Short-term Effect of Botulinum Toxin Injection on the Surface EMG of Masticatory Muscles and Jaw Function

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Botulinum toxin injection has been used in the masticatory muscle area as an effective treatment method of various movement disorders and facial contouring, but its effects on jaw function have not been evaluated. The aims of this study were to evaluate the effects of botulinum toxin type A injection into the masseter muscle on the EMG activities of masseter and anterior temporal muscles, and the limitation of jaw function. Fourteen healthy subjects were recruited. Five subjects were injected with 80 units of botulinum toxin type A (Dysport, Ipsen, Wrexham, UK) into each side of masseter muscle, and nine subjects were injected with saline into the same site as the botulinum toxin group. The surface EMG activities at maximum voluntary contraction of masseter and anterior temporal muscles were recorded before, 1 week, 2 weeks, and 3 weeks after injection. Presence of jaw functional limitations in each subject was investigated using Korean version of Jaw Functional Limitation Scale (JFLS) questionnaire. The masseter muscle EMG was gradually decreased in the botulinum toxin group comparing with that of the control group ($p<0.001$), but the anterior temporal muscle EMG did not show significant changes. There was significant increases in the mastication ($p<0.01$), and global jaw limitation ($p<0.05$) subscales of JFLS at 1 week after injection, but no significant changes in the other subscales including opening, and verbal and emotional expression during the recording periods. Our results suggest that botulinum toxin injection into masseter muscle can affect modest limitation in mastication function at 1 week after injection but recovered to the baseline until 3 weeks after injection. The EMG activity of masseter muscle had been gradually decreased until 3 weeks after botulinum toxin injection but the anterior temporal muscle did not show any significant changes.

Key words: Botulinum toxin, Masticatory muscle, EMG, Jaw functional limitation

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Ⅰ. INTRODUCTION

Botulinum toxin is a potent neurotoxin produced by the spore-forming anaerobic bacterium, *Clostridium botulinum*. It is able to block the acetylcholine release at the neuromuscular junction producing temporary chemodenervation and the reduction in activity in target organ such as muscle, sweat gland, and salivary gland[1)].

Eight immunologically distinct botulinum serotypes have been identified and seven serotypes

of A, B, C1, D, E, F, and G are known to be neurotoxins[2]. Among these serotypes, botulinum toxin type A is relatively potent, easily commercially available, and commonly used in the clinics[3,4]. Botulinum toxin has been used for many neurological disorders including cervical dystonia, strabismus, blepharospasm, hemifacial spasm, and glabellar wrinkles and other chronic pain conditions such as myofascial pain and migraine[5-8].

Botulinum toxin has been used in both medical and dental clinics as an effective treatment tool for the various neurological diseases and for the cosmetic purposes during past three decades. Especially in dental clinics, botulinum toxin is commonly used in the treatment of masseter muscle hypertrophy[9-11], bruxism[12-15], and oromandibular dystonia[16,17]. Clinical observation and many published reports have no doubt it is a potent neuromuscular blocking agent and relatively safe to other agents. However, when this neuromuscular agent is injected into the masticatory muscles, the possible influences on the jaw function and the EMG activity of the related musculature were not fully evaluated yet.

The aims of this study were to evaluate the effects of botulinum toxin injection into the masseter muscle on the EMG activities of masseter and anterior temporal muscles and the limitation of jaw function by using a Jaw Functional Limitation Scale[18,19].

Ⅱ. MATERIALS AND METHODS

1. Subjects

Fourteen healthy subjects (7 men and 7 women) without any symptoms of temporomandibular disorders and neurological disorders in the facial area were participated in this study. The mean ages were 25 ± 2 years for men and 26 ± 3 years for women. Informed consent including information about this study was given to each subject.

Subjects were randomly assigned to two treatment groups; botulinum toxin injection group (n=5) and saline injection group (n=9).

2. Botulinum toxin injection

Subjects were blinded for the injection material (botulinum toxin or saline) during the whole study. For experimental group 80-mouse unit (MU) of botulinum toxin A (Dysport®, Ipsen, Wrexham, UK) diluted in 0.8 ml saline was injected into the subjects' each masseter muscle at three sites (Fig. 1).

For control group, 0.8 ml of saline was injected into the same sites.

3. EMG data collection

Surface electrodes were placed on the right side of masseter and anterior temporal muscles. The surface EMG was recorded with Myomonitor portable EMG system (Delsys Inc., Boston, MA, USA). The recorded signals were amplified and quantified at a sampling frequency of 1,024 Hz. The acquired data were analyzed with the data acquisition program, Myomonitor software (Delsys Inc., Boston, MA, USA).

The raw EMG signal was amplified and converted to a root mean square (RMS) value. We estimated

Fig. 1. Injection of botulinum toxin into the masseter muscle area. Injections were divided by three sites along the mandibular angle area.

the maximum voluntary contraction (MVC) level by asking each subject to clench for 3 seconds with maximum force in the maximal intercuspal position. The RMS values of maximum voluntary contraction for masseter and anterior temporal muscles for each subject were calculated from mean value of the three consecutive recordings. EMG data were collected before, 1 week, 2 weeks, and 3 weeks after injection.

4. Jaw Functional Limitation Scale (JFLS)

To evaluate the limitation of jaw function after injection, Jaw Functional Limitation Scale (JFLS) was used. The JFLS consisted of 21 items divided into 4 domains, namely: mastication, opening, verbal and emotional expression, and global jaw limitation. The responses to each of the JFLS statements were based on the 0-5 scales. The scores of each domain were obtained from the mean values of the responses. The JFLS questionnaire used was based on the studies reported by Ohrbach and List[18,19].

The original English version questionnaire of the JFLS was first translated into Korean. This translation was then evaluated and revised by several faculty members in the Department of Oral Medicine and Oral Diagnosis, Seoul National University. A native English speaker who was fluent in Korean then translated the draft Korean version back into English. The backward translated English version was compared with the original English version to confirm that the questions had been properly translated, and the final Korean version was completed. Korean version demonstrated high reliability[20].

Each subject completed the questionnaire before, 1 week, 2 weeks, and 3 weeks after injection.

5. Statistical analysis

For each subject the mean and standard deviation of each variable were calculated.

Repeated-measures analysis of variance (ANOVA) involving time (before, 1-week, 2-week, and 3-week), and injection group (botulinum toxin, and saline) were used with the dependent variables (masseter EMG, anterior temporal EMG, and each domain of JFLS). The time factor was treated as repeated measures. A separate ANOVA was run for each dependent variable.

Ⅲ. RESULTS

Descriptive results for EMG activity of masseter and anterior temporal muscles, and Jaw Functional Limitation Scale are shown in Table 1 and 2, respectively and analysis of variance results are given in Table 3 and 4.

The main effect for time ($p<0.001$), and interaction between time and injection group ($p<0.001$) were significant in the EMG activity of masseter muscle, but none of the tests were significant in the anterior temporal muscle (Table 3). During the recording periods, the EMG activity of masseter muscle decreased in the botulinum toxin group at 1 week and gradually decreased until 3 weeks after injection, but did not show any changes in the control group (Fig. 2A). For anterior temporal muscle, none of the tests were significant in both botulinum toxin injection and control groups (Table 3).

For Jaw Functional Limitation Scale, domains of mastication and global jaw limitation scale showed significant different changes along with time between botulinum toxin and control groups. The main effect for time ($p<0.05$) and interaction between time and injection group ($p<0.01$) were significant in mastication subscale, and interaction between time and injection group ($p<0.05$) was significant in global jaw limitation subscale (Table 4). The scores of mastication, and global jaw limitation increased at 1 week after injection in botulinum toxin group and recovered to the baseline until 3 weeks after injection while control group did not show any significant changes during the recording periods (Fig. 3A, 3D). None of the tests were significant in both botulinum toxin injection

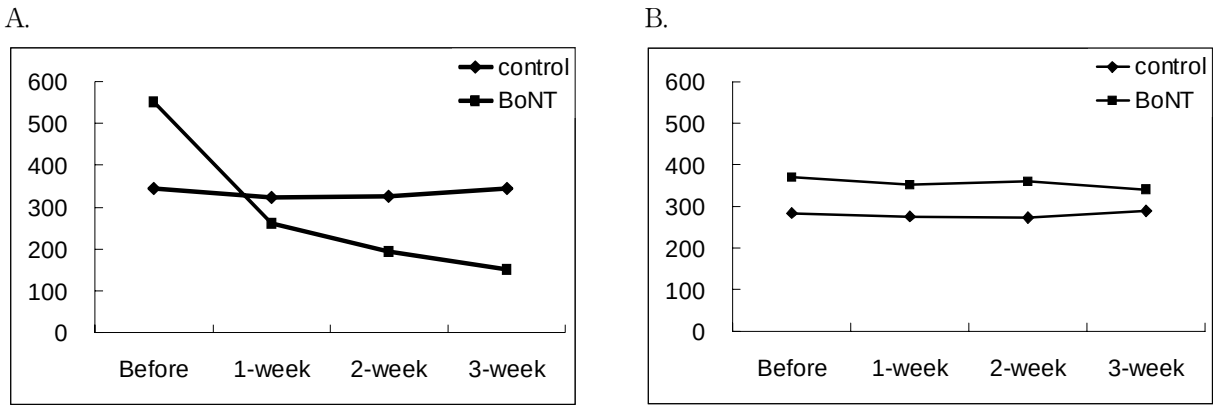

Fig. 2. Root mean square values(μV) of EMG data of right masseter(A) and anterior temporal(B) muscles.

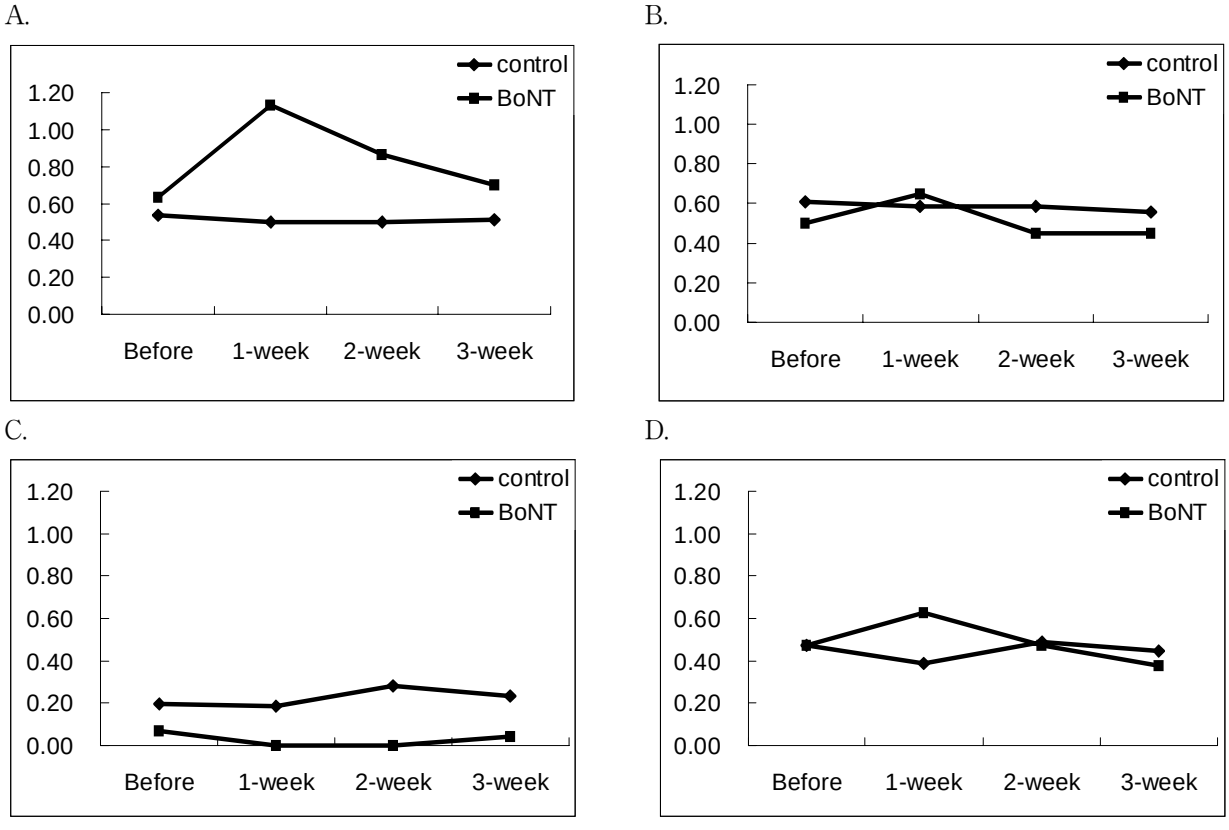

Fig. 3. Scores of each domain of jaw functional limitation scale: A: Mastication, B: Opening, C: Verbal and emotional expression, D: Global jaw limitation

Table 1. EMG data of the masseter and anterior temporal muscles

RMS EMG (μV)	Group	Before	1-week	2-week	3-week
Masseter	BoNT	553.06 ± 337.12	261.30 ± 347.79	194.56 ± 188.23	151.00 ± 130.34
	Control	343.82 ± 243.45	324.33 ± 253.78	325.18 ± 241.03	346.00 ± 241.79
Anterior temporal	BoNT	371.34 ± 152.63	352.44 ± 109.00	358.68 ± 130.75	339.92 ± 127.19
	Control	284.93 ± 141.98	275.94 ± 140.46	274.30 ± 135.14	289.67 ± 131.26

RMS: Root mean square
BoNT: Botulinum toxin injection group

Table 2. Changes in each domain of Jaw Functional Limitation Scale

Domain	Group	Before	1-week	2-week	3-week
Mastication	BoNT	0.63 ± 0.53	1.13 ± 0.40	0.87 ± 0.40	0.70 ± 0.53
	Control	0.54 ± 0.58	0.50 ± 0.59	0.50 ± 0.68	0.51 ± 0.65
Opening	BoNT	0.50 ± 0.50	0.65 ± 0.58	0.45 ± 0.37	0.45 ± 0.37
	Control	0.61 ± 0.85	0.58 ± 0.79	0.58 ± 0.79	0.56 ± 0.74
Verbal & Emotional expression	BoNT	0.07 ± 0.10	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.06
	Control	0.20 ± 0.44	0.19 ± 0.40	0.28 ± 0.69	0.23 ± 0.55
Global jaw limitation	BoNT	0.48 ± 0.39	0.63 ± 0.40	0.48 ± 0.32	0.38 ± 0.34
	Control	0.47 ± 0.58	0.39 ± 0.46	0.49 ± 0.74	0.45 ± 0.59

BoNT: Botulinum toxin injection group

Table 3. Statistical results of repeated-measures analysis of variance (P-values) of EMG data

Dependent variables	Independent variables		
	T	G	T X G
Masseter muscle	0.000***	0.746	0.000***
Anterior temporal muscle	0.618	0.332	0.466

T: time, G: injection group (botulinum toxin or saline group)
***: $p < 0.001$

Table 4. Statistical results of repeated-measures analysis of variance (P-values) in Jaw Functional Limitation Scale

Dependent variables	Independent variables		
	T	G	T X G
Mastication	0.014*	0.321	0.006**
Opening	0.418	0.855	0.504
Verbal & Emotional expression	0.659	0.422	0.393
Global jaw limitaion	0.330	0.892	0.034*

T: time, G: injection group (botulinum toxin or saline group)
*: $p < 0.05$
**: $p < 0.01$

and control groups in domains of opening, and verbal and emotional expression (Table 4).

Ⅳ. DISCUSSION

Although the intramuscular injection of botulinum toxin into the masseter muscles has been accepted as a successful alternative treatment of the masseter hypertrophy[9-11] and bruxism[12-15], there has been no study focusing on the changes of jaw function which can be occurred from decreased activity of masseter muscle. In the clinic, patients who complain discomfort from the weakness of mastication after injection of botulinum toxin into the masseter muscle can be easily met. This study was performed to evaluate the changes and the relationship between the EMG activities of masticatory muscles and patients' jaw functional limitations after botulinum toxin injection into the masseter muscle.

The evaluation of jaw function has been assessed using a wide range of techniques, such as mandibular function assessment including bite force, range of motion, number of chewing strokes needed before swallowing of a food bolus, or self-assessment questionnaires by research participants themselves[21-23]. Among these mandibular function measurements, the patient's awareness of the function impairment[24] or jaw functional limitation [18,19] by using a self-administered questionnaire has several advantages as a means of assessing function impairment or jaw functional limitation. It does not depend on the skill of a particular interviewer, and does not require an inter-observer validation. Clinical observations suggested that the real impact of symptoms and signs on the jaw function could be widely various. From the patient's point of view, the characteristic of the dysfunction becomes truly symptomatic when the dysfunction interferes with the daily activities in some way.

The Jaw Functional Limitation Scale (JFLS) is a comprehensive measure of jaw functional limitation consists of 21 items, which are grouped into four domains, namely chewing, opening, verbal and emotional expression, and global jaw limitation. The original English version of JFLS was translated into Korean, and the Korean version of the JFLS questionnaire has been evaluated in dental students and TMD patients and demonstrated moderate to good reliability[20].

As results showed in the present study, the JFLS scores of mastication and global jaw limitation increased significantly at 1 week after injection. We interpreted that decrease of the masseter muscle activity by the botulinum toxin injection could affect the mastication function. The change in the global jaw limitation score of JFLS seems to be originated from the increase of mastication score

since the global jaw limitation score is calculated from the combination of three subscales (mastication, opening, and global and verbal expression) of JFLS. For domains of opening, and verbal and emotional expression, it seems that the short period of decreased localized masseter muscle activity could not affect these functions. Verbal and emotional expression could be affected by more complex factors such as psychological factors, and other facial muscles. We suspect that the opening limitation could occur with higher decrease in the masticatory muscle activity or combined joint problem.

Our results showed that the increases in mastication and global jaw limitation at 1 week after botulinum toxin injection were recovered to the baseline until 3 weeks after injection while the EMG activity of the masseter muscle with botulinum toxin injection decreased gradually during the recording periods. The recovery of such increase of JFLS scores in spite of further decrease of EMG activity of the masseter muscle can not be explained clearly. It has been postulated that other collaborating masticatory muscles such as temporal and pterygoid muscles would compensate the decreased activity of the masseter muscles. However, our study did not show any significant increase in the EMG activity of anterior temporal muscle after botulinum toxin injection into masseter muscle until 3 weeks. It can be assumed that such recovery of jaw functional limitation is due to the compensation of entire masticatory muscles including temporal, and pterygoid muscles or to the subjective adaptation to the decreased muscle activity without practical functional compensation. To evaluate this hypothesis, further study to measure the EMG of other masticatory muscles and to evaluate the additional mandibular function assessment including jaw movement and occlusal bite force might be needed. Our study analyzed the changes of EMG activity and jaw functional limitation in short-term period, therefore, the long-term effect of botulinum toxin injection on the masticatory muscles also should be evaluated.

In conclusion, our results suggest that botulinum toxin injection into masseter muscle area can affect modest limitation in mastication function at 1 week after injection but recovered to the baseline until 3 weeks after injection. The EMG activity of masseter muscle had been gradually decreased until 3 weeks after botulinum toxin injection but the anterior temporal muscle did not show any significant changes.

V. CONCLUSIONS

Botulinum toxin injection has been widely used in the masticatory muscle area as an effective treatment method of various neuromuscular conditions but its effects on jaw function have not been evaluated. We evaluated the effects of botulinum toxin type A injection into the masseter muscle on the EMG activities of masseter and anterior temporal muscles, and the limitation of jaw function in fourteen healthy subjects. Botulinum toxin injection into masseter muscle could affect modest limitation in mastication function in the short period after injection but recovered after 1 week. The EMG activity of masseter muscle had been gradually decreased until 3 weeks after botulinum toxin injection but the anterior temporal muscle did not show any significant changes. Further longitudinal study including the effects of botulinum toxin on the EMG of other masticatory muscles and additional mandibular function assessment should be needed.

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국문요약

교근 부위의 보툴리눔 독소 주사가 저작근의 근전도 및 악기능에 미치는 영향

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저작근과 관련하여 나타나는 여러 운동장애의 치료나 심미적인 목적으로 교근 부위에 보툴리눔 독소를 주사하는 방법이 널리 이용되고 있다. 그러나 보툴리눔 독소의 교근 부위 주사가 다른 저작근의 근전도와 악기능에 어떠한 영향을 미치는 지에 대한 자료는 부족하다. 이에 본 연구에서는 측두하악관절장애 등 하악의 기능 이상을 가지고 있지 않는 건강한 성인남녀 14명을 대상으로 양측 교근에 각각 80 unit씩의 보툴리눔 독소 A(Dysport, Ipsen, Wrexham, UK)를 주사한 5 명의 실험군과 같은 위치에 같은 양의 생리식염수를 주사한 9 명의 대조군에서 주사 전과 주사 후 3 주까지 매주 교근과 전측두근의 표면 근전도를 측정하고, 국문판 악기능제한지수(Jaw Functional Limitation Scale) 설문지를 이용하여 악기능제한 정도를 평가하여 비교 분석하였다. 교근의 근전도는 실험군에서 주사 후 1주부터 감소하기 시작하여 3주 동안 지속적인 감소를 나타냈으며, 전측두근의 근전도는 유의한 변화를 나타내지 않았다. 악기능제한지수는 저작지수와 전반적 악기능 지수가 실험군에서 보툴리눔 독소 주사 후 1 주째에 증가한 뒤 점차 회복하는 양상을 보였으며, 개구지수와 대화 및 감정표현 영역 기능제한지수는 통계적으로 유의한 변화를 보이지 않았다. 이러한 결과로부터 교근에 시행하는 보툴리눔 독소 주사는 교근의 활성을 지속적으로 저하시키지만 전측두근의 활성에는 영향을 미치지 않았으며, 주관적 저작기능을 단기적으로 저하시키나, 근활성의 저하가 지속되는 과정에서도 주관적 저작기능은 짧은 기간 내에 회복됨을 알 수 있었다.

주제어: 보툴리눔 독소, 저작근, 근전도, 악기능제한지수