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The study of maximum electromyogram of masseter muscle before and during modified electroconvulsive therapy in psychiatric patients

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ABSTRACT

Background: Electroconvulsive therapy (ECT) is generally used to treat various severe and treatment resistant psychiatric disorders. Nowadays modified ECT is used, injury to teeth and other oral structure remain a risk in ECT despite the use of muscle relaxants due to the electrodes are placed on the temporal, quite close to the masseter muscle. The use of a bite guard is essential to prevent dental and soft tissue injuries; however, limited evidence exists regarding electromyogram (EMG) of the masseter muscle before and during modified ECT.

Objectives: To compare the maximum EMG of the masseter muscle under three conditions: 1) maximal clenching without a bite guard, 2) maximal clenching with a bite guard, and 3) during modified ECT with anesthesia, muscle relaxants and a bite guard and to evaluate post procedural oral complications.

Materials and methods: This cross-sectional study included 40 psychiatric inpatients who undergoing modified ECT at Suanprung Psychiatric Hospital. Surface EMG signals of the masseter muscle were recorded using the Thymatron® System IV (Somatics LLC, USA) under the three conditions: before anesthesia without a bite guard (NB), before anesthesia with a bite guard (B), and during ECT with anesthesia, muscle relaxants and a bite guard (ECT). Differences among conditions were analyzed using repeated measures ANOVA, and independent samples t-tests were used to compare EMG values between groups (<5,451.1 μV vs ≥5,451.1 μV). Significance was set at $p<0.05$. Post procedural oral examinations were performed to identify any trauma or soft-tissue injuries.

Results: All 40 participants completed the study (mean age 35.63±13.17 years). Schizophrenia was the most prevalent diagnosis (45%), and 67.5% of patients were classified as ASA Class II. The maximum EMG amplitude during ECT was significantly higher than in the NB and B conditions ($p<0.001$). No significant differences in EMG amplitude were found between the NB and B conditions ($p>0.05$). Across all participants, EMG values differed significantly among all three conditions ($p<0.001$). Notably, no oral complications were observed with the use of the newly designed silicone bite guard.

Conclusion: Modified ECT induces significantly higher masseter muscle EMG activity approximately 15-fold greater than pre-ECT clenching. The use of newly designed silicone bite guard effectively prevents oral injury during ECT, supporting its routine clinical application to enhance patient safety and minimize oral complications.

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Introduction

Treatment for psychiatric patients primarily involves three aspects: psychological therapy, such

as counseling, encouragement, and understanding the patient; milieu therapy, which includes creating a comfortable and relaxing environment for the patient; and pharmacological therapy. Electroconvulsive therapy (ECT) is a procedure used to treat psychiatric patients with severe symptoms, those who may pose a danger to themselves or others, or those for whom other treatments have been ineffective, or who experience intolerable side effects from medication, or cannot wait for the medication to take effect. An example is patients with severe suicidal ideation who require rapid stabilization of their mental state.

Electroconvulsive therapy is a method that uses electrical current to stimulate the brain, inducing a seizure. During the seizure, increased cerebral blood flow, elevated metabolism, and higher oxygen and glucose consumption are observed, leading to changes in neurotransmitters[1,2] and a balance in neurotransmission.[3] It is generally used in psychiatric patients with severe symptoms, especially those unresponsive to medication, those with medication administration difficulties, those for whom other methods have been ineffective, and those with various complications.[3,4] It is an effective and rapid treatment.[5] There are two types of ECT: Unmodified ECT, which is performed without anesthesia and muscle relaxants. In this type, the patient remains conscious during the procedure, and when the electrical current passes through the patient's temporal, they experience tonic-clonic seizures followed by relaxation. The other type is Modified ECT, which involves the use of anesthetics and muscle relaxants. In this type, the patient is unconscious during the procedure, and the convulsive movements are less severe.[3]

During ECT, patients experience muscle and joint contractions throughout the body, including the temporomandibular joint (TMJ) and jaw muscles. This can result in higher-than-normal biting forces,[6] which may lead to oral problems such as trismus (jaw locking), temporomandibular joint pain, fractured or broken teeth, tooth avulsion, or oral mucosa lacerations.[7] Dentists play an important role in assessing patients' oral health before ECT and by using a bite guard during the procedure, which helps to reduce the incidence and severity of oral and jaw complications.[8]

A study by Watt and colleagues found that the most common complications of ECT were tooth and tongue injuries, often attributed to incorrect bite guard placement or the absence of a bite guard during ECT. A total of 73,440 ECT treatments were administered, resulting in 12 recorded injuries associated with the dental and oral regions; 5 cases involving an injury to a tooth, while 7 cases were related to lacerations of the tongue or lip. In each case, either incorrect bite guard placement or failure to use a bite guard was cited as the reason for the injury. One patient had a minor laceration to his arm because of incomplete paralysis and striking his arm on a bed rail.[9]

Ogami and colleagues found that the average occlusal force before anesthesia without bite guard was 844±412 N. The average occlusal force during ECT was 989±433 N. The average occlusal force before anesthesia with bite guard was 313±150 N. The average occlusal force during ECT was 365±166 N. The main finding of the study was that the use of a custom-made bite guard resulted in an average occlusal force reduction of 58%±22% during modified ECT. This study concluded that occlusal force significantly decreased both before anesthesia and during ECT when a bite guard was used. The bite guard was exceptionally effective at preventing procedure related complications. Without the bite guard, a high incidence of adverse effects was observed: 18 out of 22 patients (82%) reported post-procedural pain and 5 out of 22 patients experienced bleeding in the mouth. In contrast, when the bite guard was used, no complications neither pain nor bleeding.[6]

A positive linear relationship between electromyogram (EMG) and bite force has been reported.[10-14] A study by Gonzalez and colleagues found that the relationship between EMG and bite force of the temporalis and masseter muscles during molar and incisor area clenching was reliable. The research found that the reliability of the slopes describing the relationship between EMG activity and bite force was generally acceptable for the masseter and temporalis muscles, especially for molar biting tasks compared to incisor biting tasks. Test-retest reliabilities were generally above acceptable levels for masseter and temporalis muscles, with molar biting showing more reliable results than incisor biting. However, suprahyoid muscles showed more variable results for both molar and incisor biting tasks and often did not meet reliability criteria. The reliability of masseter and temporalis muscles for molar biting was excellent and ranged from acceptable to excellent for incisor biting, with the potential for further improvements using electrode position templates. The study demonstrated reproducibility of EMG versus bite force data and emphasized the importance of consistent biting conditions for reliability.[15]

A study of oral complication incidence in ECT patients at a psychiatric hospital (Suanprung Psychiatric Hospital, Chiang Mai) shows that a complication cause was the inappropriate bite guard size for the patient's mouth or a bite guard shape that hindered the procedure. Suanprung Psychiatric Hospital has therefore developed and manufactured silicone bite guards in various size; small (S), medium (M), and large (L), with clearly color-coded, to suit the mouth size of each patient and to facilitate ease of use for the physician. A specific type is also available for the patients who require an endotracheal tube, also in S, M, and L sizes. Descriptively, it was found that the incidence of oral complications in ECT patients is decreased from 5.45% to 0.12%.[16] Suanprung Psychiatric Hospital has undertaken a continuous quality improvement initiative for patients

receiving Modified ECT since 2022. Analysis of procedure related oral injuries revealed that in 2022, among 4,106 ECT sessions, 10 cases of oral injury occurred, including one tongue laceration. In 2023, there were 4,751 procedures with 4 oral injuries, again including one tongue laceration. By July 2024, 3,827 procedures had been performed, with 2 oral injuries reported; one case involved a severe tongue laceration requiring suturing.

These findings indicate that tongue lacerations remain a significant clinical concern. In response, a new bite guard was specifically designed to address tongue biting injuries (Figure 1). This design was introduced in August 2024, and no oral injuries have been reported since its implementation. The development of this device was based on clinical experience at Suanprung Psychiatric Hospital, without reference to biomechanical or force related evidence from the scientific literature.

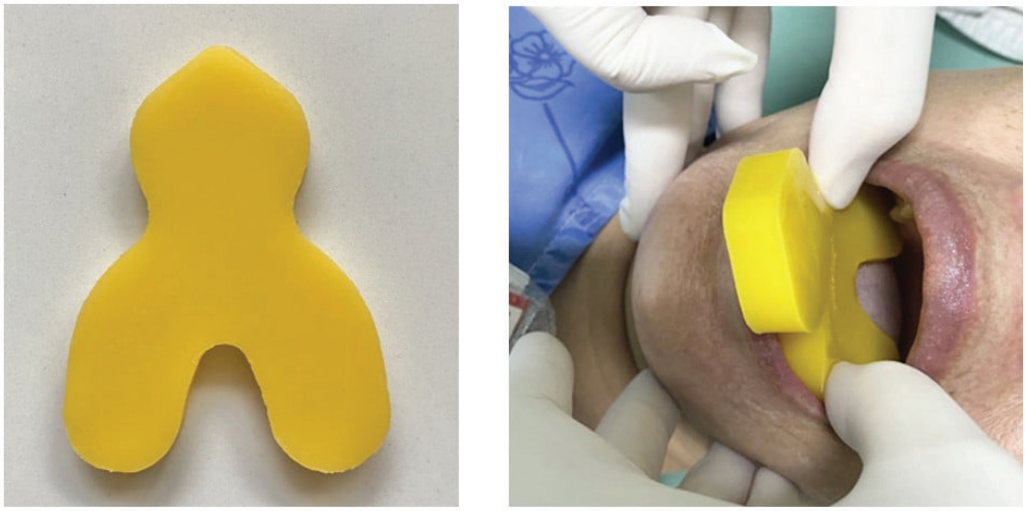

Figure 1. *A new bite guard design with a shape of silicone provides a space for the tongue to prevent biting the tongue.*

Currently, Suanprung Psychiatric Hospital exclusively uses Modified ECT with the Thymatron® System IV (Somatics, LLC, USA), which includes monitoring for electroencephalogram (EEG), electrocardiogram (ECG), and electromyogram (EMG). Surface electrodes are used for EMG signal recording. Although patients undergoing Modified ECT receive anesthetic agents and muscle relaxants before the electrical current is applied and are unconscious with reduced convulsive movements during the procedure. To our best knowledge, there are no study examining the relationship of masseter muscle EMG values in patients during Modified ECT compared to when they clench their teeth before receiving anesthetics and muscle relaxants.

Therefore, The purpose of this study was to compare the maximum EMG of the masseter muscle under three conditions: 1) prior to administration of anesthetic agents and muscle relaxants, during maximal clenching without a bite guard, 2) prior to administration of anesthetic agents and muscle relaxants, during maximal clenching with a bite guard, and 3) during ECT, after administration of anesthetic agents and muscle relaxants, while the patient was wearing a bite guard and to evaluated the complications during ECT.

Materials and methods

This study was conducted in the inpatient department of Suanprung Psychiatric Hospital. Ethical approval was obtained from the Human Ethics Committee for Psychiatric Clinical Research at Srithanya Hospital (Approval No. STY.COA007/2568).

Inclusion criteria

1. Psychiatric inpatients scheduled for modified electroconvulsive therapy (ECT) at Suanprung Psychiatric Hospital
2. Both male and female patients, irrespective of psychiatric diagnosis
3. Age ≥18 years
4. Possessing ≥20 natural teeth
5. Able to communicate and follow instructions

Exclusion criteria

1. Patients unable to cooperate due to psychiatric symptoms or poor comprehension
2. Fewer than 20 teeth present
3. Presence of Grade 3 tooth mobility (horizontal mobility >2 mm and/or vertical mobility)

Data collection

All data were collected by a single officially trained researcher. In accordance with standard ECT patient care protocols, all participants underwent an oral health examination before treatment. Eligible patients received a verbal explanation of the study, and written informed consent was obtained prior to participation. Participation was entirely voluntary.

The following data were collected:

1. Dental examination: A complete clinical examination was performed, and findings were recorded in a standardized dental chart.
2. Personal data: Demographic and clinical information were obtained from the patients' medical records.
3. EMG monitoring: EMG of the masseter muscle was recorded using the Thymatron® System IV (Somatics LLC, USA), which also provides EEG and ECG monitoring. Surface EMG electrodes (Somatics Cat. #EEDS) were placed randomized unilaterally over the masseter muscles following skin preparation (cleansing with alcohol swabs and drying). Electrodes were connected to the EMG input channel. The device's maximum measurable EMG amplitude was 5,451.1 μV.
4. Measurement protocol: Masseter EMG activity was recorded under three conditions (Figure 2):
   - (NB) Prior to administration of anesthetic agents and muscle relaxants, without a bite guard: patients were instructed to clench maximally for 3 seconds.
   - (B) Prior to administration of anesthetic agents and muscle relaxants, with a bite guard inserted: patients performed maximal clenching for 3 seconds.
   - (ECT) During the ECT procedure: after receiving propofol (0.75-1.0 mg/kg) and succinylcholine (0.3-1.0 mg/kg), a bite guard was inserted, electrical stimulus was applied, and the maximum EMG value during the convulsion was recorded.
5. Post-procedural oral examination: After ECT, the bite guard was removed and the oral cavity examined for trauma or soft tissue injury. Findings were recorded.

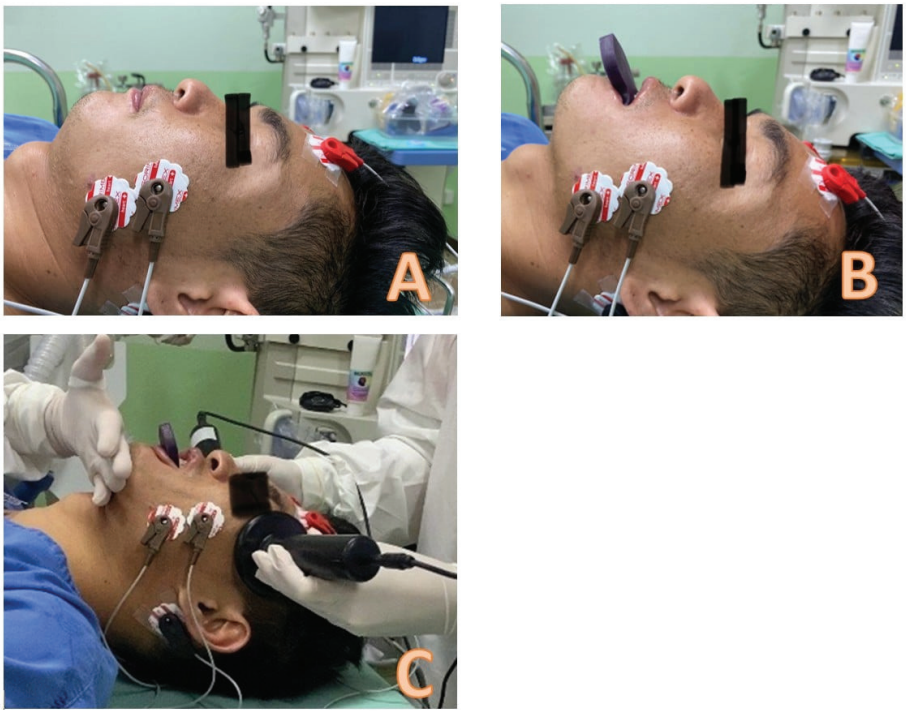

Figure 2. *Measurement protocol. A: prior to administration of anesthetic agents and muscle relaxants, maximal clenching without a bite guard, B: prior to administration of anesthetic agents and muscle relaxants, maximal clenching with a bite guard, and C: during ECT, after administration of anesthetic agents and muscle relaxants, while the patient was wearing a bite guard*

Data analysis

Data normality was evaluated using the Shapiro-Wilk test. Differences in EMG amplitudes across conditions (NB, B, ECT) were analyzed using repeated measures ANOVA with Pairwise comparison post hoc. Independent samples t-tests were used to compare EMG values between groups (<5,451.1 μV vs ≥5,451.1 μV). All analyses were performed using SPSS version 29.0 (IBM Corp., USA), and statistical significance was set at $p<0.05$.

Results

A total of 40 patients (20 males and 20 females) participated in the study. Participant ages ranged from 20 to 65 years (mean=35.63±13.17 years). The most common age group was 20-29 years (45%). Body weight ranged from 39 to 80 kg (mean=57.18±10.44 kg).

The most prevalent diagnosis was schizophrenia (F20.0) in 45% of patients, followed by bipolar disorder (F31.2) in 10%. According to the American Society of Anesthesiologists (ASA) physical status classification, 67.5% of participants were classified as ASA Class II.

The mean number of teeth was 27.7±2.33. Demographic data are summarized in Table 1.

Participants were divided into two groups based on maximum masseter EMG amplitude during ECT:

- Group 1: <5,451.1 μV
- Group 2: ≥5,451.1 μV

Independent samples t-tests compared the maximum masseter EMG values across three conditions: before anesthesia without bite guard (NB), before anesthesia with bite guard (B), and during ECT with anesthesia, muscle relaxants, and bite guard (ECT).

Table 1. Demographic data of study participants.

Characteristic	Category	Number (%)	Mean±SD	Min	Max
Sex	Male	20 (50.0)			
	Female	20 (50.0)			
Age (years)	20-29	18 (45.0)	35.63±13.17		
	30-39	8 (20.0)			
	40-49	9 (22.5)			
	50-59	2 (5.0)			
	60-69	3 (7.5)			
Weight (kg)			57.181±0.44	39	80
Diagnosis	Multiple drug use	3 (7.5)			
	Schizophrenia	18 (45.0)			
	Bipolar disorder	4 (10.0)			
	Depression	3 (7.5)			
	Other	12 (30)			
ASA classification	I	13 (32.5)			
	II	27 (67.5)			
Number of teeth			27.70±2.33	23	32

Under the NB and B conditions, no significant differences in EMG amplitude were observed between the two groups (p>0.05). However, in the ECT condition, group 2 exhibited a significantly higher mean EMG amplitude compared to group 1 (p=0.001), with a mean difference of approximately 532.4 μV (Figure 3).

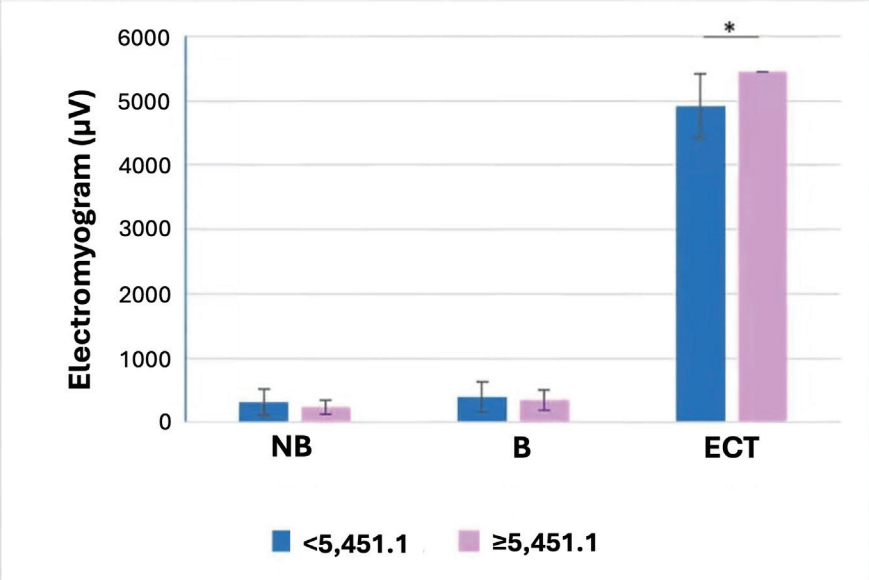

Figure 3. *The bar graph of EMG values before anesthesia and muscle relaxants without a bite guard (NB), before anesthesia and muscle relaxants with a bite guard (B), and during ECT with anesthesia, muscle relaxants and a bite guard (ECT) between both groups (*p=0.001).*

Further analysis revealed that maximum EMG values across all three conditions (NB, B, and ECT) differed significantly ($p<0.001$) in all participants (Figure 4).

Note: with the use of the newly designed bite guard, no oral complications were observed following any ECT session.

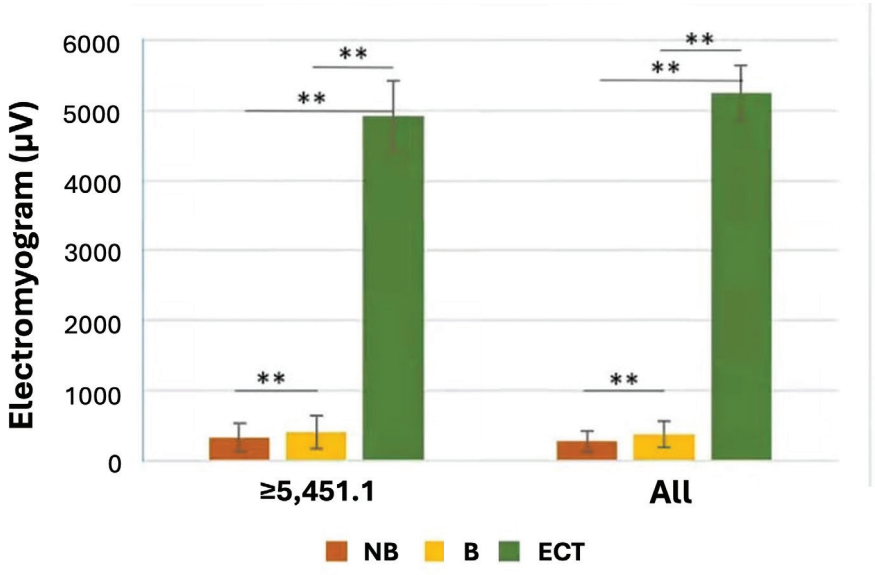

Figure 4. *The bar graph of electromyogram values. NB: before anesthesia and muscle relaxants without a bite guard, B: before anesthesia and muscle relaxants with a bite guard, ECT: during modified ECT with anesthesia and muscle relaxants with bite guard (ECT) in patients with values less than 5,451.1 μV and all patients (**p<0.001).*

Discussion

Electroconvulsive therapy (ECT) is generally used to treat various severe and treatment resistant psychiatric disorders. Nowadays modified ECT is used, this procedure involves administering an anesthetic and a muscle relaxant before passing a controlled amount of electrical current from an ECT machine into a specific brain region for a limited time to induce a generalized tonic–clonic (grand mal) seizure. This seizure causes widespread muscle contractions, including those of the masticatory muscles particularly the temporalis and masseter which are located close to the electrode placement site and may be directly stimulated by the electrical current, leading to a severe, sudden jaw closure.

Even with the use of muscle relaxants, the normal neuromuscular feedback mechanism that prevents excessive biting force does not take place in anesthetized patients. Consequently, injuries to oral and jaw structures may occur. Such injuries include tooth avulsion (which carries a risk of aspiration), tooth fractures, lacerations to the cheek, lips, or tongue, bleeding, and temporomandibular joint pain.[6,17,18] Watt and colleagues reported that the most common complications of ECT were injuries to the mouth, including dental and tongue trauma.[9]

Pre-ECT oral assessment by dentists and the use of appropriate mouth protection have been recommended to prevent injury to the teeth and other oral structures.[19,20] To reduce the risk of oral and dental injury during ECT, the American Psychiatric Association[21] recommends the use of oral protection devices made of flexible materials that cover the molar region.[22,23] However, various types and sizes of bite guards should be available to accommodate the individual characteristics of each patient's oral cavity.[24]

An ideal bite guard should prevent dental injuries without obstructing the airway,[20] be easy to insert and remove, not interfere with the placement or seal of the oxygen mask, be inexpensive, and be easy to clean and sterilize.[17] The severity of the bite reaction in ECT patients, including bite force and EMG activity, remains unclear when compared with maximum voluntary bite force.

In the present study, most patients were diagnosed with schizophrenia and classified as ASA Class II, like a study conducted at Siriraj Hospital, which utilized a rolled gauze bite guard. That study analyzed 217 ECT sessions and reported a significant oral injury incidence of 10.1%. The most common type of injury was mucosal or lip abrasion, accounting for 72.8% of all incidents. A key finding was a direct correlation between the dosage of the muscle relaxant succinylcholine and the likelihood of injury. Patients who received a lower dose (0.9 mg/kg versus 1.0 mg/kg) were significantly more likely to experience oral injury ($p=0.009$). The authors concluded that the incidence of oral injury was not negligible and could be reduced through a multidisciplinary approach involving appropriate anesthetic dosing, the use of properly sized and softer bite guards, and comprehensive pre-procedural dental assessment. [25] The bite guard used in our study was a customized bite guard fabricated from food-grade silicone (Silicone Food Grade USA SF820). No oral injuries were observed

among patients in this study. Similarly, Watt and colleagues demonstrated that custom-made bite guards fabricated individually from 3-mm ethyl-vinyl-acetate (EVA) sheets using impressions and pressure forming to ensure a precise fit were highly effective in preventing ECT-related oral complications. In their study, a high incidence of adverse events occurred without bite guards, while no complications, pain, or bleeding were reported when bite guards were used in 22 patients.[6]

It has been thoroughly searched for the study about the comparison the effectiveness of different bite guard types, there are no any study comparing the effectiveness of bite guard's types, the further study is required, however, the ethical concerns are taken into the considerations.

The bite guards are still recommended to use in edentulous patients, as the bite force is still very high and can potentially cause injury to the temporomandibular joint, lips, and tongue.

A positive linear relationship between EMG activity and bite force has been reported. [10-14] González and colleagues found that EMG activity of the temporalis and masseter muscles during clenching in the molar and incisor regions was strongly correlated with bite force.[15] Bogdanov and colleagues reported that the EMG and bite force relationship varied between the temporalis and masseter muscles; the masseter exhibited a more consistent linear relationship bilaterally, suggesting that masseter EMG can serve as a reliable indirect indicator of bite force in situations where direct measurement is unsafe.[26]

Accordingly, the results of our study, which assessed unilateral masseter muscle activity, demonstrated a significant increase in EMG values during the ECT procedure compared with normal biting force, consistent with previous findings. These results support the use of optimized, customized bite guards to prevent oral injuries. The findings also confirm that maximum EMG activity of the masseter muscle is significantly reduced when a bite guard is used and further altered during ECT under anesthesia. Therefore, the routine use of bite guards in ECT is strongly recommended to minimize oral injury. Moreover, the study emphasizes the need for properly designed, size appropriate, and material optimized bite guards for psychiatric patients undergoing ECT. Further improvements in the design of bite guards for Modified ECT require evidence-based guidance on biomechanical factors. Specifically, research is needed to determine the optimal material, shape, size, and thickness. While minimizing thickness is desirable for patient comfort, the device must still provide adequate force absorption to prevent temporomandibular joint complications and ensure overall safety. Such evidence will be essential for the future development and planning of Modified ECT services.

Limitations

Bite force measurement can be performed using devices equipped with electrical sensors. However, this method is unsuitable during ECT because the device's electrical activity could interfere with the ECT process,[6] representing the first limitation of our study. Another limitation involves the Thymatron® System IV (Somatics, LLC, USA), which monitors EMG activity from the extensor digitorum brevis muscle on the dorsal surface of the foot a site distant from the electrode placement and records a maximum measurable value of 5,451.1 μV. In contrast, our study monitored EMG activity from the masseter muscle, located closer to the electrode site and directly stimulated by the current. This proximity can cause severe, sudden jaw closure, occasionally exceeding the measurable range of the device.

Further research is needed to optimize bite guard design to improve ease of use and ensure secure intraoral placement during ECT. Studies with larger sample sizes are also required to establish average bite force values in ECT patients, particularly if safe and compatible bite force measuring devices can be developed for use during ECT.

Conclusion

Modified ECT induces masseter muscle EMG activity approximately 15 times greater than that observed during pre-ECT maximal clenching. Despite the use of anesthesia and muscle relaxants, substantial masticatory muscle activation persists during ECT.

In summary, EMG monitoring provides valuable objective evidence of masticatory muscle activity during ECT and supports the routine integration of customized silicone bite guards as a standard preventive measure in clinical practice.

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Conflict of interest

Authors declared no conflict of interest.

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