

# The effects of unilateral posterior crossbite toward the superficial masseter and anterior temporalis on muscle activity during mastication: A surface electromyographic study

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## ABSTRACT

**Background:** Adapted patterns of mastication caused by unilateral posterior crossbite require early orthodontic treatment to prevent permanent muscle change. Stable orthodontic results depend on the harmonious contraction of the occlusion and masticatory muscles.

**Purpose:** Using surface electromyography, this study aimed to analyse the effects of unilateral posterior crossbite on the superficial masseter as well as anterior temporalis muscle activity on the crossbite and non-crossbite sides during chewing soft and hard foods.

**Methods:** A cross-sectional study was conducted on 20 subjects with at least two posterior teeth who had a unilateral posterior crossbite without mandible shifting. Surface electromyography was used to measure activity amplitudes for the superficial masseter and the anterior temporalis muscles while chewing soft and hard foods. An independent t-test was used to determine the mean difference between chewing soft and hard foods through the superficial masseter and anterior temporalis muscles. **Results:** Results showed a significant difference in amplitude mean between crossbite and non-crossbite sides of the superficial masseter and anterior temporalis muscles with both soft and hard food chewing ( $p < 0.05$ ). The study also revealed a decrease in the activities of superficial masseter and anterior temporalis muscles when masticating soft and hard foods on the crossbite sides as compared to the non-crossbite sides.

**Conclusion:** A unilateral posterior crossbite results in a decrease in the superficial masseter and the anterior temporalis muscle activity when masticating both soft and hard foods on the crossbite side.

**Keywords:** anterior temporalis muscle activity; surface electromyography; superficial masseter muscle activity; unilateral posterior crossbite.

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## INTRODUCTION

Mandibular deviation in normal occlusion generally occurs due to genetic and environmental factors such as oral bad habits, premature loss, deciduous teeth persistency or broad caries that evolve into a malocclusion.<sup>1</sup> Transversal malocclusion causes a posterior crossbite with a higher prevalence of the unilateral side than the bilateral. The onset of a posterior crossbite occurs during the eruption of the deciduous teeth, involving permanent teeth at a later stage of development and affecting the masticatory function through the growth stage.<sup>2</sup> A unilateral posterior crossbite causes dentoalveolar asymmetry, mandible deviation and

imbalanced muscle function.<sup>3</sup> Early mixed dentition has a variable prevalence of unilateral posterior crossbite. Early orthodontic correction is crucial to prevent abnormal transversal growth in the intermolar region by developing an advanced upper jaw.<sup>4</sup> The effectiveness of mastication in a unilateral posterior crossbite is different between each side of the jaw, changing the mastication pattern via a preferred chewing side that is considered more effective and comfortable. Occlusal interference in mastication leads to excessive stimulation of mechanoreceptors at the periodontal ligament and continuous afferent impulses to the receptor that stimulates motoneuron behaviour, increasing the mastication muscles' activity.<sup>5,6</sup>

Electromyography (EMG) can identify changes in muscle activity and kinematic patterns with regard to chewing load capacity adjustment. Surface EMG (sEMG) is performed by attaching electrodes to the skin's surface to detect potential electric action of a muscle movement or rest period.<sup>7</sup> Many studies have focused on the relation between malocclusion and the muscle activity of mastication using EMG. Some research into class I malocclusion has shown more increased sEMG activity than class II or class III. As elevator muscles, the superficial masseter and anterior temporalis are responsible as anti-gravity extensors, maintaining muscle posture during the rest position and mandible movement during mastication.<sup>8,9</sup> Assessments of sEMG in superficial masseter and anterior temporalis muscle activity during clenching and chewing gum among post-orthodontic treatment patients showed more balanced results than normal occlusion in patients without orthodontic treatment.<sup>9</sup> Research on children aged 10–14 years revealed that superficial masseter muscles were less active among crossbite subjects than normal occlusion subjects with bilateral mastication patterns.<sup>9,10</sup> The aim of this study was to investigate muscle activity of the superficial masseter and anterior temporalis during mastication soft and hard foods in subjects 19–21 years old with unilateral posterior crossbite using surface electromyography.

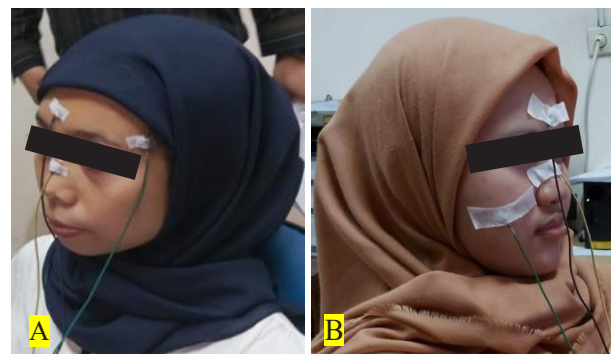
## MATERIALS AND METHODS

Cross-sectional analysis was performed to investigate the influence of risk factors and effects of this study. A total of 20 subjects were involved in this study, aged between 19–21 years and consisting of 15 woman and 5 men, with unilateral posterior crossbite. Subjects included students in the Dentistry and Dental Hygiene Program of Dentistry Faculty, Universitas Gadjah Mada, selected via the following inclusion criteria: (a) a unilateral posterior crossbite involving at least two teeth; (b) unilateral posterior crossbite identified during centric relation and centric occlusion position; (c) no mandible displacement when opening and closing; (d) complete teeth except third molars; (e) never had facial trauma; (f) no temporomandibular joint clicking, crepitus or pain when mouth opening; (g) no dentures or occlusal splint; (h) no history of orthodontic or orthognathic care; and (i) not diagnosed with a systemic disease. The exclusion criteria included (a) subjects with single tooth crossbite and (b) bilateral posterior crossbite.

This study used a questionnaire as the instrument to measure oral condition and history of malocclusion before examination. The subjects were measured on crossbite and non-crossbite sides. The non-crossbite is defined as the area with normal occlusion, and the control group contains the Angle class I molars. The sampling technique performed was purposive sampling. The subjects underwent an initial assessment regarding health status and crossbite history. They received an explanatory sheet describing the study

objectives, benefits, evaluation, process and informed consent. Subjects were approved to join this research protocol after reading the assigned informed consent form. This research received a feasibility permit from the Faculty of Dentistry, Universitas Gadjah Mada research ethics commission 00367/KKEP/FKG-UG/EC/2020.

The research instrument used in this study was an electromyograph (Nihon Kohden series EMB 2306, US) with a 10kHz/10Hz filter and 2 mv calibration, consisting of three electrodes. The active electrode was positioned over the muscle, a reference electrode was positioned on the nose, and a ground electrode was positioned on the forehead. Forty grams of roasted peanuts (Dua Kelinci, Indonesia) and 42 grams soft cakes (Nextar, Indonesia) were used in this study. The measured object in this study were the superficial masseter and the anterior temporalis muscles (Figure 1). Preceding electrode placement, the superficial masseter muscle was measured three millimetres from the line of the inferior mandible to each side. The electrodes of anterior temporalis muscle were attached at two-thirds inferior arcus zygomaticus of both the crossbite and the non-crossbite sides. The subjects were initially instructed to initiate a clenching movement to detect the muscle. The electrode on the superficial masseter muscle was attached parallel to the muscle, and the electrodes of anterior temporalis were placed perpendicular to the muscles. The activities of the superficial masseter and the anterior temporalis muscle were not measured simultaneously. The surface electrode applied with electrolyte gel and tape over skin cleaned before application. Subjects were instructed to remain in the rest position for two minutes without any measurements, and then chew soft cakes for 20 seconds for the evaluation. Afterwards, they were to chew roasted peanuts for 20 seconds, and measurements were taken. Evaluations began with the right superficial masseter, right anterior temporalis, left superficial masseter and left anterior temporalis. Subjects had to rinse their mouths to remove food debris when measuring each muscle was complete. Electrode removal was performed after all measurements were completed.



**Figure 1.** (A) Electrode placement during temporalis muscle examination. (B) Electrode placement during superior masseter muscle examination.

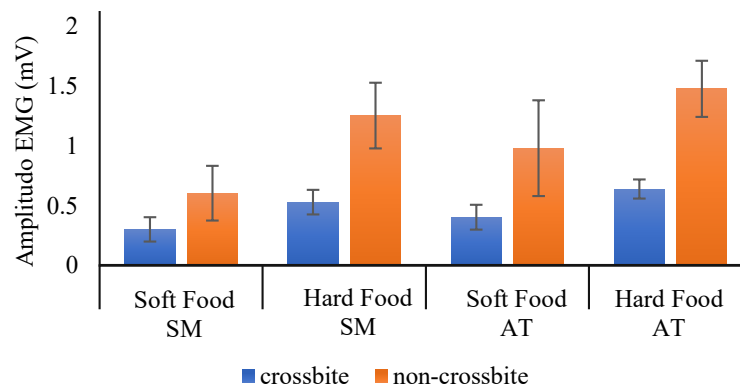
The measurement results are interpreted based on the synchronisation of the observation time at intervals of 0–5 seconds; 5–10 seconds; 10–15 seconds and 15–20 seconds by marking the highest amplitude in each period. Intervals were determined by manual Motor Unit Potential (MUP) recording muscle action potentials through four scoring panels on the EMG screen monitor. The evaluation not only measured the highest amplitude of each interval, but also the arithmetic process on one screen per interval time measurement. The Shapiro-Wilk was used for data analysis in this study for the normality test and an independent t-test to compare the mean of each group.

## RESULTS

The difference in activity of the superficial masticatory muscle and the anterior temporal muscles during chewing can be seen in Figure 2. The results of the normality test

(Shapiro-Wilk) have a significance value ( $p > 0.005$ ) showing that the data of both muscles are normally distributed in soft and hard chewing (Table 1). The independent t-test (Table 2) showed that a unilateral posterior crossbite affected the activity of the superficial masseter and anterior temporal muscles during the chewing of soft and hard foods ( $p < 0.05$ ).

Muscle activity on the crossbite side was lower than on the non-crossbite side in both the superficial masseter muscle and the anterior temporomandibular muscle during chewing of soft and hard foods. Activity of the superficial masseter muscle on the crossbite side is least when chewing soft foods, followed by the anterior temporalis muscle. The highest activity was observed by the anterior temporalis muscle during hard food chewing, followed by the superficial masseter muscle of the non-crossbite side. Differences in amplitude of superficial EMG activity between superficial masseter muscle and anterior temporalis muscle from the crossbite and



**Figure 2.** Mean and standard deviation superficial masseter and anterior temporalis muscle on the crossbite and non-crossbite sides. Note: SM: superficial masseter; AT: anterior temporalis.

**Table 1.** Normality test of superficial masseter and anterior temporalis muscle activity on soft and hard foods between crossbite and non-crossbite side

Variable	Sig. (p)			
	SM Soft food	SM Hard food	AT Soft food	AT Hard food
Crossbite	0.055*	0.626	0.68	0.99
Non-crossbite	0.179	0.274	0.38	0.55

Note: lowest significant  $p > 0.05$ ; SM: superficial masseter; AT: anterior temporalis

**Table 2.** Independent t-test results of superficial masseter and anterior temporalis muscle activity on soft and hard foods between crossbite and non-crossbite side

Muscle Activity	Mean $\pm$ Standard deviation (mV)		Sig. (p)
	Crossbite	Non-Crossbite	
Superficial masseter (Soft food)	0.529 $\pm$ 0.103	1.254 $\pm$ 0.275	0.001*
Anterior temporalis (Soft food)	0.639 $\pm$ 0.080	1.478 $\pm$ 0.235	0.001*
Superficial masseter (Hard food)	0.301 $\pm$ 0.102	0.604 $\pm$ 0.229	0.001*
Anterior temporalis (Hard food)	0.403 $\pm$ 0.104	0.981 $\pm$ 0.401	0.001*

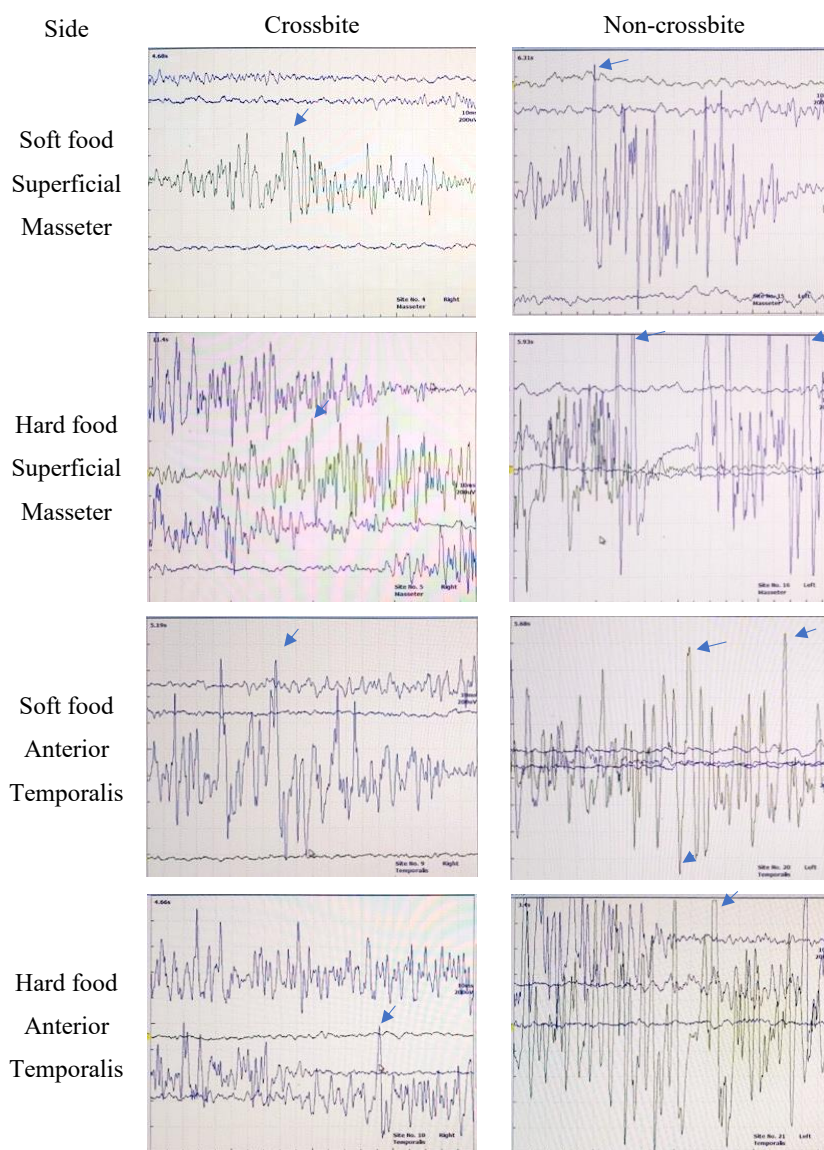
Note: \*) significant  $p < 0.05$

non-crossbite side (Figure 3) revealed that the amplitudes of the superficial masseter and anterior temporalis muscle are lower on the crossbite side than the non-crossbite when chewing soft food. Similar to soft food, the amplitude was increased in hard food chewing than on the crossbite side, characterised by more narrow and steep waves than the non-crossbite side.

## DISCUSSION

Muscle activity decreased in the crossbite side of the superficial masseter and anterior temporal during mastication of soft and hard foods. There was a decrease in elevator muscle activity in crossbite side when chewing soft and hard food, influenced by the broad surface areas

of chewing, duration and individual strength. Occlusal disturbances caused narrow chewing areas, contributing to the lower duration and reduced strength of individual mastication.<sup>1</sup> In this study, surface EMG indicated a narrower peak amplitude with amplitude frequency caused by similar food characteristics at the non-crossbite side. Shapes and heights of amplitudes differed between the crossbite and non-crossbite sides were a result of the type of muscle contraction during mastication.<sup>2</sup> This study revealed decreasing anterior temporalis muscle activity on the crossbite side during the soft and hard food mastication compared to the non-crossbite side. It also showed the peak of amplitude was lower on the crossbite side than the non-crossbite for both types of food (Figure 3). At the same time, occlusal disturbances decreased masticatory strength on the crossbite side, which affected the activity of the superficial



**Figure 3.** Amplitude difference among crossbite and non-crossbite side of superficial masseter and anterior temporalis muscle during mastication soft and hard food mastication. Blue arrows indicate the highest amplitude in the area of the electromyograph.



masseter and anterior temporalis muscle contraction during jaw closure.<sup>3</sup> The EMG evaluation revealed that the distance between the amplitudes on the crossbite side is larger than on the non-crossbite side. Magnitude gap refers to the decreasing frequency of amplitude as the muscle on the crossbite side contracts. This study's results differ from those reached by Piancino et al.<sup>3</sup> who found that masseter muscle activity on the non-crossbite side did not increase during chewing based on the assessment of food density. Emerging potential action that occurred due to contractions are influenced by food variant, area and duration of chewing.<sup>4</sup>

The electromyogram in this study revealed frequent low amplitude on the side of the crossbite, whereas, in the non-crossbite side, several peak amplitudes arose with a narrow form and approached the limits (Figure 3). During the hard food mastication, the contraction of the superficial masseter muscle on the non-crossbite side occurs more rapidly due to the texture of the food that require greater mastication power. Muscle contraction acceleration during the hard food mastication is influenced by the linear work of chewing duration and surface areas.<sup>5,6</sup> These findings suggest that the non-crossbite side has more substantial occlusal stability, resulting in the mastication force experienced by mastication muscles compared to the crossbite side.<sup>6,7</sup> Gungor et al.<sup>8</sup> confirmed that the activity and strength of the superficial masseter and anterior temporalis muscles on the crossbite side were less active than the non-crossbite side in 6–9 year age group. The chewing area in this study was represented by molars and premolars that had a crossbite. Mastication efficiency was thus also affected by the occlusal surface which received the mechanical load.<sup>9</sup> The size of teeth varied among the participants, which also affected the chewing area during mastication.<sup>10</sup> Despite tooth morphology, Ardani et al.<sup>11</sup> did not find significant difference in Class I and II malocclusions among Javanese ethnic patients. These were measured by sEMG temporalis, masseter and suprahyoid muscles. Rahmawati et al.<sup>12</sup> also investigated the relationship between muscle activity in class I and class III malocclusion among subjects of Javanese ethnicity. Results showed a greater value in the class III temporalis muscles during clenching than in class I malocclusion.<sup>12</sup> Komino et al.<sup>13</sup> concluded that the pathway, rhythm, and velocity of masticatory movements are altered by varying the muscular activity of the masseter muscles responsible for the hardness of test foods. Tomonari et al.<sup>14</sup> suggested that the use of standardised food is the best choice for measurements with EMG given the homogeneous shape and size and a texture that is not easily decomposed; in contrast, raw foods can change shape, colour and texture according to temperature and conditions. Controlled variables in this study, including age, seating position with natural head position, type and size of food, and electrode position that were more than 2 cm apart, are known to affect the measurement results. One of the inclusion criteria in this study defined crossbite as involving at least two teeth, so it is not merely involving

the first dental molar. Shimada et al.<sup>15</sup> found that efficiency of chewing on the premolar area was less than the molar area. This difference is caused by difference surfaces and the anatomy of those teeth. Value improvements of the amplitude side without a crossbite are caused by maximal muscle contraction occurring simultaneously without occlusal interference, while decreased muscle activity on the crossbite side was influenced by the number of chewing teeth and muscle thickness.<sup>16,17</sup> In a study focusing on gender, Koç et al.<sup>18</sup> found that masticatory strength among males is more remarkable than females due to differences in muscle volume.

The limitations of this study included sample size and sex distribution, which affected the results. The large standard deviation value is due to the research being conducted in a study with a cross-sectional approach that aims to identify a relationship of exposure to risk factors. An unequal sex distribution influences the chewing force on both sides when chewing soft and hard foods. Contributory factors such as poor oral habits, crossbite molar involvement and muscle thickness had not been previously controlled for. According to this study, reducing the activity of the crossbite side in superficial masseter and anterior temporalis muscles by using surface EMG had a significant effect on mastication. Future studies should differentiate between mastication muscle activity and controlled oral bad habits, first molar involvement, gender and muscle thickness. Evaluation of mastication muscle activity using surface EMG can provide accurate data to make better orthodontic treatment.

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