Mandibular movement during sleep bruxism associated with current tooth attrition

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Abstract

Patient: Observation of attrition patterns suggests that mandibular movement in sleep bruxism (SB) may be associated with current tooth attrition. The aim of this study was to confirm this phenomenon by investigating mandibular movement and masseter muscle activity. The subject was a healthy 21-year-old Japanese male. We recorded biological signals including mandibular movement and masseter electromyograms (EMGs) with a polysomnograph. Based on the EMG using Okura's criteria, SB events were classified into clenching, grinding and mixed types according to mandibular movement criteria. The close-open mandibular movement cycles (CO-cycles) during grinding and mixed type events were selected based on mandibular movement trajectories. **Discussion:** Fifty-eight CO-cycles were selected in seven grinding and three mixed types. We found that SB mandibular movements associated with current tooth attrition. Excessive lateral movements (ELM) beyond the canine edge-to-edge position were observed in the closing (10.3%) and opening (13.8%) phases of the CO-cycle. Total masseter muscle activity was significantly higher during voluntary grinding (VGR) than during CO-cycle including ELM (working side: $P = 0.036$, balancing side: $P = 0.025$). However, in the middle and late parts of the opening phase, working side masseter muscle activity was significantly higher during CO-cycle including ELM than during VGR ($P = 0.012$). In the early part of the closing phase, balancing side masseter muscle activity was significantly higher during CO-cycle including ELM than during

VGR ($P = 0.017$). **Conclusion:** These findings suggest that excessive forceful grinding during ongoing SB events may have caused canine attrition in this patient.

1. Introduction

Bruxism is caused by the hypertonic contraction of the masticatory muscles and is defined as a diurnal or nocturnal mandibular parafunction that includes clenching, bracing, gnashing, and grinding of teeth [1]. In general, it includes parafunctional habits, such as finger sucking or nail biting [2,3]. Sleep bruxism (SB) can cause damage to the masticatory system including tooth fracture, severe attrition, tooth abfraction, periodontitis, dental prosthesis breakage, dental implant body drop out, temporomandibular disorders, headache or shoulder stiffness [3-6]. Previous SB studies have mostly focused on masticatory muscle activity or occlusal force [7-9], from which the mandibular movement pattern during SB has been speculated. However, according to our previous study on real mandibular movement during SB, SB cannot be predicted from kinetic methods (e.g. masticatory muscle activity or occlusal force) [10]. Therefore, some investigators have tried to measure and analyze mandibular movement during SB [10-12]. Akamatsu et al. studied occlusal contacts during sleep with a pair of magnetic switches and found that there are two types of grinding (unilateral grinding and bilateral grinding) [11]. Okura et al. observed two directions (right/left and vertical) of mandibular movement during SB with a magnet and two hall elements and found that more than half of the subjects clenched out of the intercuspal position[10]. Amemori et al. analyzed mandibular incisal movement and found that clenching movements were the most common in SB[12]. Mandibular movements have six-degrees-of-freedom, but the abovementioned mandibular tracking systems did not have enough degrees of freedom to evaluate the mandibular position during sleep. To overcome this problem, we developed a six-degrees-of-freedom electromagnetic mandibular tracking device that can be used for sleep studies[13,14].

Although it is speculated by observing tooth attrition that mandibular movements in SB occur associated with current tooth attrition, no studies have investigated this phenomenon. In this study, the mandibular movement and biological signals of a 21-year-old Japanese male subject were recorded during sleep. We found unique mandibular movement and masseter muscle activity patterns during SB events that may be responsible for the subject's dental attrition.

2. Outline of case

We recorded the mandibular movement and biological signals of a subject using a six-degrees-of-freedom system to measure mandibular position during sleep[13,14]. For recording incisal position, the small (8*8*8mm) and light weight (2gram) magnetic transmitter (D32FU887FU-332. TOKO INC, Saitama) and sensor (KE4513CTE283M, KOA corporation, Nagano) were attached by acrylic resin to the teeth of the maxilla and mandibular respectively. This system can simultaneously record mandibular movement, respiration, electroencephalogram (EEG), electrooculogram (EOG), electrocardiogram (ECG), electromyogram (EMG), and audio visual data during sleep (Fig. 1), and consists of an electromagnetic mandibular tracking device with an intra-oral sensor, an ambulatory polysomnograph (Polymate 1132, TEAC, Tokyo, Japan), a GPS clock (LS-20K, Hakusen, Tokyo, Japan) and an AV Monitor (HDR-SR8, Sony, Tokyo Japan) [15]. Mandibular movements and biological signals were recorded at sampling frequencies of 100 Hz and 2.0 kHz. We confirmed that this system allow to record the position resolution of incisal point was 0.048 mm RMS (Root Mean Square) and angular resolution was 0.104 degree RMS and that time consistency (0.053 %) was stable for 7-hr recording.

To temporarily synchronize the data stream among the mandibular tracking device, polysomnograph and AV monitor, we used IRIG_B signals derived from the GPS time marker and the image recording tool program (Video Recording Tool, Noru Pro Light Systems, Tokyo Japan).

The subject was a 21-year old male university student, who was aware of his SB and had individual normal occlusion with moderate to severe attrition on the upper right canine (Fig. 2). The subject was healthy and had no dental restorations, missing teeth or orofacial pain. His BMI was 22.0kg/m^2, and overbite and overjet were 4 mm. The subject completed two consecutive overnight recordings of his sleep in the sleep laboratory. We analyzed the second night data to avoid the first night effect. Before and after the sleep recordings, the subject was asked to perform maximal voluntary clenching (MVC) and various border movements of the mandible including voluntary grinding (VGR). VGRs were indicated that forceful rhythmical lateral movement in both right and left side for 5 s. During sleep, we monitored the subject in an adjacent room all night.

The EMG data of the right and left masseter muscles during the night were converted to RMS values using a time constant of 60 ms. The amplitude of the RMS EMG was quantified in terms of the subject's 100% MVC level recorded before sleep, and then Okura's EMG criteria for detection of an SB event was applied (Fig. 3) [10]. The detected SB events were classified into clenching, grinding and mixed type events based on the following mandibular movement criteria. The clenching type corresponds to all EMG bursts included in an SB event lasting more than 2 s; the grinding type corresponds to all other EMG bursts included in an SB event lasting less than 2 s; and the mixed type event is a combination of the clenching and grinding type [10]. Close-open mandibular movement cycles (CO-cycles) of less than 2.5 s during grinding or mixed type events were defined from successive most inferior mandibular positions (Figs. 4 and 5). Most inferior points were selected as onset of closing phase in CO-cycles and most superior mandibular points were selected as onset of opening phase in CO-cycles. As shown in Figure 5, each opening and closing phase in the CO-cycle was subdivided into three equal time parts: early (EP), middle (MP) and late (LP) parts. The CO-cycles were subdivided into excursion and non-excursion types based on the presence or absence of lateral tooth excursion. The side where the closing phase of the CO-cycle began was defined as the working side, and the other side was defined as the balancing side. We also investigated the relationship between the subject's attrition and ongoing SB to analyze the mandibular movement and masseter muscle activity pattern during the CO-cycle.

We used IBM SPSS 22.0 (IBM Japan, Tokyo, Japan) for statistical analysis, and the Wilcoxon signed-rank test was used for the group comparison. Statistical significance was set at $\alpha = 0.05$.

3. Discussion

The sleep condition of the subject was good (total sleeping time: 6.9 h, sleep efficiency: 97.6% and sleep latency: 2.7 min). Sixteen SB events (clenching type: 6, grinding type: 7 and mixed type: 3) during one night (2.3 events/h) were detected and there were 58 CO-cycles during the grinding and mixed type SB events. Masseter muscle activity was greater during the closing phase than during the opening phase in the CO-cycle, but there were no significant differences ($P = 0.298$). There were various-mandibular movement patterns observed during the CO-cycle and they were classified into two groups based on the absence or presence of lateral excursion with masseter muscle activity of more than 5% MVC: non-excursion type ($n = 8$, 13.8%) and excursion type ($n = 50$, 86.2%) (Fig. 6). In the excursion type, two cycles were teardrop-shaped chewing-like mandibular movements (3.4%). Interestingly, we found unique mandibular movements and masseter EMG activity patterns during SB events that are strongly implicated as a cause of the patient's upper right canine attrition (Fig. 7). As show in Fig. 7, the incisal point paths during these SB events passed within a small neighborhood of awake lateral border path. These were excessive lateral movements (ELM) past the right canine edge-to-edge position in which masseter EMG activity was more than 5% MVC, and were observed in both the closing (n = 6, 10.3%) and opening (n = 8, 13.8%) phase of the CO-cycle (Figs. 6, 7, 8). The more cranial position of the excessive movement path indicated by the dotted circle in Fig. 6 also suggested that excessive friction was applied to the patient's right upper canine surface during ELM. We compared masseter muscle activity during CO-cycle including ELM and VGR movement, and found that EMG activity during CO-cycle including ELM could be more than 5% MVC, not only in and around the intercuspal position during VGR, but also during movement to eccentric positions including the right canine edge-to-edge position (Fig. 8). Total masseter muscle activity during VGR was significantly greater than during CO-cycle including ELM (P = 0.036 for the working side, and P = 0.025 for the balancing side) (Fig. 9). However, in the middle and late parts of the opening phase, working side masseter muscle activity during CO-cycle including ELM was significantly higher than during VGR (P = 0.012 for the middle part and P = 0.012 for the late part) (Fig. 10). Additionally, in the early part of the closing phase, balancing side masseter muscle activity during CO-cycle including ELM was significantly higher than during VGR (P = 0.017) (Fig. 11).

The most common cause of dental attrition is bruxism, or grinding of the teeth. However, dental attrition status is not predictive of ongoing bruxism [16,17]. Excessive dental attrition is the most common sign of SB and it is easy to assume that dental attrition is caused by the repeated excessive friction created from SB. However, the use of tooth wear as an indicator of SB is not very reliable for current or active grinding diagnosis [18-20]. Moreover, tooth wear does not help to determine the severity of SB [20]. In this report, we recorded mandibular movement and masseter muscle activity during sleep, and found that forceful grinding movement during SB events occurs not only in the closing phase (medial excursion) but also in the opening phase (lateral excursion), unlike the grinding cycle in chewing. Although the integral value of masseter muscle activity during VGR was greater than during CO-cycle including ELM, greater masseter muscle activity was observed at eccentric mandibular positions (e.g. the canine edge-to-edge position) during the CO-cycle. It was observed that the muscle activity pattern during excessive lateral excursions in the CO-cycle was different from that during VGR, and it is speculated that mandibular movement during SB events is not controlled well by the masticatory muscles. General muscle activity during sleep was lower than in the awake condition [21], and facial muscle tonus during rapid eye movement (REM) sleep was lower than during non-REM (NREM) sleep [21]. Moreover, these phenomena were usually observed in antigravity muscles (e.g. the mentalis muscle) and they were hardly observed in the masseter and temporalis muscles [21]. It has also been reported that twitch-like muscle activity occurs in the REM sleep stage, despite low background muscle tone[21].

The limitation of the current study includes the following: 1. Upper part of awake border movement is configured by only four border movements (both sides lateral, anterior and posterior border movement). 2. Mandibular movement data alone can not indicate the appearance of dynamic occlusal contact on the facet of his right canine quantitatively. However, we found excessive lateral movements that were almost on the awake lateral border movements in sagittal, frontal, and horizontal plane projection. The right canine edge to edge position while awake is placed 4.97 mm apart from intercuspal position where is almost the same as the more cranial position of ELM path.

We analyzed the relationship between mandibular movement and masseter muscle activity during CO-cycle including ELM and VGR and concluded that during ELM past the right canine edge-to-edge position, masseter muscle activity could be more than 5% MVC. We also observed that both the closing and opening phases of the CO-cycle resulted in attrition on the buccal and palatal surfaces of the upper right canine. Our findings suggest that it is necessary to record and analyze not only biosignals (e.g. muscle activity and occlusal force), but also mandibular movement. These recordings may be useful in the diagnosis of dental attrition and in treatment planning decisions (e.g. individual ideal occlusion, guidance of prosthesis and occlusal splint). Further investigations should include more subjects and should focus on clarifying the relationships between mandibular movements, masseter EMG patterns during SB events, and dental attrition. Consequently, it is necessary to investigate dynamic occlusal contact patterns during SB quantitatively.

4. Conclusion

We report a case of a patient with ELM past the right canine edge-to-edge position in which masseter muscle activity was more than 5% MVC. These phenomena were observed in both the closing and opening phases of the CO-cycle and it is strongly suggested that repeated excessive forceful grinding movement during sleep may have caused severe attrition on the buccal side of the canine.

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Conflict of Interest

All author report no conflict of interest related to the manuscript.

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Legends to Figures

Fig. 1: The six-degrees-of-freedom mandibular tracking system for studying sleep bruxism (SB) was developed at Tokushima University and allows simultaneous recording of mandibular movement data and polysomnograph data. We recorded mandibular movement, respirogram, electroencephalogram (EEG), electrooculogram (EOG), electrocardiogram (ECG), electromyogram (EMG) and audio visual data (AV). To temporarily synchronize the data stream, a GPS time marker and an image recording tool program were used.

Fig. 2: Intra-oral photographs of the subject. Attrition was observed on the buccal surface (severe) and palatal surface (moderate) of the upper right canine.

Fig. 3: Criteria for SB detection based on masseter muscle activity. SB events were determined on the basis of the EMG by applying Okura's methods [10]. An EMG evaluation that satisfied the following criteria was defined as a bruxism event: 1) elevations of the EMG signal above 5% MVC were selected as EMG bursts; 2) if the duration of the EMG burst was less than 0.25 s, the EMG burst was excluded; 3) if the inter-burst interval was equal to or less than 2 s, these bursts were linked; and 4) if the total duration of this linked burst was greater than 2 s, it was defined as an SB event.

Fig. 4: Selection of the close-open mandibular movement cycle (CO-cycle) from SB events. The figure shows an example of SB event data including RMS EMG signals for the right and left masseter muscles, and mandibular positions in antero–posterior, left–right, and superior–inferior directions. In this bruxism event, grinding and clenching periods were found. Based on mandibular movement trajectories in the superior–inferior direction, the grinding period was divided into two phases: the closing phase and the opening phase.

Fig. 5: The duration of each closing and opening phase in the CO-cycle was subdivided into three equal parts: early (EP), middle (MP), and late (LP) parts.

Fig. 6: Mandibular movement during the CO-cycle was classified roughly into two types: non-excursion type (n = 8, 13.8%) and excursion type (n = 50, 86.2%). Among the excursion type movements, teardrop-shaped movement of the mandible was observed in two cases (3.4%). Unique mandibular movement and masseter activity patterns indicated by the dotted circle were observed during SB events and are strongly implicated as a cause of the subject’s upper right canine attrition. These consisted of excessive lateral movements (ELM) past the right canine edge-to-edge position in which masseter EMG activity could be more than 5% MVC, and they were

observed in the both the closing (n = 6, 10.3%) and opening (n = 8, 13.8%) phase of the CO-cycle.

Fig. 7: Trajectory of CO-cycle including ELM mandibular movement in three plane projection.

Fig. 8: Masseter muscle activity was observed around the intercuspal position during voluntary grinding (VGR). Masseter muscle activity during CO-cycle including ELM could be more than 5% MVC in and around the intercuspal position during VGR, and also in eccentric positions including in the right canine edge-to-edge position. The more cranial position of the excessive movement path suggests that excessive friction is exerted on his right upper canine surface during ELM.

Fig. 9: The total integral value of masseter muscle activity was statistically greater in VGR (n = 10) than in CO-cycle including ELM (n = 8).

Fig. 10: We compared the integral value of working side masseter muscle activity during the early, middle and late parts of the closing and opening phases. Greater masseter muscle activity was observed during CO-cycle including ELM (n = 8) than during VGR (n = 10) in the middle and late parts of the opening phase (P = 0.012).

Fig. 11: Comparison of balancing side masseter muscle activity between CO-cycle including ELM and VGR.

We compared the balancing side integral value of masseter muscle activity during the early, middle and late parts of the closing and opening phases. Greater masseter muscle activity was observed during CO-cycle including ELM ($n = 8$) than during VGR ($n = 10$) in the early part of the closing phase ($P = 0.017$).

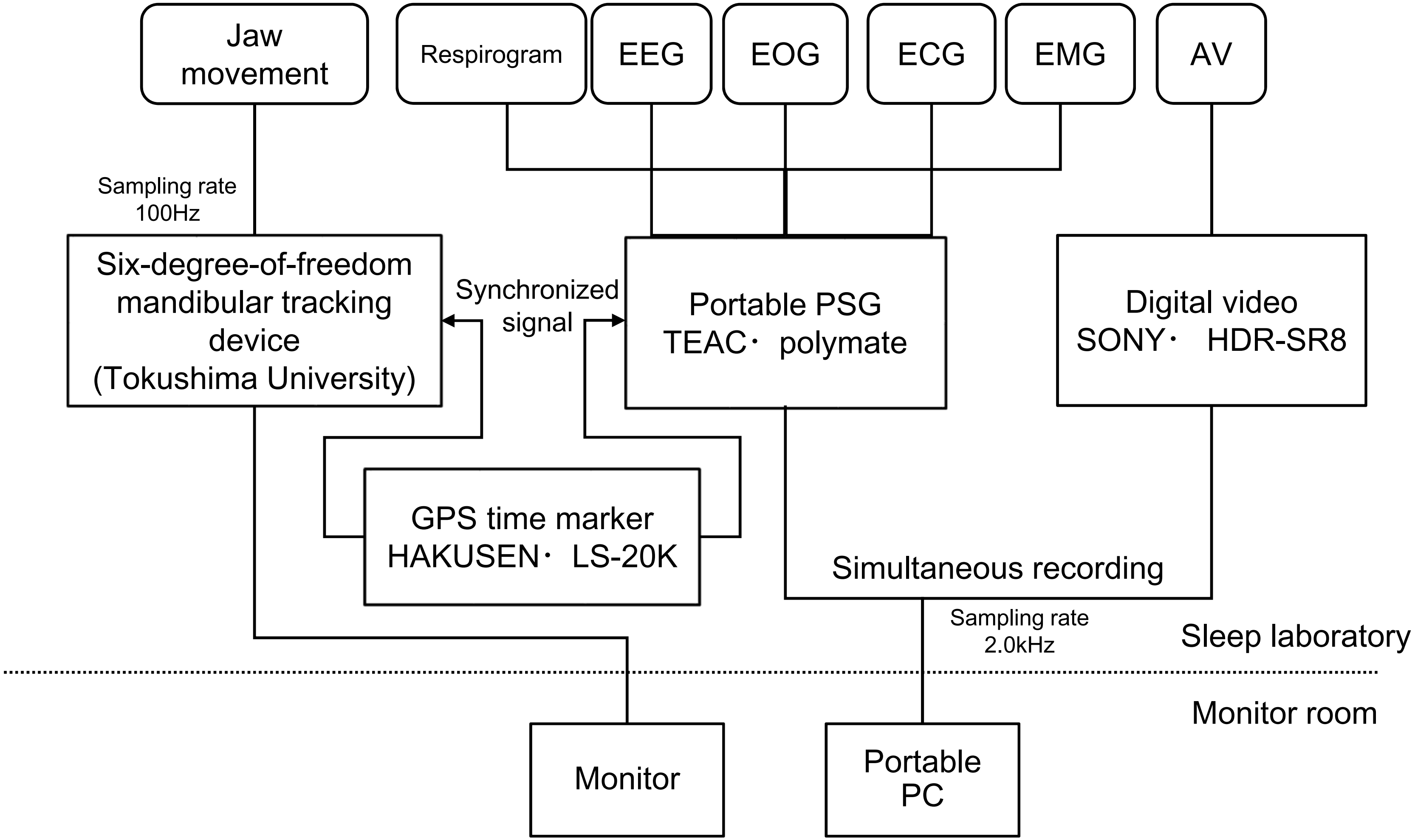

Jaw movement
Respirogram
EEG
EOG
ECG
EMG
AV
Sampling rate 100Hz
Six-degree-of-freedom mandibular tracking device (Tokushima University)
Synchronized signal
Portable PSG TEAC・ polymate
Digital video SONY・ HDR-SR8
GPS time marker HAKUSEN・ LS-20K
Simultaneous recording
Sampling rate 2.0kHz
Sleep laboratory
Monitor room
Monitor
Portable PC

Fig. 1

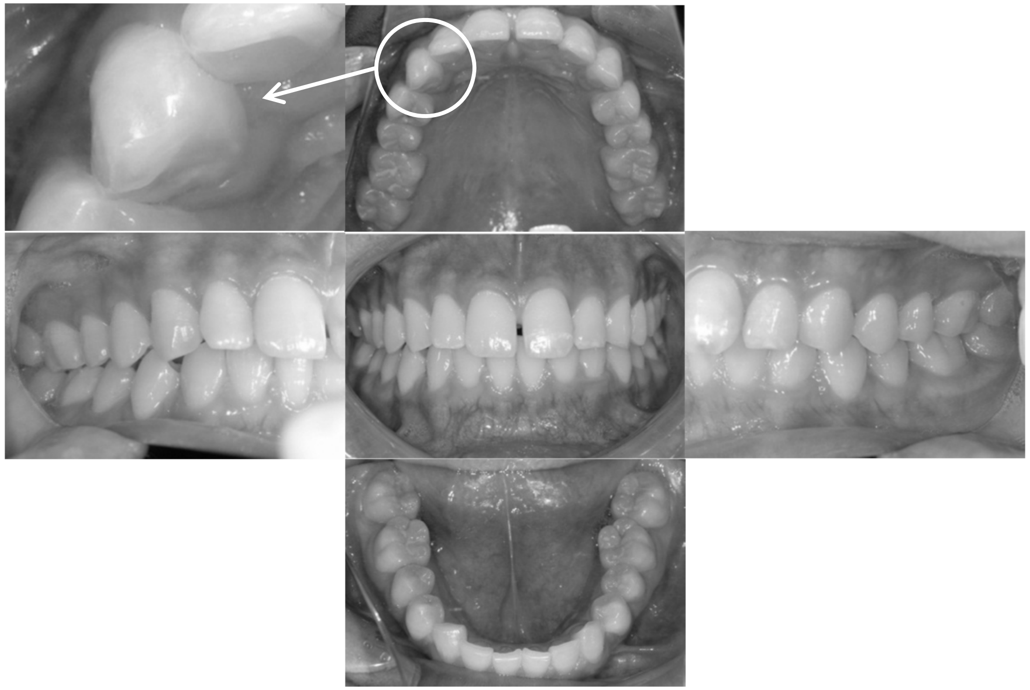


Fig. 2

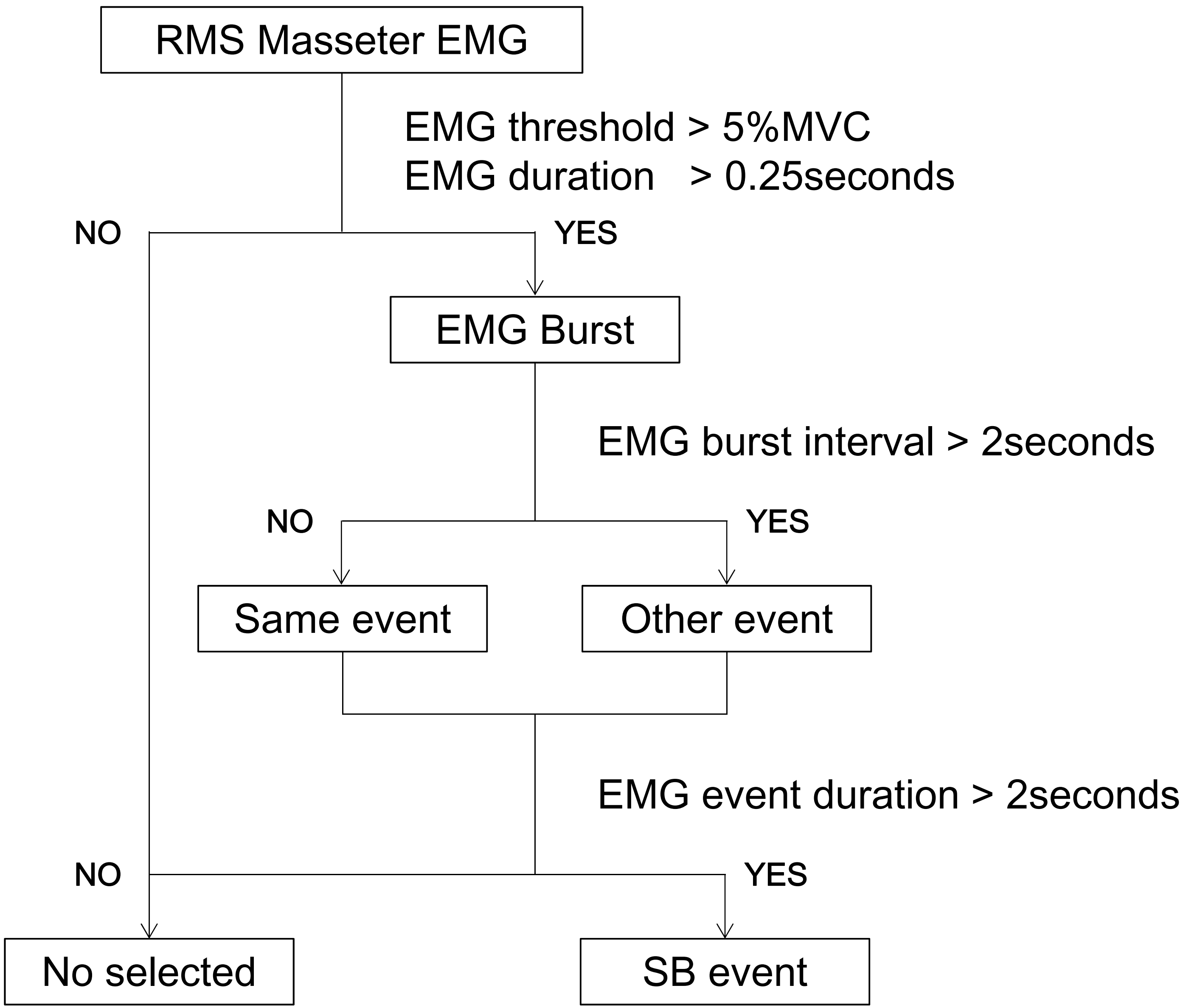

RMS Masseter EMG
EMG threshold > 5%MVC
EMG duration > 0.25seconds
NO
YES
EMG Burst
EMG burst interval > 2seconds
NO
YES
Same event
Other event
EMG event duration > 2seconds
NO
YES
No selected
SB event

Fig. 3

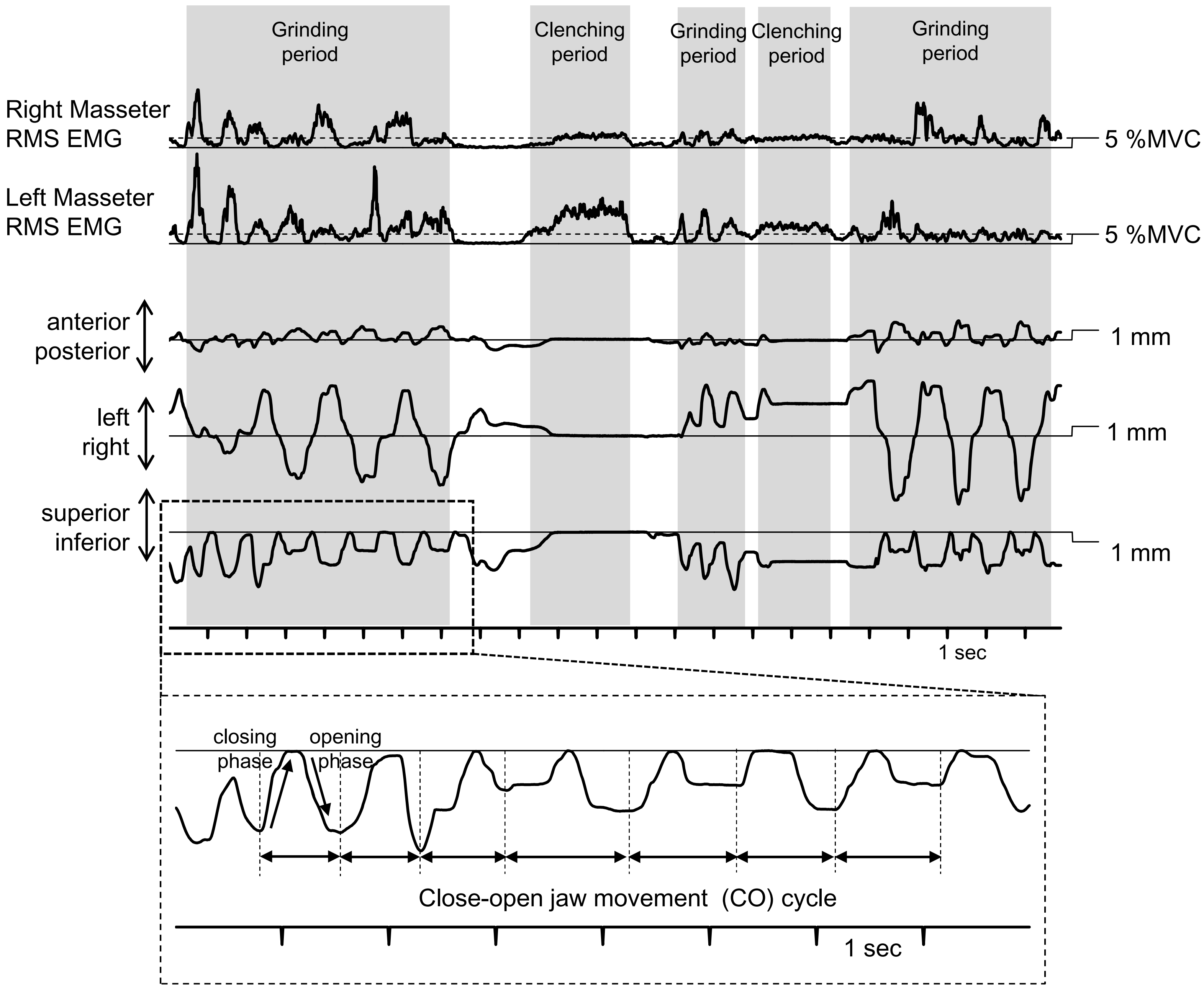

Grinding period
Clenching period
Grinding period
Clenching period
Grinding period
Right Masseter RMS EMG
5 %MVC
Left Masseter RMS EMG
5 %MVC
anterior
posterior
1 mm
left
right
1 mm
superior
inferior
1 mm
1 sec
closing phase
opening phase
Close-open jaw movement (CO) cycle
1 sec

Fig. 4

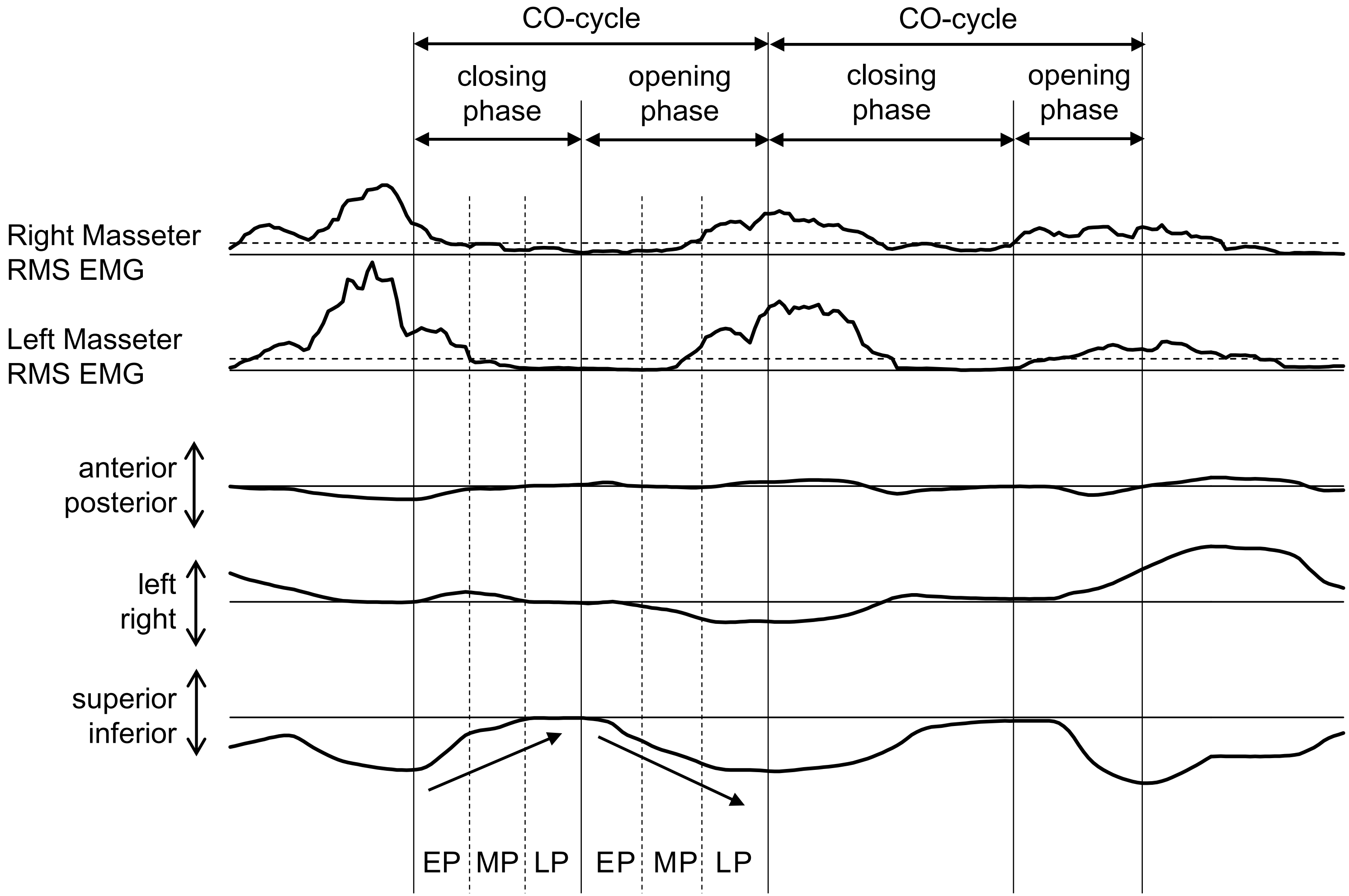
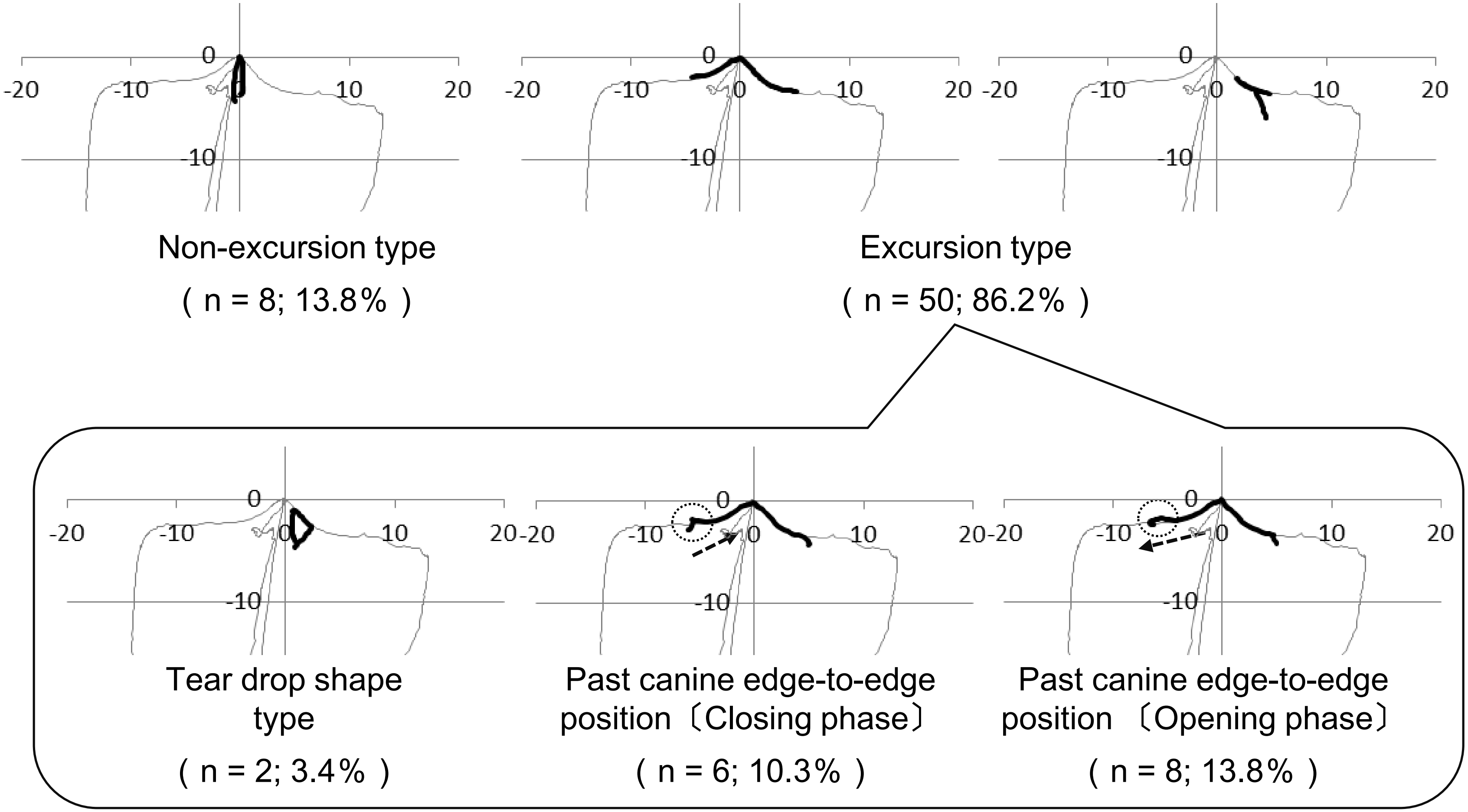

CO-cycle
CO-cycle
closing phase
opening phase
closing phase
opening phase
Right Masseter RMS EMG
Left Masseter RMS EMG
anterior
posterior
left
right
superior
inferior
EP
MP
LP
EP
MP
LP

Fig. 5



0
-20
-10
10
20
-10
Non-excursion type
(n = 8; 13.8%)
Excursion type
(n = 50; 86.2%)
Tear drop shape type
(n = 2; 3.4%)
Past canine edge-to-edge position〔Closing phase〕
(n = 6; 10.3%)
Past canine edge-to-edge position 〔Opening phase〕
(n = 8; 13.8%)

Fig. 6

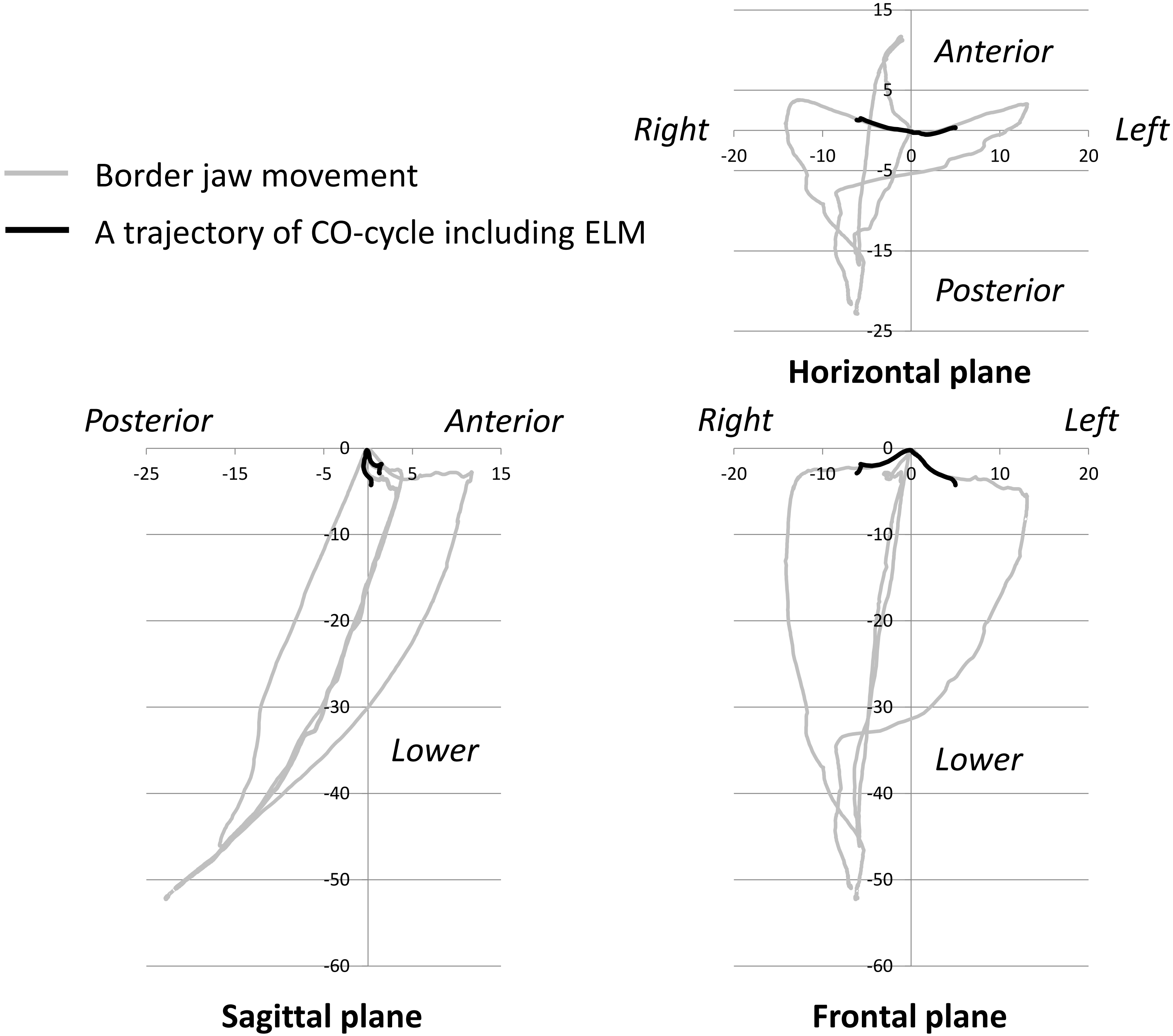

Border jaw movement
A trajectory of CO-cycle including ELM
Anterior
Right
Left
Posterior
15
5
-5
-15
-25
-20
-10
0
10
20
Horizontal plane
Posterior
Anterior
0
-25
-15
-5
5
15
-10
-20
-30
-40
-50
-60
Lower
Sagittal plane
Right
Left
0
-20
-10
0
10
20
-10
-20
-30
-40
-50
-60
Lower
Frontal plane

Fig. 7

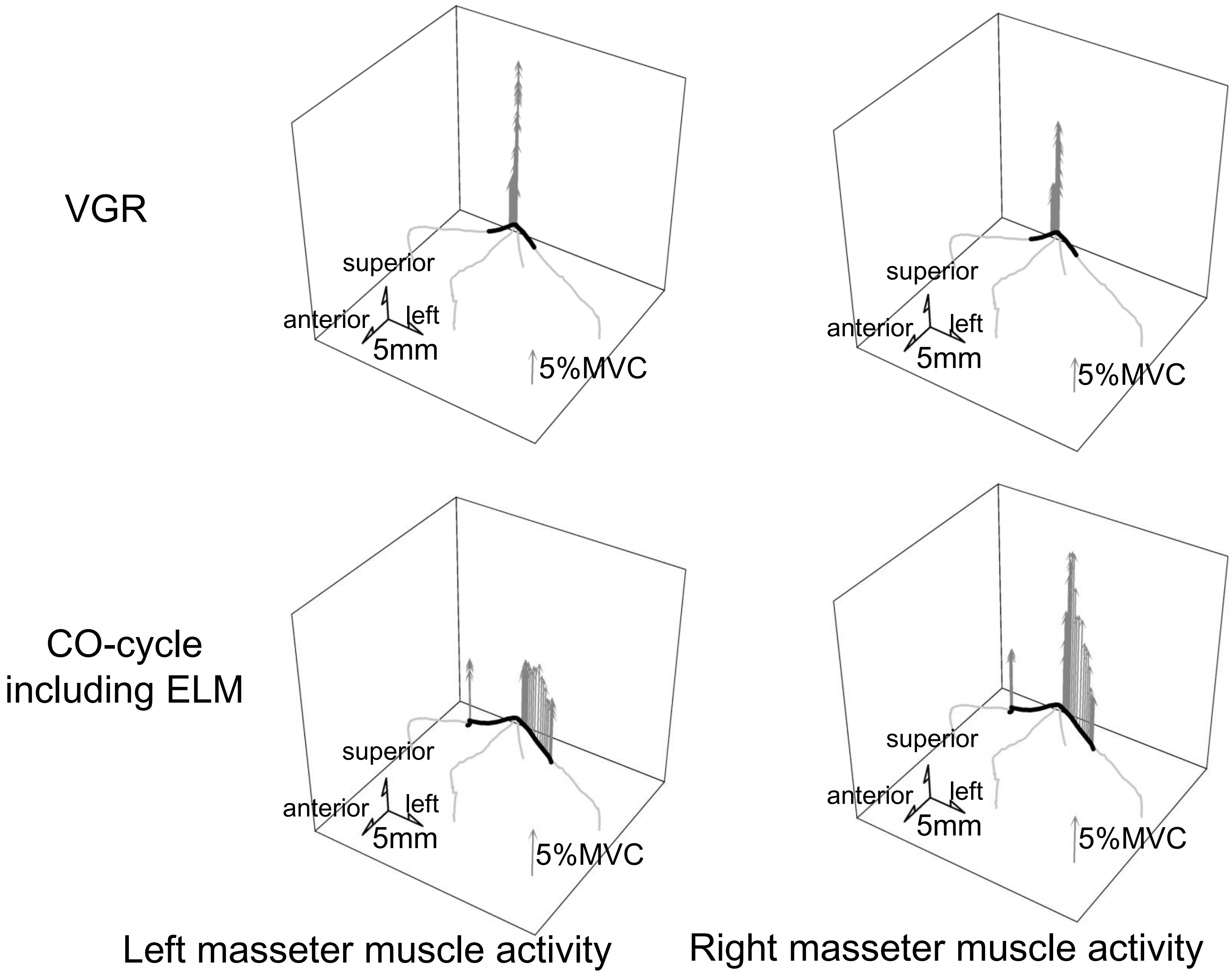

VGR
CO-cycle
including ELM
superior
anterior
left
5mm
5%MVC
Left masseter muscle activity
Right masseter muscle activity

Fig. 8

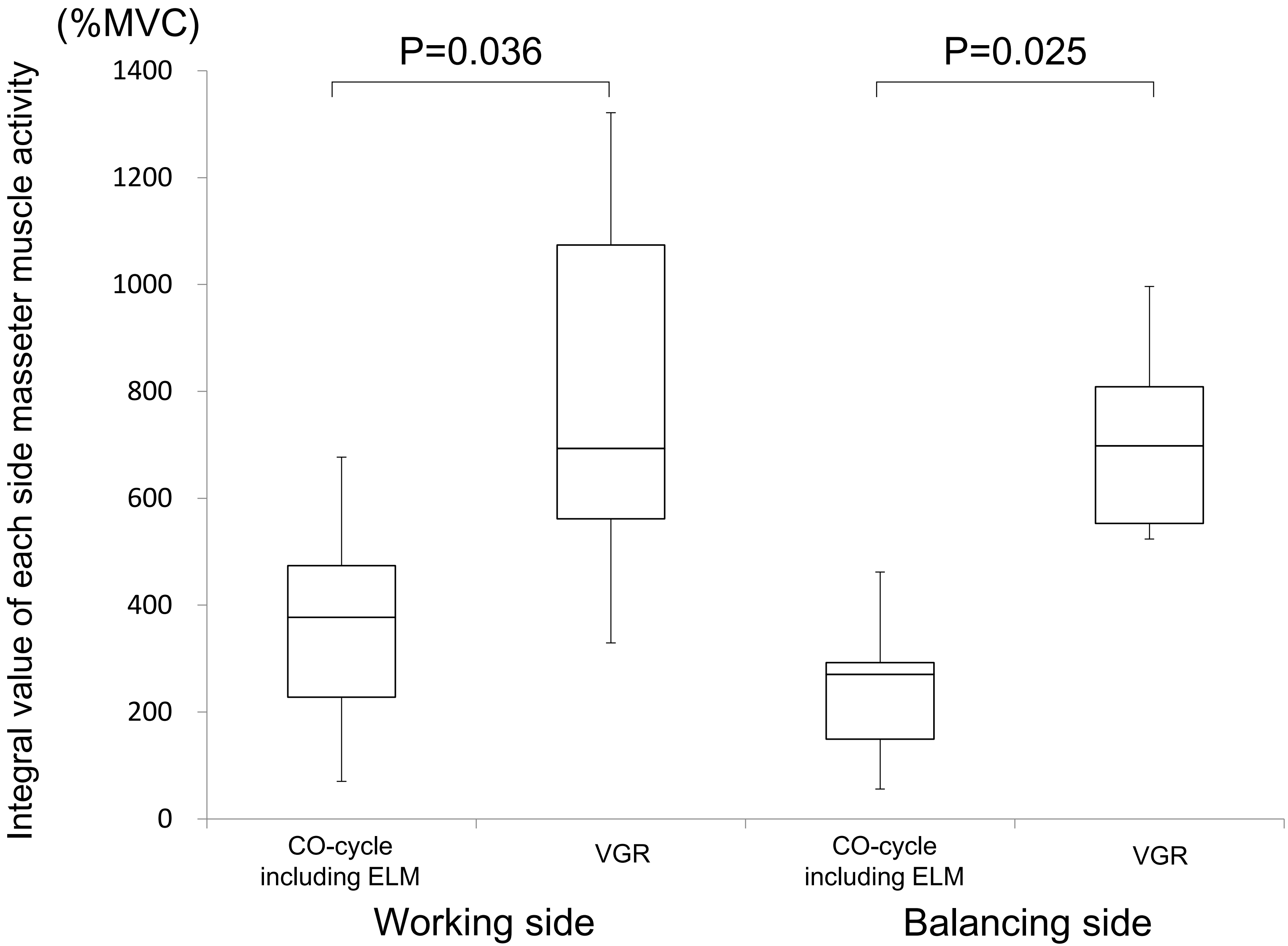

(%MVC)
Integral value of each side masseter muscle activity
P=0.036
P=0.025
1400
1200
1000
800
600
400
200
0
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
Working side
Balancing side

Fig. 9

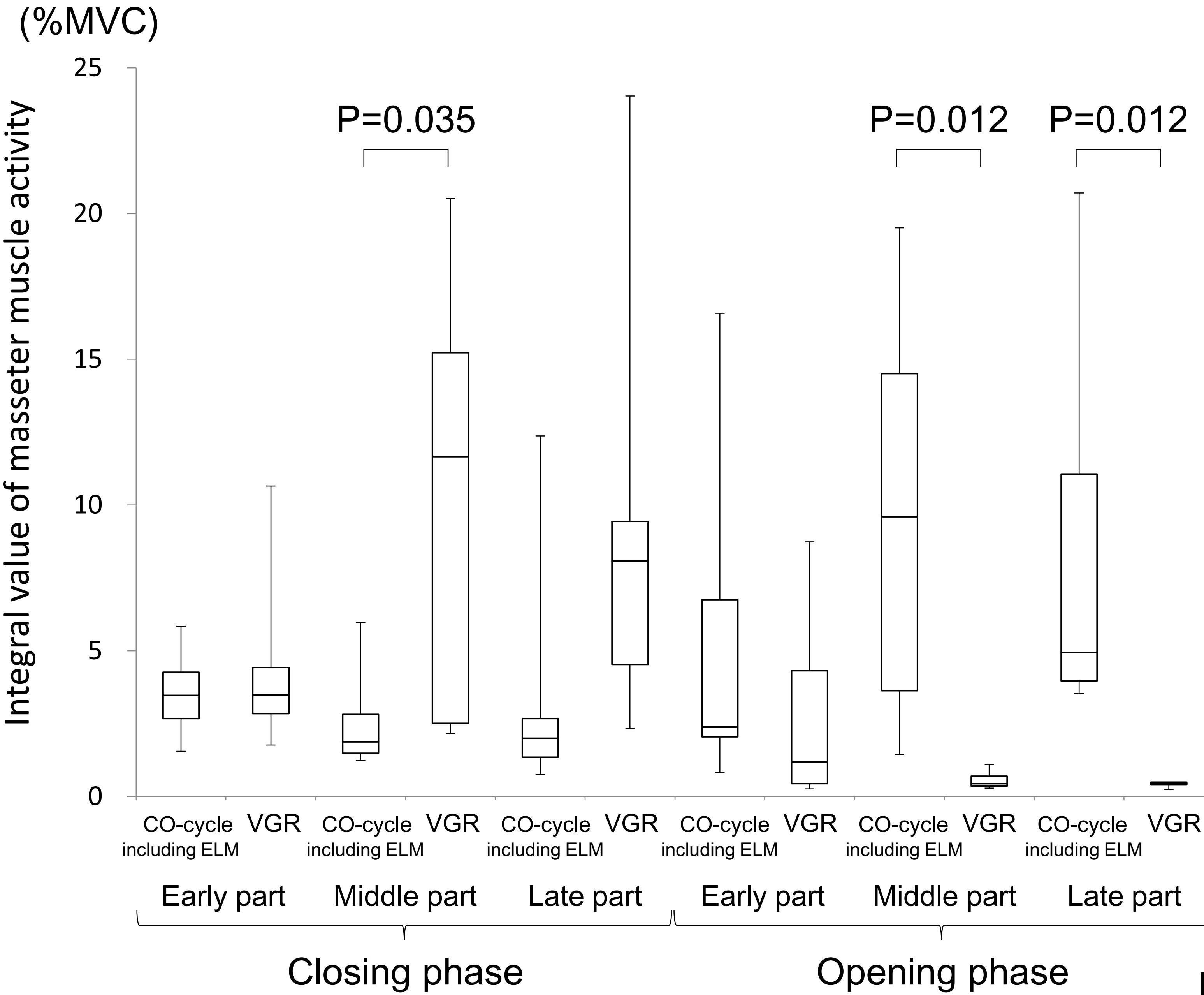

(%MVC)
Integral value of masseter muscle activity
25
20
15
10
5
0
P=0.035
P=0.012
P=0.012
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
Early part
Middle part
Late part
Early part
Middle part
Late part
Closing phase
Opening phase

Fig. 10

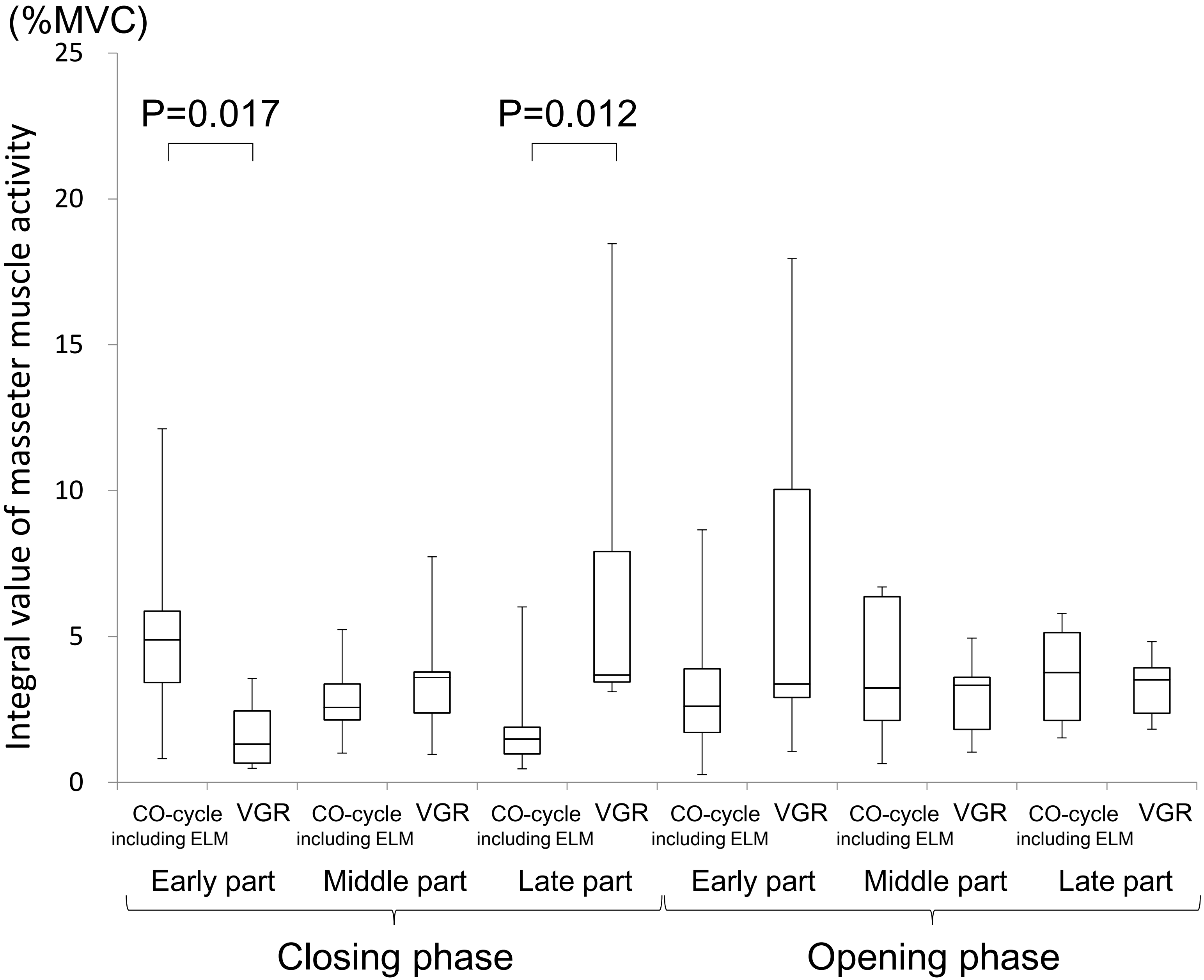

(%MVC)
Integral value of masseter muscle activity
25
20
15
10
5
0
P=0.017
P=0.012
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
CO-cycle including ELM
VGR
Early part
Middle part
Late part
Early part
Middle part
Late part
Closing phase
Opening phase

Fig. 11