Original Article

Surface Anatomy of the Lip Elevator Muscles for the Treatment of Gummy Smile Using Botulinum Toxin

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ABSTRACT

Objective: To propose a safe and reproducible injection point for botulinum toxin-A (BTX-A) as a supplementary method for the treatment of gummy smile, as determined by assessment of the morphologic characteristics of three lip elevator muscles.

Materials and Methods: A total of 50 hemi-faces from 25 adult cadavers (male 13, female 12; ages, 47 to 88 years) were used in this study. Topographic relations and the directions of the lip elevator muscles (ie, levator labii superioris [LLS], levator labii superioris alaeque nasi [LLSAN], and zygomaticus minor [ZMi]), were investigated. Possible injection points were examined through the study of predetermined surface landmarks.

Results: The insertion of the LLS was covered partially or entirely by the LLSAN and the ZMi, and the three muscles converged on the area lateral to the ala. The mean angle between the facial midline and each muscle vector was 25.8 $\pm$ 4.8 degrees for the LLS, 55.7 $\pm$ 6.4 degrees for the ZMi, and -20.2 ± 3.2 degrees for the LLSAN; no significant differences were noted between male and female subjects or between left and right sides. The three vectors passed near a triangular region formed by three surface landmarks. The center of this triangle, named the ''Yonsei point'', was suggested as an appropriate injection point for BTX-A. The clinical effectiveness of the injection point was demonstrated in selected cases with or without orthodontic treatment.

Conclusions: Under careful case selection, BTX-A may be an effective treatment alternative for patients with excessive gingival display caused by hyperactive lip elevator muscles. (*Angle Orthod.* 2009;79:70–77.)

KEY WORDS: Injection point; Botulinum toxin; Lip elevator muscles; Gummy smile

INTRODUCTION

An excessive display of gingival tissue on smiling, usually referred to as a ''gummy smile,'' is often esthetically displeasing. Several etiologic factors have been proposed in the literature; these include skeletal, gingival, and muscular factors that may occur alone or in combination.[1,2] Although vertical maxillary dental and/or skeletal excess[3–5] or gingival problems from delayed passive eruption[6–8] have been treated in the orthodontic field, hyperactive lip elevator muscles have not been managed as often, possibly because hard tissue has been the main target for most orthodontists.

Garber and Salama[9] have suggested that the relationships between the three primary components—the

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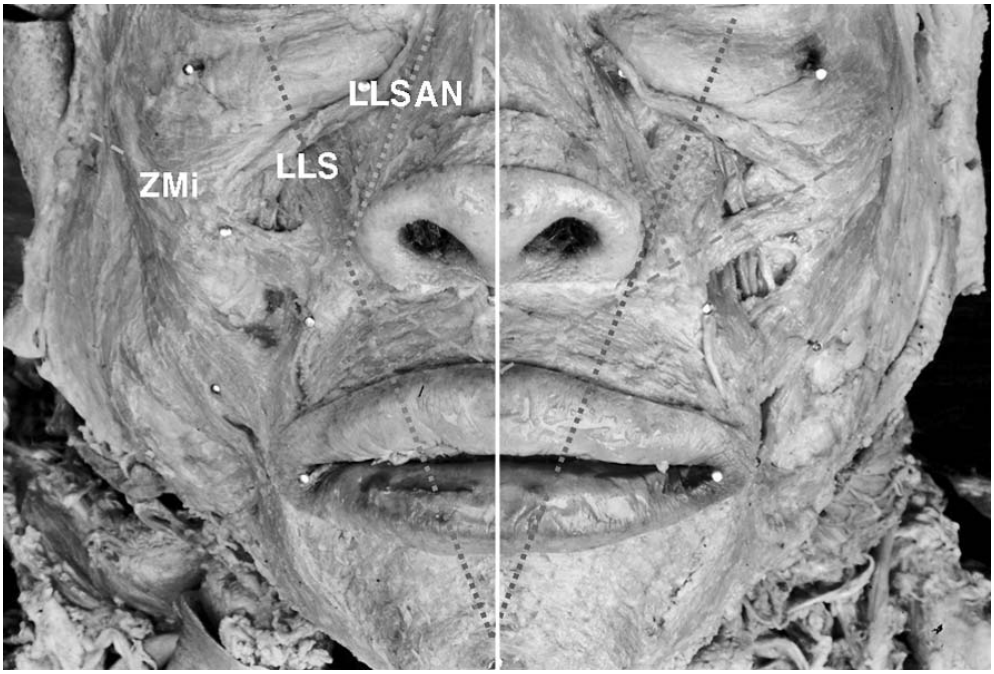

Figure 1. Photograph of dissected specimen with vectors showing the direction of muscle fibers.

teeth, the lip framework, and the gingival scaffold—determine the esthetic appearance of a smile. The appearance of this lip framework is determined by the activity of various facial muscles, such as the levator labii superioris (LLS), the levator labii superioris alaeque nasi (LLSAN), and the zygomaticus minor (ZMi)/major muscles (ZMj). Among these, the LLS, the LLSAN, and the ZMi determine the amount of lip elevation that occurs during smiling. The LLS originates from the orbital rim of the maxilla and inserts into the upper lip; the LLSAN originates from the frontal process of the maxilla and inserts into the upper lip and the skin tissue of the ala of the nose. The ZMi originates from the zygomatic bone and inserts into the skin tissue of the upper lip.[10] Variations in the morphology, distribution, and activity of the facial muscles of expression account for variations in facial expression.[11]

The literature reports that several surgical procedures have been performed to correct gummy smiles caused by hyperfunctional muscles.[1,12–14] However, surgical procedures may lead to frequent relapse and undesirable side effects such as scar contraction. Hence, a minimally invasive treatment modality that can serve as a substitute for the surgical procedure, i.e., the use of botulinum toxin (BTX) has been suggested. This toxin acts by cleaving the synaptosomal-associated protein (SNAP-25) and inhibiting the release of acetylcholine, thus preventing muscle contraction. Among the seven serologically distinct types of botulinum neurotoxin, type A (BTX-A) appears to be the most potent and is most often used clinically.

Recently, Polo[15] introduced the use of BTX for patients with hyperfunctional lip elevator muscles and reported a significant reduction in gingival display with the use of electromyographic guidance. However, considering the diffusion and the immediacy of the toxin, it is crucial for the clinician to understand the distribution and morphology of the target muscles, so that highly selective deactivation of muscles can be performed while a natural smile is maintained. The purposes of this study were (1) to investigate the distribution, morphologic characteristics, and direction of muscle fibers of the three lip elevator muscles (LLSAN, LLS, and ZMi), and (2) to propose a safe and reproducible injection point for BTX with simple surface landmarks as references.

MATERIALS AND METHODS

Dissection of the Cadavers

Fifty hemi-faces from 25 Korean adult cadavers (male 13, female 12; average age, 71 [47 to 88] years) surveyed at Yonsei University College of Dentistry were used in this study. After an incision was made at the midline, LLSAN, LLS, and ZMi muscles were dissected carefully, and the direction of muscle fibers was viewed. Facial midlines were established by connecting the soft tissue glabella, subnasale, and pogonion. Standardized frontal photographs were taken for each dissected specimen with a FinePix S3 Pro camera. (Fujifilm Co, Tokyo, Japan) (Figure 1). Topographic relations and

morphologic variations among lip elevator muscles were observed.

Direction of Lip Elevator Muscles

The vector that represented the center of each muscle fiber was defined on the photograph on the basis of muscle origin and insertion. The angle between the vector of each lip elevator muscle and the facial midline was measured with the ImagePro program (Media-Cybernetics, Des Moines, Iowa) (Figure 2). Angular measurements were given as positive (LLS, ZMi) or negative (LLSAN) values, depending on the direction relative to the midline.

Location of an Injection Point for BTX

Stainless steel pins were placed at the following surface landmarks before the dissection procedure was performed (Figure 3):

- 1, 2: Lateral point of ala
- 3, 4: Midpoints of nasolabial fold between ala and commissure
- 5, 6: Maxillary point located at one-quarter distance between ala and tragus
- 7: Soft tissue subnasale
- 8, 9: Commissure
- 10: Soft tissue pogonion
- 11, 12: Lateral chin point located 2 cm lateral to pogonion (right and left) for standardization of measurement

A triangular area was constructed by connecting the landmarks 1(2), 3(4), and 5(6) on each side (Figure 4C). The effective range of BTX in this study was set at approximately 2 cm, as suggested by Garcia and Fulton[16] (Figure 5). Circles with a radius of 1 cm from each point and from the center of the triangle were drawn. The frequency of overlap with each muscle vector and the circular area from each landmark were counted under the assumption that a single injection of BTX at that point should affect all three muscles.

Statistical Analysis

Descriptive statistics were conducted to describe the distribution of each muscle. Independent *t*-tests were performed to assess differences between male and female subjects and between left and right side measurements. The level of significance was $P \leq .05$.

RESULTS

Topographic Relations of Lip Elevator Muscles

The ZMi and the LLSAN were located in the superficial layer that covers the medial and lateral margins of the LLS. The insertion of the LLS was partially covered by the LLSAN and the ZMi (Figure 4A) in 31 hemi-faces (62.0%) and was entirely covered in 19 hemi-faces (38.0%) (Figure 4B). As can be seen in Figure 4C, the three muscles converged on the area lateral to the ala.

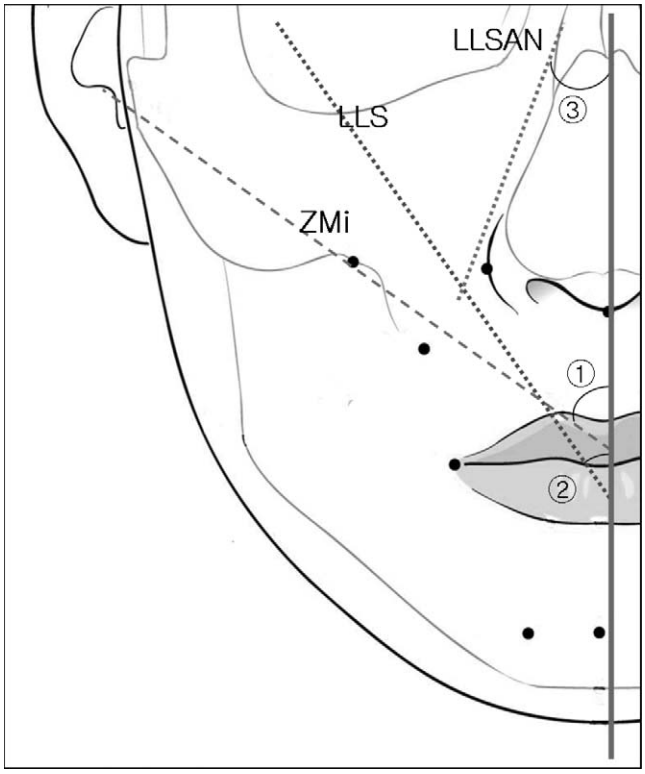

Figure 2. Angular measurements between facial midline and each muscle vector. (A) Angle between the vector of the levator labii superioris (LLS) and the facial midline. (B) Angle between the vector of the zygomaticus minor (ZMi) and the facial midline. (C) Angle between the vector of the levator labii superioris alaeque nasi (LLSAN) and the facial midline.

Direction of Lip Elevator Muscle Fibers

The mean angle between the facial midline and each muscle vector was 25.8 $\pm$ 4.8 degrees for the LLS, 55.7 $\pm$ 6.4 degrees for the ZMi, and -20.2 ± 3.2 degrees for the LLSAN (Tables 1 through 3). No significant differences in angular measurements could be found between male and female subjects or between left and right sides. For the LLS, 22 of 25 subjects (88%) showed angular differences less than 5 degrees between right and left sides. Among the 25 subjects, 21 subjects (84%) and 20 subjects (80%) displayed angular differences of less than 5 degrees for the ZMi and for the LLSAN, respectively.

Determination of Injection Point for BTX

Consistent with the finding that the LLSAN, LLS, and ZMi converge toward the lateral area with regard to the

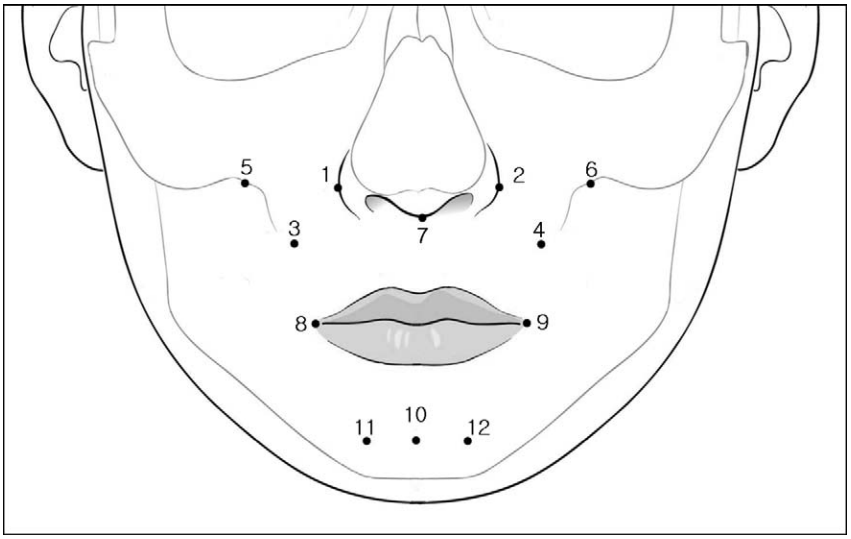

Figure 3. Surface landmarks used in this study.

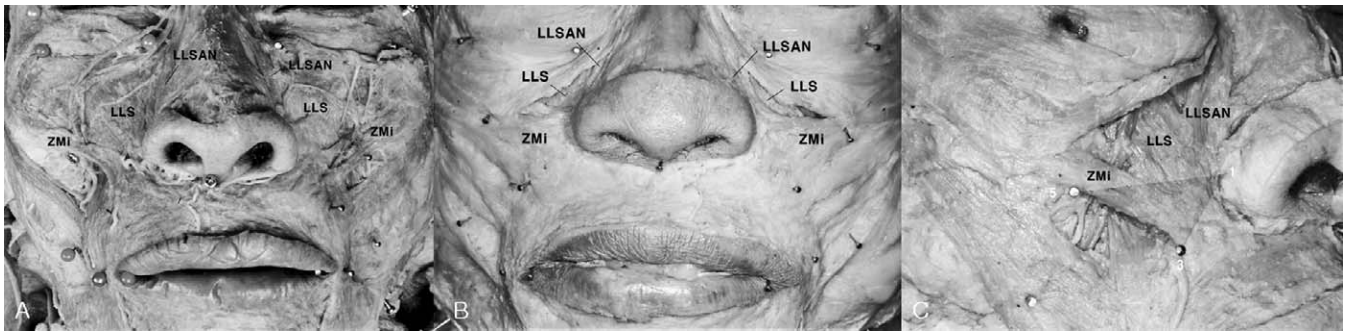

Figure 4. Distribution of the lip elevator muscles. (A) Insertion of the levator labii superioris (LLS) partially covered by the levator labii superioris alaeque nasi (LLSAN) and the zygomaticus minor (ZMi). (B) Insertion of the LLS entirely covered by the LLSAN and the ZMi. (C) Convergence of the LLSAN, the LLS, and the ZMi on the lateral ala area.

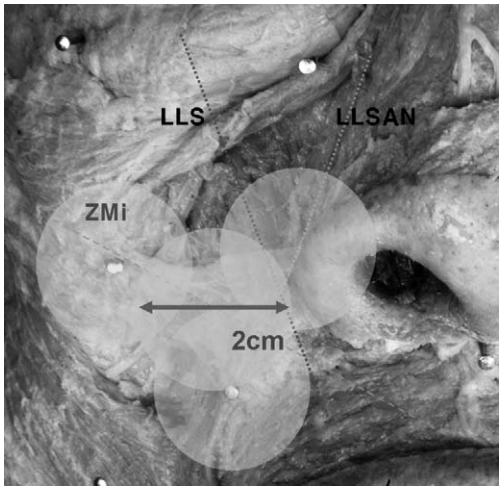

Figure 5. Circles with a 1 cm radius (2 cm diameter) drawn on each photograph represent the effective range of botulinum toxin.

Table 1. Angular Measurements for LLS, ZMi, and LLSAN

			Mean	SD	Minimum	Maximum
LLS	Male	Lt.	24.5	3.5	16.1	29.5
		Rt.	25.1	3.9	19.3	31
	Female	Lt.	27.7	5.4	20.9	37.3
		Rt.	25.8	4	20.7	33.4
ZMi	Male	Lt.	56.4	7	44.1	69.4
		Rt.	56.3	6.1	47.6	66.4
	Female	Lt.	55.8	6.4	44.2	65.7
		Rt.	54.7	5.3	46.8	65.7
LLSAN	Male	Lt.	−20.5	2.1	−17.9	−25.5
		Rt.	−20.2	4	−13.6	−23.9
	Female	Lt.	−20.1	3.2	−14.5	−24.2
		Rt.	−19.8	3.7	−13.3	−25.6

Values are expressed in degrees.

LLS indicates levator labii superioris; LLSAN, levator labii superioris alaeque nasi; Lt., left; Rt., right; ZMi, zygomaticus minor.

Table 2. Comparison of Angular Measurements of the Three Muscles According to Gender

	Male (n = 13)		Female (n = 12)		
	Mean	SD	Mean	SD	Sig.
LLS	24.8	3.7	27	4.9	NS
ZMi	56.1	7.1	55.2	5.7	NS
LLSAN	−20.5	2.7	−19.8	3.4	NS

Values are expressed in degrees.

LLS indicates levator labii superioris; LLSAN, levator labii superioris alaeque nasi; Sig., significance; ZMi, zygomaticus minor. NS, not significant.

Table 3. Comparison of Left and Right Side Angular Measurements of the Three Muscles

	Left (n = 25)		Right (n = 25)		
	Mean	SD	Mean	SD	Sig.
LLS	26.2	4.7	25.4	4	NS
ZMi	55.9	7.3	55.5	5.7	NS
LLSAN	−20.3	2.7	−20	3.8	NS

Values are expressed in degrees.

LLS indicates levator labii superioris; LLSAN, levator labii superioris alaeque nasi; Sig., significance; ZMi, zygomaticus minor. NS, not significant.

ala, the three muscle vectors all pass through a triangular area formed by the points 1(2), 3(4), and 5(6). As is shown in Figure 5, the circular area drawn at each surface landmark lateral to the ala contained primarily the muscle vectors.

In Table 4, the frequency of the muscle vectors (LLS, LLSAN, and ZMi) passing through each circle is presented. The number of hemi-faces through which all three muscle vectors passed was greatest at the center of the triangle; this was statistically significant (Chi-square test; $P < .05$). Thus, the center of the triangle was suggested as an appropriate injection point and was named the "Yonsei point".

Table 4. Frequency of Muscle Vectors Passing Through the Circle of Each Injection Point

		Number of Muscles		
	N	3	2	1
Landmark 1(2)	50	17 (34.0%)	33 (66%)	0
Landmark 3(4)	50	14 (28%)	32 (64%)	4 (8%)
Landmark 5(6)	50	0	4 (8%)	46 (92%)
Center of triangle	50	44 (88%)	6 (12%)	0

Chi-square test; $P < .05$.

The distance of the center of the triangle from the ala and the lip line (the line that connected both commissures) was then measured. The mean horizontal distance from the ala was 10.4 ± 2.1 mm in males and 10.3 ± 2.1 mm in females. The mean vertical distance from the lip line was 32.3 ± 4.2 mm in males and 31.5 ± 3.3 mm in females, with no statistically significant difference noted (*t*-test; Figure 6A).

Clinical Application

Case 1. A 25-year-old woman complained of excessive gingival display on smiling. Clinically, she displayed no lip incompetency or muscle strain with her lips reposed. She showed adequate upper incisor ex-

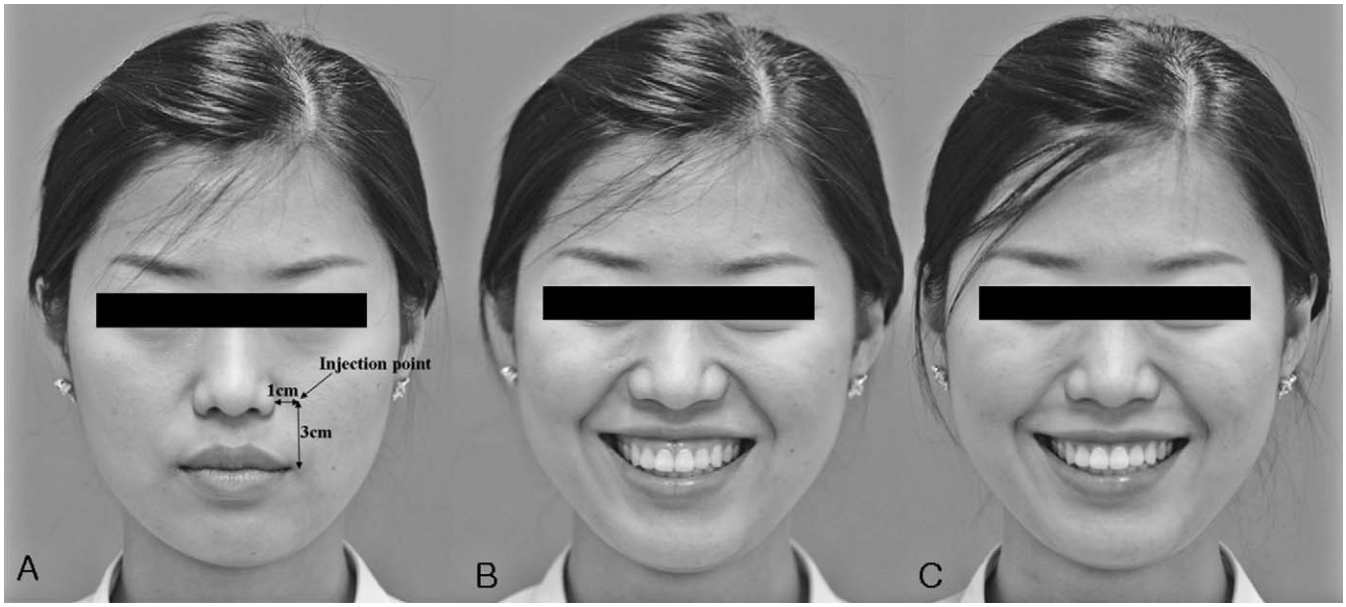

Figure 6. Extraoral photographs of case 1. (A) Initial photograph indicates the single injection point. (B) Initial smile view shows significant gingival display. (C) Smile view 3 weeks after botulinum toxin (BTX) injection.

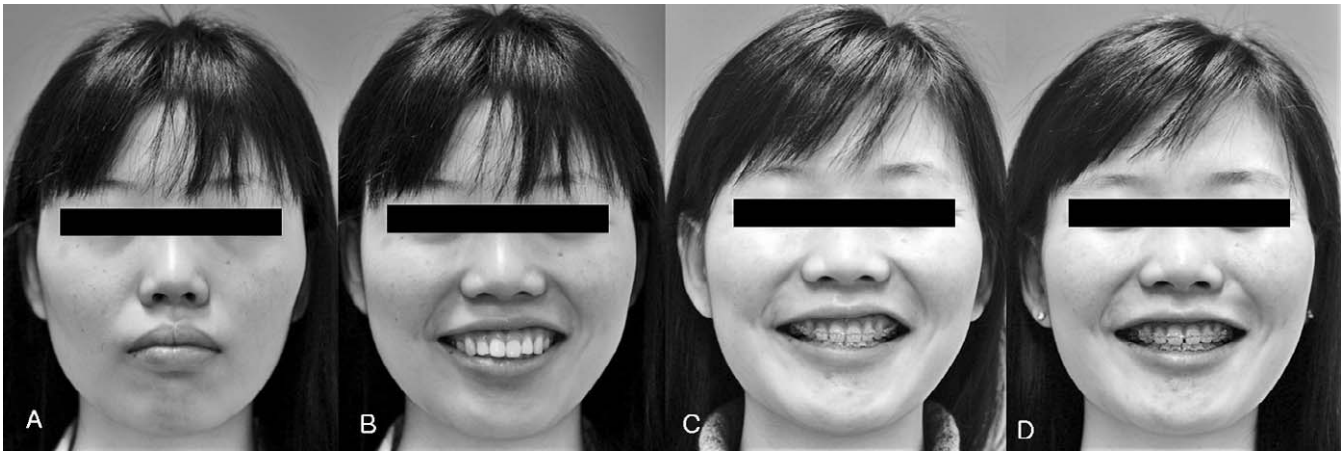

Figure 7. Extraoral photographs of case 2. (A and B) Initial rest and smile view shows relatively asymmetric lip elevation. (C) Asymmetric smile remained after 19 M of anterior retraction. (D) One week after BTX injection.

posure at rest (Figure 6A,B) but 5 mm of gingival display on smiling. Hence, the clinician diagnosed that her gummy smile was due to hyperactive lip elevator muscles. BTX-A (Botox; Allergan Inc, Westport, Ireland), supplied as a freeze-dried powder of 100 U, was reconstituted with 2 mL normal saline (0.9%) solution to make a 5.0 U/0.1 mL dose according to the manufacturer's instructions, and 3.0 U was injected at each Yonsei point. The gingival display was reduced to 2 mm after 1 week (Figure 6C). At 5 months after injection, the effects of BTX faded and relapse was noted.

Case 2. An 18-year-old female patient presented with upper anterior protrusion and excessive gingival display on smiling. Initial clinical photographs revealed lip protrusion and mentalis hyperactivity (Figure 7A,B). The treatment plan required extraction of four first premolars and retraction of the anterior teeth to correct lip protrusion. After 19 months of treatment, space closure had been completed via controlled retraction of the incisors. However, the patient's smile was still asymmetric because of the uneven lip line with unilateral gingival display of 4 mm above the left canine, which was not necessarily due to occlusal plane canting (Figure 7C). With the patient's consent, BTX was unilaterally injected. After 1 week, gingival exposure was eliminated and symmetric elevation of the upper lip was clinically observed with no side effects such as infection or edema (Figure 7D).

DISCUSSION

The anatomy of the facial musculature must be understood by orthodontists, whose main interest is the appearance of the teeth and periodontal tissue, because the behavior of perioral muscles critically influences the structure of a smile. Excessive gingival display during smiling, or ''gummy smile,'' usually is associated with the ''canine smile.''[17] Hyperactive lip elevator muscles and skeletal and gingival causes of this condition have been described in the literature. According to Peck et al,[18] patients with a gummy smile had 20% or greater facial muscular capacity to raise the upper lip on smiling. When cephalometric analysis reveals normal maxillary dimensions and 2 mm of upper incisor is measured with the lips in repose, excessive gingival display on smiling may be due to hyperfunction of the lip elevator muscles. This suggests the need for reasonable guidelines for the application of BTX in orthodontic practice.

In the present study, mean angles for the LLS, ZMi, and LLSAN muscles were not significantly different between the left and right sides or between male and female subjects, implying that an asymmetric smile may be due largely to differences in muscle activity rather than to differences in muscle distribution. This can be effectively corrected with BTX, as is demonstrated in Figure 7. Tjan et al[19] reported gender differences in smile line frequency. They showed that low smile lines were predominantly a male characteristic (2.5:1), and high smile lines were predominantly a female characteristic (2:1). This finding contrasts with results of the present study, which show no sex differences in the direction of muscle fibers. Considering that complex coordination of the perioral musculature determines the eventual smile configuration, the cause of the previously stated gender difference remains inconclusive. Inability to evaluate muscle activity and the actual smile conformation in cadavers is another limitation of this study.

The safety of the toxin must be thoroughly investigated. The injection dose of BTX that is used has been stated in a number of reports but differs among studies. Polo[15,20] attempted multiple serial injections into each elevator muscle, with variable doses ranging from 0.625 U to 2.5 U at different phases, under electromyographic

guidance. Kane[21] treated excessive gingival display through improvement of the nasolabial fold, targeting the LLSAN with 5 U per side. The injection dose was 1 U initially; at 2 to 3 weeks' follow-up, the subsequent dose was determined according to clinical response. Clinically, muscle weakness was seen approximately 2 to 4 days after injection, with full effect apparent at 7 to 10 days. Garcia[16] recommended that 2 to 5 U of BTX was as effective as higher doses. In contrast to larger muscles elsewhere in the body, doses around 5 U are considered appropriate for the facial muscles.

The method of identifying the injection site in this study was based on Garcia's report,[16] which stated that the toxin can spread through an area of 15 to 30 mm. Different efficacies of type A BTX have been reported, with a resultant conversion ratio of 1:2.5 to 4 between Botox (Allergan) and Dysport (Beaufour Ipsen Biotech).[22–24] Dysport showed greater efficacy and longer duration of effect but with an increased possibility of side effects.[23] Considering the relatively smaller area of diffusion with Botox compared with Dysport and the relative safety, Botox may be more suitable for use in facial expression muscles because highly specific deactivation of each muscle is indicated.

Although electromyographic guidance may provide supplemental information on muscle topography among individuals,[20] anatomic study can clearly reveal the distribution of each muscle. It is therefore crucial that the results of clinical trials are substantiated by empirical outcomes; this was one of the main goals of the present study. The injection point for BTX suggested in this study is located easily and targets the whole of LLSAN, LLS, and ZMi with a single injection, as opposed to one injection for each muscle.[15] Low individual variation in the position of the proposed point also explains the reliability of the point. However, the validity of the proposed point must be confirmed by additional clinical evidence, so that a statistically sound conclusion can be derived. The reversibility of BTX via regeneration of the nerve-muscle complex and of SNAP-25 proteins can be considered a minor drawback, but it conversely verifies the fail safety of the procedure.

Relatively thin fat tissues at the proposed injection point (data not shown) allow intramuscular injection of BTX at a rather superficial level and permit avoidance of possible needle injury to anatomic structures such as the infraorbital nerve plexus, which is located in the deepest layer, and the facial vessels that run lateral to the injection sites.[25,26] Aspiration should be performed before BTX is injected so that possible intravascular deposition can be avoided.

Despite all of the promising aspects, investigators in this study do not at this time encourage the use of BTX in clinical patients. Further evidence is still required, including data on the efficacy of BTX in different muscles among individuals and information on its safety in humans according to dose. Because data in this study were obtained from Asian subjects, additional studies undertaken to compare ethnic groups, genders, and ages would be helpful. With careful case selection and a thorough understanding of its actions and limitations, BTX may represent a strong treatment alternative for patients with excessive gingival display of muscular origin.

CONCLUSIONS

- The three lip elevator muscles—LLS, LLSAN, and ZMi—converged on the area lateral to the ala.
- No significant differences in angular measurements of the LLS, LLSAN, and ZMi could be found between male and female subjects or between left and right sides, implying that muscle distribution was largely symmetric and uniform.
- A safe and reproducible injection point for BTX around the converging area of the three muscles was proposed and proved effective in clinical applications.
- These findings and the clinical examples presented herein suggest that the application of BTX under proper case selection may be a favorable treatment supplement for patients with excessive gingival display.

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