteristics, such as in the stomatognathic system.^{4,5}

The mutilations between the supra and infra-hyoid regions that connect the jaw, hyoid bone, and external and clavicle^{2,6} directly interfere with the function of the stomatognathic system, leading the patient to develop compensatory neuromuscular parafunctions with the remaining muscular structures.^{7,8} These parafunctions represent the intricate impact on mandibular biomechanics derived from damage to structures that belong or are related to the stomatognathic system.⁹⁻¹¹ One way to analyze these biomechanics is the measurement of amplitude and velocity of jaw movements, using predictive variables such as kinematic changes. In this context, electrognathography (EGN), a method tracks movements using magnetoresistive sensors, can be an excellent way to obtain these data.^{12,13}

The measurement of amplitude and speed of movements related to the mandibular biomechanics of total laryngectomy patients has not yet been reported in the literature. The importance of this work was the quantitative data survey, which can support, reconfigure, or assist multidisciplinary therapeutic programs targeted at this issue.

This study aimed to characterize the amplitude and speed of masticatory cycles on total laryngectomy patients evaluated by electrognathography and to compare these data with those of two other groups of non-laryngectomized individuals differentiated by age.

Methods

This was a cross-sectional, observational, exploratory, case series study with comparison groups, conducted between February and July of 2012. It included patients treated with total laryngectomy and volunteers without surgical intervention on neck or head. In addition to these study sites.

The main criteria adopted were patients in the postoperative period restricted to total laryngectomy with neck dissection, in the absence of recent post-operative complications or difficulty in understanding simple instructions. The study population comprised 20 patients with mean age

of 61.5 years and mean postoperative period of 3.65 years, one (5%) of whom was a female (group C).

The type of sample was defined by the characteristics of the group of non-laryngectomized subjects. For this reason, non-probabilistic sampling was adopted, by accessibility or convenience; it builds on the subject specificity and allows them to represent the universe, by being descriptive and exploratory.¹⁴

To determine the sample size of the comparison groups, identified as young-adult group (group A) and adult group (group B), a ratio of 1.6:1.0, 0.05 significance level, and 80.0% power of evidence were assumed. This estimated a sample of 31 individuals in group A and 19 in group B; adequate estimates for the group B retained more characteristics similar to the universe of laryngectomy patients.¹⁵

Groups A and B had as common inclusion criteria: individuals of both genders; dentate or partial or total edentulous, with or without a prosthetic or orthodontic mouthparts; not submitted to surgery in the head and neck regions; no complaints of dysphagia; not subjected to any physical therapy and/or speech treatment; and no difficulty in understanding simple commands. Exclusion criteria for groups A and B were presence of neurological, neuromuscular, or neurodegenerative diseases, and clinical diagnosis of acute symptoms of temporal-mandibular disorders at the time of testing.

The differential inclusion criteria between groups A and B was age. Group A included young adults aged between 18 and 29 years; in group B, subjects were aged 40 or older.

72 individuals of both genders participated in the study, with the following distribution: group A comprised 32 volunteers, mean age equal to 22.3 years; group B comprised 20 volunteers, mean age 53.2 years; group C consisted of 20 patients who underwent total laryngectomy.

Phases of data collection

After reading and signing the informed consent, volunteers underwent history and specific physical exams.

For the electrognathographic examination, the volunteer was instructed to sit comfortably in a chair with the head erect and eyes directed forward.

An electrognathographer, model JT-3D® (BioRESEARCH), was used; the collected data was analyzed using Bio-Pak System.

In the collection of electrognathography parameters, a small magnet was originally fixed to the labial surface of the lower incisors corresponding to the midline level; the head

support was symmetrically regulated.

To evaluate the masticatory cycle, a volunteer was asked to chew 15 g of bread for 20 seconds. The jaw function and the consequent movement of the magnetic sensor were captured by electrognathographer, and transmitted and recorded into a computer, enabling the visualization and analysis of all intra-border mandibular motion graphics.

The display sweep (Fig. 1) analyzed the following variables: a) total number of cycles, b) number of lateral cycles to the right, c) number of lateral cycles to the left, d) number of protrusions, and e) number of retrusions. In the XY display (Fig. 2) the maximum values of the following variables were measured: a) opening amplitude in the frontal plane, b) right lateral movement in the horizontal plane, c) left lateral movement in the horizontal plane, d) protrusion in the sagittal plane, e) retrusion in the sagittal plane, f) maximum opening speed, and g) maximum clo-

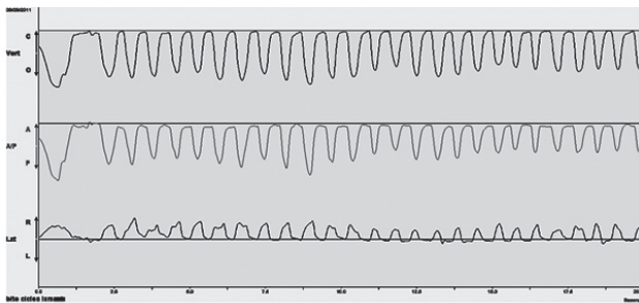


Figure 1 Vert, total count of the number of cycles. Lat, number of masticatory cycles to the right and left, and A/P, number of protrusions and retrusions.

sing speed.

All measurements were summarized as mean, mean standard error, 95% confidence interval, median, and interquartile range. In the comparison among groups A, B and C, the ANOVA test was used for differences between means. In cases with no significant difference, Dunnett's post-hoc contrast was used to identify differences among groups, assuming group C as a parameter. In cases with no significance by ANOVA, Student's t-test was used for difference of means, also assuming group C as a parameter. In all tests, a 0.05 significance level was considered for rejecting the null hypothesis of equality of means between groups.

The study was approved by the local research ethics committee, under CAAE No. 0014.0.447.172-10. Resolution 196/96 of the Brazilian National Health Council and the Helsinki Declaration of 2008 were followed.

Results

The number of masticatory cycles of laryngectomized patients was similar ingroups A and B, but differed in the frequency of lateralizations. The right lateralizations were more frequent than those to left, similar to that observed in adults in group B; however, these lateralizations reached higher frequency than that observed in group A (Table 1).

Hence the tendency to right lateralization resulted as a differentiation between the groups at the expense of major difference between group A and group C, which reached statistical significance. This difference, however, was absent in the left lateralization, for which there was no difference between groups, as well as in group C compared

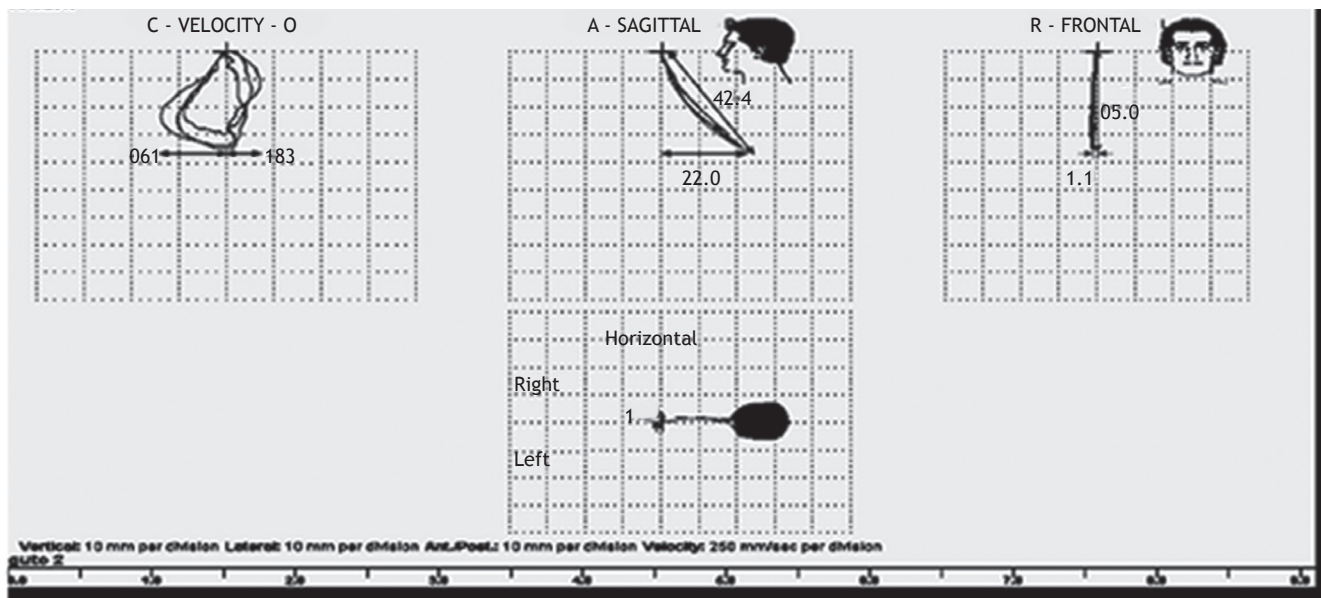


Figure 2 Velocity graph presents the maximum opening (the O side of the graph) and closing (C side of the graph) speeds. Sagittal graph presents the maximum protrusion (A side of the graph) and retraction (P side of the graph). Frontal graph presents the maximum opening amplitude. Horizontal graph presents the maximum right laterality (right side of graph) and maximum left laterality (left side of graph).

Table 1 Statistical parameters of the masticatory cycle.

| Variables of the masticatory cycle | Study groups | | | p-value ^a |
|---|-----------------|-----------------|-----------------|----------------------|
| | A (n = 32) | B (n = 20) | C (n = 20) | |
| Total number of cycles | | | | |
| Mean (mean standard error) | 22.38 ± 0.67 | 23.90 ± 1.12 | 24.00 ± 1.43 | 0.413 |
| 95% CI | 21.00 - 23.75 | 21.56 - 26.24 | 21.01 - 26.99 | |
| Range interval | 15.00 - 30.00 | 10.00 - 30.00 | 13.00 - 36.00 | |
| p-value ^b | 0.312 | 0.956 | 1.000 | |
| Median | 20.00 | 24.50 | 23.00 | |
| Interquartile range | 5.00 | 5.50 | 9.25 | |
| Number of right lateralizations | | | | |
| Mean (mean standard error) | 16.06 ± 1.00 | 19.10 ± 1.55 | 19.70 ± 1.54 | 0.092 |
| 95% CI | 14.02 - 18.11 | 15.85 - 22.35 | 16.48 - 22.92 | |
| Range interval | 3.00 - 27.00 | 5.00 - 30.00 | 7.00 - 30.00 | |
| p-value ^b | 0.043 | 0.785 | 1.000 | |
| Median | 17.50 | 21.50 | 19.50 | |
| Interquartile range | 8.00 | 10.00 | 12.25 | |
| Number of left lateralizations | | | | |
| Mean (mean standard error) | 16.09 ± 0.89 | 17.55 ± 1.18 | 15.85 ± 1.58 | 0.587 |
| 95% CI | 14.27 - 17.91 | 15.08 - 20.02 | 12.53 - 19.17 | |
| Range interval | 6.00 - 25.00 | 6.00 - 26.00 | 1.00 - 28.00 | |
| p-value ^b | 0.983 | 0.395 | 1.000 | |
| Median | 16.00 | 18.00 | 15.50 | |
| Interquartile range | 7.75 | 7.00 | 9.00 | |
| Maximum speed (cycles/20 s) | | | | |
| Mean (mean standard error) | 13.22 ± 0.80 | 10.85 ± 0.77 | 11.35 ± 1.03 | 0.010 |
| 95% CI | 11.58 - 14.85 | 9.23 - 12.47 | 9.20 - 13.50 | |
| Range interval | 6.00 - 25.00 | 6.00 - 17.00 | 5.00 - 21.00 | |
| p-value ^b | 0.036 | 0.761 | 1.000 | |
| Median | 13.00 | 10.50 | 12.00 | |
| Interquartile range | 4.00 | 6.50 | 7.00 | |
| Maximum masticatory speed (mm/s) | | | | |
| Mean (mean standard error) | 194.97 ± 8.46 | 249.60 ± 17.21 | 241.65 ± 19.40 | 0.010 |
| 95% CI | 177.72 - 212.21 | 213.59 - 285.61 | 201.04 - 282.26 | |
| Range interval | 97.00 - 275.00 | 74.00 - 418.00 | 116.00 - 438.00 | |
| p-value ^b | 0.037 | 0.761 | 1.000 | |
| Median | 210.00 | 247.00 | 242.50 | |
| Interquartile range | 66.50 | 102.50 | 138.50 | |
| Maximum opening speed (mm/s) | | | | |
| Mean (mean standard error) | 177.16 ± 9.74 | 226.25 ± 15.67 | 201.15 ± 19.02 | 0.046 |
| 95% CI | 157.29 - 197.02 | 193.44 - 259.06 | 161.34 - 240.96 | |
| Range interval | 88.00 - 354.00 | 74.00 - 363.00 | 83.00 - 357.00 | |
| p-value ^b | 0.235 | 0.356 | 1.000 | |
| Median | 174.00 | 226.00 | 199.00 | |
| Interquartile range | 67.50 | 89.75 | 136.00 | |
| Maximum closing speed (mm/s) | | | | |
| Mean (mean standard error) | 186.63 ± 8.92 | 237.70 ± 18.12 | 229.05 ± 20.92 | 0.030 |
| 95% CI | 168.44 - 204.81 | 199.78 - 275.62 | 185.25 - 272.84 | |
| Range interval | 97.00 - 276.00 | 63.00 - 418.00 | 92.00 - 466.00 | |
| p-value ^b | 0.049 | 0.703 | 1.000 | |
| Median | 202.00 | 225.00 | 229.00 | |
| Interquartile range | 74.25 | 108.00 | 147.00 | |

(Continue)

Table 1 Statistical parameters of the masticatory cycle (cont.).

| Variables of the masticatory cycle | Study groups | | | p-value ^a |
|---|---------------|---------------|---------------|----------------------|
| | A (n = 32) | B (n = 20) | C (n = 20) | |
| Maximum opening in the frontal plane (mm) | | | | 0.621 |
| Mean (mean standard error) | 33.88 ± 1.24 | 33.92 ± 1.79 | 31.92 ± 1.87 | |
| 95% CI | 31.34 - 36.42 | 30.18 - 37.65 | 28.01 - 35.82 | |
| Range interval | 17.20 - 49.50 | 18.60 - 46.80 | 14.50 - 47.00 | |
| p-value ^b | 0.366 | 0.444 | 1.000 | |
| Median | 34.20 | 34.45 | 31.95 | |
| Interquartile range | 8.65 | 14.20 | 12.00 | |

^a p-value calculated by ANOVA test associated with post-hoc Dunnett.

^b p-value calculated by Student's *t*-test for differences in means compared with the laryngectomized group.

with groups A and B.

Regarding the speeds of masticatory cycles, a difference was observed among groups in the number of cycles per second and the maximum speed of mandibular displacement in both the opening and closing the mouth. Group C was significantly different from group A, with a lesser number of cycles per second and higher speed variation, which was proved by identifying the higher interquartile range.

Similarly, when analyzing the maximum displacement speed (mm/s), the significant difference observed among groups was due to the difference between groups C and A. Laryngectomized patients had greater displacement per time unit and greater variability in this displacement (Table 1). These differences were significant.

Regarding maximum mandibular displacement speed, it was observed that the average maximum opening speed reached significance only when comparing the means of three groups, but not when considering group C as the standard for comparison. Despite the lack of significance between groups A and B compared to group C, it is worth mentioning that the mean standard error of group C diverged more from group A than from group B. Regarding the means of maximum mandibular closing speed, the significance observed among groups was determined by the difference between group C and group A. Regarding the average of maximum opening evaluated in the frontal plane, there was no significant difference among groups (Table 1).

Table 2 shows the results of the statistical parameters related to the study of protrusions and retrusions found in the masticatory cycle of the three groups. There was no significant difference among groups and A and B in relation to group C, both in the number of protrusions and in the average of maximum protrusion assessed in the sagittal plane.

Regarding retrusions, the groups did not differ in frequency and variability. This difference was observed in the mean value of maximum retrusion; there was a statistical tendency of group C to have lower values than those in A and B, since the p-value was between 0.05 and 0.10. By comparing each group separately with the laryngectomized patients, a tendency for group C to present a mean lower maximum retrusion than that of group A and significantly lower mean than that of Group B was observed (Table 2).

The average maximum latero-retrusion, measured in the

horizontal plane, had distinct behavior according to laterality. When shifted to the right, the values of group C were close to the measurements of groups A and B. However, in the shift to the left, these values were significantly lower in group C compared to the three groups, but with greater range of variation. From the comparison between group C, taken as standard, and the two other groups, it was observed that laryngectomized patients had mean maximum latero-retrusion to the left significantly lower than in group A (Table 2).

Discussion

In recent years, several studies have been conducted on the possible relationships of supra- and infra-hyoid muscles and hyoid bone in chewing and in temporomandibular and cervical spine changes; so far, no agreement that could guide clinical approach has been reached.¹⁶ This difficulty evidences the great complexity of the issue and the multiplicity of factors that may be involved.¹¹

The electrognathographic characterization of amplitude and speed of masticatory cycles in total laryngectomized patients, in turn, has demonstrated an even more complex mandibular biomechanics, which appeared to derive from the removal of the supra- and infra-hyoid muscles and hyoid bone, and to have been influenced by the aging process of muscles.

Research conducted to characterize the hyoid mechanism in the masticatory cycle has demonstrated the need for synergism between the involvement of the masseter, temporalis, and medium pterygoid muscles in mandible elevation, and the action of the supra-hyoid, anterior belly of digastric, milo-hyoid, genio-hyoid, lateral pterygoid, mimic, tongue, and infra-hyoid muscles as mandible depressors that depend on the hyoid bone position.¹⁷ The hyoid bone fixation by the infra-hyoid muscles enables the depressor muscles to promote mouth opening.¹⁸

Additionally, through electromyographic studies, there was also evidence of synergism between the extensor and flexor muscles of the head on the cervical spine and the activity of supra- and infra-hyoid muscles, and therefore the hyoid bone position, contributing to the stability of motion

Table 2 Statistical parameters of protrusion and retrusion in the masticatory cycle.

| Measurements of protrusion and retrusion in the masticatory cycle | Study groups | | | p-value ^a |
|---|---------------|---------------|---------------|----------------------|
| | A (n = 32) | B (n = 20) | C (n = 20) | |
| Maximum protrusion in the sagittal plan (mm) | | | | 0.921 |
| Mean (mean standard error) | 4.89 ± 0.51 | 5.14 ± 1.08 | 5.31 ± 0.94 | |
| 95% CI | 3.85 - 5.92 | 2.85 - 7.43 | 3.32 - 7.30 | |
| Range interval | 0.90 - 10.50 | 1.70 - 20.30 | 0.60 - 15.20 | |
| p-value ^b | 0.666 | 0.906 | 1.000 | |
| Median | 4.50 | 3.80 | 5.40 | |
| Interquartile range | 4.90 | 4.20 | 6.40 | |
| Number of protrusions | | | | 0.664 |
| Mean (mean standard error) | 14.00 ± 1.84 | 13.29 ± 2.28 | 16.22 ± 2.55 | |
| 95% CI | 10.25 - 17.15 | 8.47 - 18.12 | 10.84 - 21.61 | |
| Range interval | 1.00 - 46.00 | 2.00 - 29.00 | 1.00 - 33.00 | |
| p-value ^b | 0.476 | 0.400 | 1.000 | |
| Median | 13.00 | 10.00 | 19.00 | |
| Interquartile range | 14.00 | 17.00 | 19.25 | |
| Maximum retrusion in the sagittal plan (mm) | | | | 0.086 |
| Mean (mean standard error) | 19.68 ± 1.61 | 20.72 ± 1.91 | 14.61 ± 2.19 | |
| 95% CI | 16.40 - 22.97 | 16.70 - 24.74 | 10.00 - 19.22 | |
| Range interval | 4.10 - 47.10 | 8.10 - 35.20 | 3.50 - 30.40 | |
| p-value ^b | 0.067 | 0.042 | 1.000 | |
| Median | 19.40 | 19.70 | 12.50 | |
| Interquartile range | 10.35 | 14.00 | 16.78 | |
| Number of retrusions | | | | 0.528 |
| Mean (mean standard error) | 17.97 ± 1.31 | 20.63 ± 1.91 | 18.39 ± 2.29 | |
| 95% CI | 15.30 - 20.64 | 16.63 - 24.64 | 13.56 - 23.21 | |
| Range interval | 1.00 - 29.00 | 1.00 - 30.00 | 2.00 - 31.00 | |
| p-value ^b | 0.874 | 0.454 | 1.000 | |
| Median | 20.50 | 23.00 | 17.00 | |
| Interquartile range | 11.00 | 6.00 | 15.50 | |
| Maximum laterotrusion to the right of the horizontal plane (mm) | | | | 0.435 |
| Mean (mean standard error) | 8.02 ± 0.47 | 7.10 ± 0.45 | 8.05 ± 0.76 | |
| 95% CI | 7.07 - 8.97 | 6.16 - 8.04 | 6.46 - 9.64 | |
| Range interval | 2.00 - 14.30 | 3.00 - 11.00 | 1.70 - 13.00 | |
| p-value ^b | 0.972 | 0.290 | 1.000 | |
| Median | 8.15 | 7.30 | 7.65 | |
| Interquartile range | 3.90 | 2.95 | 6.28 | |
| Maximum laterotrusion to the left of the horizontal plane (mm) | | | | 0.016 |
| Mean (mean standard error) | 7.76 ± 0.56 | 6.29 ± 0.51 | 5.29 ± 0.74 | |
| 95% CI | 6.61 - 8.90 | 5.22 - 7.36 | 3.73 - 6.84 | |
| Range interval | 2.40 - 16.80 | 2.90 - 11.70 | 0.70 - 11.90 | |
| p-value ^b | 0.010 | 0.274 | 1.000 | |
| Median | 7.70 | 6.05 | 5.05 | |
| Interquartile range | 4.25 | 2.95 | 5.40 | |

^a p-value calculated by ANOVA test associated with post-hoc Dunnett.

^b p-value calculated by the Student's *t*-test for differences in means compared with the laryngectomy group.

of the masticatory cycle.¹⁹

In this context, it is possible to assume that total laryngectomy, excising the supra- and infra-hyoid muscles, as well as the hyoid bone and tongue muscles, promotes new dynamics in the masticatory cycle, which appears to have been evidenced in the present study. Even considering that, in total laryngectomy patients, chewing suffers less quality of life impact than speech; the findings presented here are relevant in understanding these new kinematics.²⁰

These new kinematics consisted of maintaining the number of masticatory cycles while changing the frequency and lateralization direction, which appeared to have been dictated mainly by the aging process, since the difference was observed when comparing the laryngectomy group with the younger group (group A); the difference was not observed in the group with similar age.

Compensatory and adaptive features of the stomatognathic system related to the age differential in the revelation of such data^{21,22} also appeared to explain the changes in speed expressed in number of masticatory cycles per second (cycles/20 s), whose qualitative value prevailed over the appearance of acquired by surgical action of total laryngectomy,²⁰ since statistical significance was detected in group C, due to the smaller number of cycles per second and greater variation of velocity with respect to group A, expressed by a higher interquartile range (7.00 cycles/20 s in the group C versus 13.00 cycles/20 s in the group A).

However, the strongest suggestive evidence that aging might have contributed to masticatory adaptations were the means of maximum speed of mandibular displacement (generally in opening and closing), since group C resembled group B and differed significantly from group A in general displacement and at closing.

Variables such as maximal mouth opening in millimeters, maximum number of protrusions, and maximum protrusion in millimeters showed no significant differences. Although this finding has corroborated the evidence of Paula et al.²⁰ that the masticatory characteristic is the least affected by total laryngectomy, it is plausible to assume that measurements of border movements may reveal statistically significant differences.²³

Additionally, the trend of laryngectomy patients to show average maximum retrusion, maximum latero-retrusion evaluated in the horizontal plane, and maximum left latero-retrusion smaller than those of the non-laryngectomy groups, showed for the first time the temporary or permanent disorder of stomatognathic functions, consequent to total laryngectomy and attributable to surgical manipulation in the supra- and infra-hyoid regions.²⁴⁻²⁶

Conclusion

The analysis of the variables suggested that changes of the masticatory cycle assessed by electrognathography evidence the existence of compensatory and adaptive traits in laryngectomized patients, resulting from the combined action of the age factor and changes possibly attributable to total laryngectomy.^{27,28}

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Conflicts of interest

The authors declare no conflicts of interest.

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