Longitudinal Study Involving Obesity in Women and Bariatric Surgery: An Electromyographic Approach to the Masseter and Temporal Muscles

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Abstract: This longitudinal study was aimed to evaluate the electromyographic activity (EMG) of the masticatory muscles during mandibular tasks in women with grade II and III obesity, who were eligible for bariatric surgery. Twenty-one patients were followed up for 3 and 6 months after the Roux-en-Y gastric bypass. The EMG included analyses of the masseter and temporalis muscles during rest, right and left laterality, protrusion, and dental clenching at maximal voluntary contraction with and without parafilm. Data were tabulated and submitted for statistical analysis using the repeated measures test ($P<0.05$) with the Bonferroni post-test. Significant differences were observed between the right temporal

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muscle during maximal voluntary contraction (P=0.003) and maximal voluntary contraction with Parafilm M for the right masseter (P=0.01), left masseter (P=0.03), right temporal (P=0.002), and left temporal (P=0.03) muscles. There was gradual decrease in the resting EMG of the masticatory muscles 6 months after surgery. There was an increase in the EMG of the muscles that are the most active in the neuroanatomical movements of laterality and protrusion 6 months after surgery. There was an increase in EMG in maximal voluntary contraction with and without parafilm, 3 and 6 months after surgery. This study suggests that women with severe obesity who underwent bariatric surgery had better functional results of the masticatory muscles 3 and 6 months after the procedure, which is an important parameter in surgical planning, functional recovery, and nutritional status.

Introduction

Obesity is a chronic non-communicable disease (Fang et al., 2019; Hagberg and Spalding, 2024) that modifies the composition of the human body by excessive accumulation of fat (Romero-Corral et al., 2008) and is considered a public health problem with serious physical and psychological consequences that affect the quality of life (Nimptsch et al., 2019; Ji et al., 2022). According to the World Health Organization, by the year 2025, one in five adults worldwide will develop obesity (Mohammed et al., 2018).

Food insecurity is a key factor in the development of obesity because it is related to a nutritionally deficient diet (Kamal et al., 2024). According to international results, this is related to increasing number of women who are overweight (41%) and have high-risk obesity (29%) (Hernandez et al., 2017).

Bariatric procedures have been implemented in high-risk patients with obesity because they modify the physiology of the gastrointestinal tract. This leads to weight loss and likely resolution of associated comorbidities, thus improving quality of life (Mechanick et al., 2020). However, important side effects were observed, such as vomiting and intolerance to protein (de Almeida Godoy et al., 2020), in addition to loss of mass of the skeletal striated musculature with alterations related to the stomatognathic system. Obesity has been related to several aspects of oral health, such as alteration of salivary glands, periodontal disease, tooth loss, changes in oral microflora, lower masticatory efficiency, lower bite force intensity, and increased masticatory muscle thickness (Taghat et al., 2021; Hunger Malek-Zadeh et al., 2022).

Bariatric surgery is considered the main treatment with proven improvement in metabolic pattern which presents consistent short-term results such as weight loss and improvement in obesity-associated comorbidities, including diabetes, hypertension, and dyslipidemia. The most used technique in Brazil is Fobi-Capella or Roux-en-Y distal gastrojejunal bypass gastroplasty, which is considered the gold standard procedure in the control of severe obesity and diabetes (Arterburn et al., 2020).

Therefore, the aim of this study was to evaluate over time the electromyographic activity of the masseter and temporal muscles during mandibular tasks in women with obesity grades II and III who were eligible for bariatric surgery. The null hypothesis of this study was that severely obese women undergoing bariatric surgery would not show changes in the electromyographic activity of the masseter and temporal muscles over time. This study presents an alternative hypothesis. Postoperatively, functional pattern during mandibular tasks gets better over time in women with severe obesity who undergo bariatric surgery.

Material and Methods

This prospective study was approved by the ethics committee (process # 02.044.012.4.0000.5440). Informed consent was obtained from all the women participating in this study.

Study population

This study observed electromyographic activity of the masseter and temporal muscles during mandibular tasks in 21 women with clinically severe obesity after bariatric surgery. Eligible participants were re-evaluated at 3 and 6 months after undergoing the Roux-en-Y gastric bypass procedure.

Body mass index was calculated by dividing the weight of the patient by the square of their height (kg/m^2). Height was measured using a vertical rod with a graduation of 0.5 cm. Abdominal circumference was measured by passing an inextensible measuring tape with a graduation of 0.1 mm at the largest circumference. Measurements of body composition, fat-free mass, and fat mass were evaluated with a BIA 450 Bioimpedance Analyzer (Biotecmed, Seattle WA, USA), after 12 h of fasting, with complete emptying of the bladder (Table 1).

The inclusion criteria were women with obesity grades II and III, aged between 18 and 60 years, with complete dentition, normal occlusion (Angle Class I), or

Table 1 – Preoperative means of anthropometric data and body composition of women with obesity (n=21)

Variables	Averages
Body weight (kg)	112.1
BMI (kg/m^2)	44.9
Abdominal circumference (cm)	126.0
Fat free mass (kg)	59.9
Fat mass (kg)	52.2

BMI – body mass index

clinically satisfactory dentition due to the use of adapted prostheses in the oral cavity. Patients with temporomandibular disorders, chronic degenerative diseases, neurological and systemic pathologies, mental or physical discomfort during the evaluations, usage of sedatives or drugs that depress the central nervous system, and those undergoing orthodontic or speech therapy and/or otorhinolaryngological treatment were ineligible for this study.

The Research Diagnostic Criteria for Temporomandibular Disorders (Axis I and II) were used as diagnostic criteria for temporomandibular disorder. A single trained examiner administered the questionnaire. This study did not involve male patients because their percentage in the health service where the sample was selected was approximately 5%, which was considered low for the study.

Intraexaminer reliability was assessed by calculating the intraclass coefficient (ICC). The reliability was considered acceptable for electromyographic activity (ICC = 0.936).

Electromyographic analysis

An electromyograph with wireless sensors (TrignoTM Wireless, EMG System, Delsys Inc., Boston, MA, USA) was used to determine the electromyographic activity of the masseter and temporal muscles during mandibular tasks at rest (4 s), right laterality (5 s), left laterality (5 s), protrusion (5 s), and dental clenching at maximum voluntary contraction with (5 s) and without (5 s) inert material.

The inert material (Parafilm M, Pechiney Plastic Packaging, Batavia, IL, USA) consisted of a folded paraffin sheet (18×17×4 mm, weight 245 mg) placed between the permanent molars (upper and lower) on both sides of the dental arch (Siéssere et al., 2009; Cecilio et al., 2022).

Participants were comfortably seated in a chair in a standardized position before each examination. Prior to placement of the wireless surface electrodes, the skin was cleaned with 70% ethanol to reduce the electrical impedance of biological tissues (Di Palma et al., 2017).

Wireless electrodes were symmetrically applied to the skin over the masseter and temporal muscles on both sides, aligned with the direction of the muscle fibers. Their placement and orientation were verified by palpating the muscle belly during resisted contractions. The electrode placement followed the guidelines from the Surface Electromyography for the Non-Invasive Assessment of Muscles project (Hermens et al., 2000).

The protocol was explained to the participants, and they were asked to remain calm during data collection. Mandibular tasks during the electromyographic examination were performed by a single trained researcher.

Method error

The measurement method error related to the electromyographic signal during the mandibular tasks of the masticatory muscles of five participants was calculated using the Dahlberg formula (Kallner et al., 2020) during two sessions, with an interval of 7 days. The measurements showed a slight variation between the first and second sessions, with an average percentage value of 3.74% for electromyography.

Statistical analysis
Data distribution was verified using the Shapiro-Wilk test. A prospective study was performed using repeated-measures analysis (ANOVA) with the Bonferroni post-test. Electromyographic data were subjected to statistical analysis using the IBM SPSS software (version 22.0; IBM SPSS Inc., Chicago, IL, USA). The results were obtained using descriptive analysis (mean and standard error). Statistical significance was set at $P<0.05$.

Results

Significant differences in the electromyographic activity of the masseter and temporal muscles during mandibular tasks were observed before bariatric surgery and at 3 and 6 months postoperatively. There was increased muscle activity after bariatric surgery for the right temporal muscle in the maximum voluntary contraction ($P=0.003$) and maximum voluntary contraction with parafilm for the right masseter ($P=0.01$), left masseter ($P=0.03$), right temporal ($P=0.002$), and left temporal ($P=0.03$) muscles.

From clinical observation, there was a gradual reduction in the electromyographic activity of the masticatory muscles during rest. In addition, there was an increase in the electromyographic activity of the muscles most active in neuroanatomical movements during laterality (right and left) and protrusion after 6 months of bariatric procedure (Table 2).

Discussion

The null hypothesis of this study was rejected, as there was a significant difference between pre-surgical obesity at 3 and 6 months after bariatric surgery in the electromyographic activity of the right temporal muscles in maximum voluntary contraction, and masseter and temporal muscles in maximum voluntary contraction with parafilm. This demonstrated that there was a relationship between body composition and functionality of the stomatognathic system.

The alternative hypothesis of this study was that over time (before surgery and at 3 and 6 months after bariatric surgery), women with clinically severe obesity presented a better electromyographic pattern during mandibular tasks compared to the pre-surgical pattern. This hypothesis was based on the metabolic principle of weight loss with an improvement in the lipid profile of the muscle fibers, which was

Table 2 – Electromyographic activity during the mandibular tasks of women with obesity before bariatric surgery and 3 and 6 months after bariatric surgery

Mandibular tasks	Muscles	Obesity			P-value
		pre-surgical (µV)	post-surgical 3 months (µV)	post-surgical 6 months (µV)	
Rest	RM	6.76 (±1.15)	5.43 (±0.54)	4.43 (±0.52)	0.270
	LM	6.06 (±0.82)	6.36 (±1.03)	5.63 (±0.74)	0.760
	RT	8.42 (±1.49)	7.31 (±0.89)	5.98 (±0.71)	0.130
	LT	8.24 (±1.20)	7.42 (±0.91)	6.58 (±0.65)	0.310
Right laterality	RM	11.06 (±1.71)	8.80 (±1.34)	11.67 (±2.18)	0.240
	LM	11.40 (±2.08)	13.45 (±2.33)	15.71 (±2.98)	0.170
	RT	11.07 (±1.49)	10.27 (±1.16)	9.71 (±0.91)	0.610
	LT	8.43 (±1.21)	6.46 (±0.82)	7.99 (±1.08)	0.210
Left laterality	RM	12.80 (±1.63)	15.00 (±2.44)	17.92 (±3.26)	0.160
	LM	13.62 (±2.16)	11.46 (±2.04)	14.55 (±2.80)	0.420
	RT	9.73 (±1.67)	7.25 (±1.01)	6.99 (±0.90)	0.120
	LT	13.09 (±1.68)	9.75 (±1.24)	14.09 (±2.37)	0.160
Protrusion	RM	22.12 (±3.37)	32.98 (±7.04)	24.59 (±4.42)	0.070
	LM	20.65 (±3.86)	28.49 (±5.36)	26.70 (±5.41)	0.220
	RT	8.19 (±1.44)	7.38 (±0.99)	10.63 (±2.91)	0.460
	LT	7.81 (±1.07)	8.43 (±1.15)	10.68 (±2.08)	0.320
Maximal voluntary contraction	RM	71.30 (±18.10)	107.24 (±21.45)	94.90 (±16.29)	0.060
	LM	73.46 (±16.08)	100.35 (±17.97)	94.56 (±15.21)	0.150
	RT	44.17 (±6.36)[a]	63.56 (±11.57)	73.15 (±12.16)[b]	0.003
	LT	54.99 (±7.88)	73.83 (±10.10)	67.58 (11.67)	0.200
Maximal voluntary contraction with parafilm	RM	94.75 (±19.35)[a]	172.43 (±38.51)[b]	127.62 (±21.89)	0.010
	LM	103.82 (±18.21)[a]	151.68 (±21.96)[b]	133.09 (±21.52)	0.030
	RT	59.55 (±7.83)[a]	86.04 (±14.12)[b]	90.41 (±15.58)	0.002
	LT	70.49 (±9.72)[a]	99.44 (±12.05)[b]	81.17 (±13.70)	0.030

Repeated-measures analysis of variance (ANOVA) with Bonferroni post-test. Different letters represent P<0.05. Values are expressed as mean (± standard error). RM – right masseter muscle; LM – left masseter muscle; RT – right temporalis muscle; LT – left temporal muscle

directly related to muscle function and improved functional pattern (Coral et al., 2021; Hunger Malek-Zadeh et al., 2022).

There is a relationship between obesity and dyslipidemia in the pro-inflammatory process of adipose tissue (Scheja and Heeren, 2022). The accumulation of body fat triggers dyslipidemia, which promotes lipid infiltration in skeletal striated muscles, causing an increase in inflammatory cytokines and reduction in the number and size of myocytes. This impairs glucose uptake, interfering with mitochondrial activity (Warfel et al., 2016).

The dysfunction of mitochondrial energy metabolism, for example, is related to the process of alteration of muscle physiology (Beltrà et al., 2021), promoting the loss of muscle mass, cell death, and other pathological situations in different organs (Gehrig et al., 2016). Studies have shown that individuals with obesity have a disturbance in skeletal striated muscle metabolism that increases the risk of metabolic disorders, such as mitochondrial disorders that reduce muscle activity (Pileggi et al., 2021).

In this study, it was observed that the electromyographic patterns of the masseter and temporal muscles during mandibular tasks were considered less functional before surgery than at 3 and 6 months after surgery. What could have happened to the metabolism of these women after bariatric surgery that improved the electromyographic patterns of the masticatory muscles?

This study showed a significant increase in the electromyographic patterns of the right temporal muscle and of the masseter and temporal muscles in maximal voluntary contraction with Parafilm M after bariatric surgery.

Excess body fat impairs metabolism, especially when it promotes capillary rarefaction, where adipocytes become larger and there is a greater distance between microvessels. This leads to a reduction in blood flow and oxygenation that triggers inflammatory responses with decreased endothelial permeability (Frayn and Karpe, 2014).

In turn, the functionality of the endothelial cells that make up the inner lining of blood vessels regulates physiological processes (Kim et al., 2021), and when it is achieved through methodologies that lead to weight loss, including surgery, a reduction in weight can be observed in the lipid profile of the skeletal striated musculature. Consequently, tissue adipose vascularization becomes more effective, promoting functional improvement of muscles (Bigornia et al., 2013; Gokce et al., 2021). This fact could explain the observation that masticatory muscles exhibited a greater electromyographic activity after bariatric surgery in maximal voluntary contraction with and without parafilm.

Skeletal striated musculature, in conjunction with the skeletal system, adipose tissue, and adipokine secretion, plays key roles in muscle metabolism (Kirk et al., 2020). When any of these anatomical and physiological structures enter disequilibrium, the organ system is affected due to functional alterations (Li et al., 2017). Neuroanatomic functions can benefit from maintenance of homeostasis.

This fact could explain the balance of the neuroanatomical pattern, especially of the masseter muscle, in post-surgical obesity at 3 and 6 months because during the left lateral mandibular task, the activation of the right masseter muscle did not follow the adequate neuroanatomical pattern. This demonstrated that greater contralateral muscle activity during function was not found in pre-surgical obesity (Cecílio et al., 2010).

During jaw rest, a gradual reduction in electromyographic activity of the masseter and temporal muscles was observed when comparing pre- and post-surgical obesity

(3 and 6 months). The components of the neurohumoral system, leptin and insulin, are released into skeletal muscle and adipose mass to control energy homeostasis (Park and Ahima, 2015).

In response to muscle energy storage, leptin is synthesized in white adipose tissue under the control of glucocorticoids and insulin (Boghossian et al., 2007). Circulating leptin levels have anabolic effects on skeletal muscle in association with the amount of body fat, which decreases with gradual weight loss.

The decrease in the percentage of leptin can be interpreted by the hypothalamus as a situation of starvation that triggers an adaptive response, decreasing energy expenditure in the rest condition with performance in muscle-bone crosstalk over time (Hamrick, 2017; Marques et al., 2021), thereby increasing the production of follistatin and actinin, which are myostatin-inhibiting proteins (Lee et al., 2010).

With myostatin inhibition, which is a negative regulator of skeletal muscle morphology, restoration of muscle mass and functional balance occurs (Nakatani et al., 2008). These physiological arguments could explain the gradual reduction in electromyographic activity during jaw rest 6 months after bariatric surgery, when there is a reduction in leptin circulation.

During protrusion, the activation pattern of the masseter muscles was greater than that of the temporal muscles, with respect to the neuroanatomical pattern of this mandibular task in the three periods evaluated in this study. This showed greater electromyographic activity in postoperative obesity (3 and 6 months).

Another process that would show the difference between pre- and post-surgery in women with severe obesity with associated consequences on muscle function would be the action of insulin to increase glucose uptake in the muscle, increasing blood flow and, therefore, capillary perfusion (Sylow et al., 2021). In obese patients, there is a decrease in vascularization, a reduction in insulin action in the muscle, and a high influx of lipids, which contributes to the reduction of glucose uptake. When weight loss occurs, metabolism is normalised, resulting in improved muscle function (Ugwoke et al., 2022).

The breathing pattern is another factor that could explain the electromyographic values of women with clinically severe obesity in relation to post-surgical obesity, because it promotes myofunctional changes in the stomatognathic system, making the feeding process difficult. For example, mouth breathing is a function adapted by the body because of upper airway obstruction, especially in the nasal and/or pharyngeal regions, which can affect the biomechanics of the stomatognathic system (Suzuki and Tanuma, 2020; Lima et al., 2021). Obese individuals present a compromised breathing pattern due to fat deposition in muscles, which impairs oral sensory and motor function (Castro et al., 2022). In this study, breathing patterns were not evaluated.

Therefore, the alternative hypothesis of this study was accepted because over time, women with clinically severe obesity showed a better functional pattern during mandibular tasks, especially in maximal voluntary contraction. This is due to the greater potential of muscle fibers that is related to reduced weight gain 6 months after bariatric surgery (Wolfe et al., 2016).

This study has some limitations. The main limitation was the sample size, but as it was a longitudinal study in which women with severe chronic functional complexity were evaluated and a specific surgical process for weight reduction was involved, the sample size can be considered adequate.

Obesity is recognized as a serious disease that affects millions of people around the world. When exploring interventions to improve quality of life, it is important to study systems directly involved in the complex process of weight gain and loss, such as the stomatognathic system, particularly the masticatory system. Understanding the functions of its anatomical structures, both dynamic and static, can assist healthcare professionals in developing effective treatment plans. Research suggests that bariatric surgery may positively impact masticatory function and enhance the quality of life for obese women.

Conclusion

This study suggests that bariatric surgery positively influenced the electromyographic activity of the masseter and temporal muscles of women with clinically severe obesity 3 and 6 months after the procedure. It resulted in an improvement of the masticatory process and consequently in the quality of life of the patients. This is an important surgical indicator in the interpretation of results as it affects the stomatognathic system, which is interconnected with all other systems of the human body.

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