

Original Article

Application of ultrasound imaging of upper lip orbicularis oris muscle

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Abstract: In this study, we aim to understand the morphology and structure of upper lip orbicularis oris muscle, and to provide clinical evidence for evaluating the effect of repair operation in cleft lip. Subjects included 106 healthy people and 36 postoperative patients of unilateral cleft lip. The upper lip orbicularis oris muscle was scanned using ultrasound in natural closure and pout states. Our results showed that the hierarchical structure of upper lip tissue was demonstrated clearly in ultrasonic images. After reconstruction of unilateral cleft lip, the left and right philtrum columns were still obviously asymmetric, their radian displayed clearly and showed better continuity. In the place of cleft lip side equivalent to philtrum columns, orbicularis oris muscle showed discontinuity and unclear hierarchical structure, which was replaced by hyperechoic scar tissue. The superficial layer would become thicker when pouting. In reconstructed unilateral cleft lip, the superficial layer was thinner than that of healthy controls. In normal upper lip orbicularis oris muscle, the superficial layer thickness was no less than 2.89 mm in philtrum dimple and no less than 3.92 mm in philtrum column, and the deep layer thickness was no less than 1.12 mm. Otherwise, the layer thickness less than above reference values may be considered as diagnostic criteria for dysplasia of upper lip orbicularis oris muscle. In conclusions, ultrasound imaging is able to clearly show the hierarchical structure of upper lip orbicularis oris muscle, and will be beneficial in guiding the upper lip repair and reconstruction surgery.

Keywords: Upper lip orbicularis oris muscle, ultrasonic images, unilateral cleft lip, thickness measured value

Introduction

Congenital unilateral cleft lip is a common facial development malformation, and shows one side upper lip split, accompanied with basis nasi wider or split, ala nasi collapse and nasal columella bias toward contralateral. As an important aesthetic unit that contributes to the feature of human face, unilateral cleft lip causes a great mental burden and serious psychological obstacle to patients and families [1]. At present, its postoperative effect is assessed by clinicians using subjective aesthetic vision method and some objective inspection techniques [2-8]. Subjective evaluation is simple but depends on different esthetic sense, and is not conducive to make a clear judgment to postoperative effect. Objective evaluation does not clear the condition of orbicularis oris muscle in reconstructed cleft lip. Currently, domestic and foreign scholars investigate orbicularis oris muscle mainly by gross and microscopic anatomy of human specimen [9-13]. So far, little literature has reported the application of

ultrasound technology in upper lip orbicularis oris muscle [14, 15]. Ultrasound technology reflects clearly and accurately the upper lip orbicularis oris muscle, measure the scar tissue thickness and understand the adjacent tissue relations. Compared with biopsy technique, ultrasonic examination is more objective, convenient, pain-free and reusable check method, and is also easily accepted by patients. The scar width and thickness was measured in postoperative unilateral cleft lip, and the width of scar tissue was regarded as a factor to impact unilateral cleft lip repairing effect. When the continuity of orbicularis oris muscle was better and scar tissue was narrower, the appearance evaluation was more excellent. When the continuity of orbicularis oris muscle was obvious dislocation and scar tissue was wider, the appearance evaluation was poorer [16].

In this study, we performed ultrasonic imaging of upper lip orbicularis oris muscle in postoperative unilateral cleft lip and normal controls, by

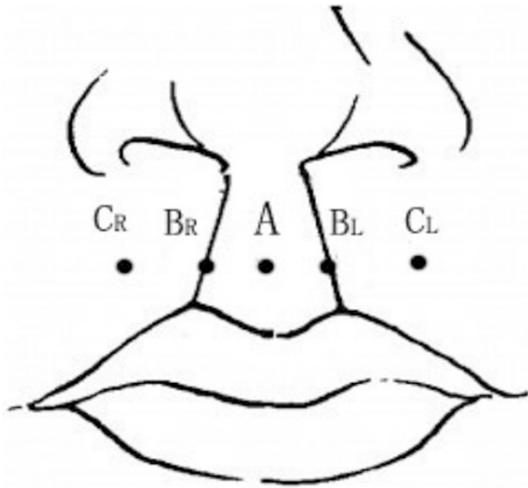


Figure 1. The measured points on the upper lip. A point: philtrum dimple; BL, BR points: philtrum columns; CL, CR points: paramedial philtrum dimple (1 cm).

measuring the thickness and establishing reference value range of normal youth's upper lip orbicularis oris muscle. We obtained ultrasonic images and the reference value range of normal youth's upper lip orbicularis oris muscle. Our results will provide a certain evidence for the cleft lip repair and reconstruction surgery. Ultrasonic imaging may be an objective, simple and reusable method in evaluating the postoperative effects of unilateral cleft lip.

Patients and methods

Subjects

A total of 36 postoperative patients of unilateral cleft lip (29 males and 7 females) were included in this study, whom were hospitalized in Department of Plastic and Reconstructive Surgery between August 2010 and May 2011. None of these patients underwent the second stage surgery. inclusive, A total of 106 young students (48 males and 58 females, range 19 to 25 years old) of Guangxi Medical University were selected between August 2010 and May 2011 as healthy controls, who had well-formed features and no oral and maxillofacial surgery disorders (such as congenital malformations and acquired defects, lip trauma, etc). Their teeth occlusion were basically normal and had no a history of orthodontic treatment. The written informed consent was in accordance with the Declaration of Helsinki and was obtained from all study subjects. Ethical approval was

granted from the Guangxi Medical University Research Ethics Committee.

Equipment

LOGIQ 9 (GE Medical System) and ultrasonic coupling agent were used in this study. LOGIQ 9 provides a high-resolution linear array transducer (10 to 14 MHz band-width).

Measurements

The philtrum dimple midline was chosen as A point, the left and right philtrum columns were chosen as BL and BR points, respectively, and the left and right paramedial philtrum dimple (1 cm) were chosen as CL and CR points, respectively (**Figure 1**). Participants were in supine position and ultrasonic coupling agent was applied between transducer and upper lip, then the transducer was placed on the upper lip, perpendicular to the nasal septum and midway between the columella and vermilion border. Following the natural curvature of the upper lip, the transducer was then slowly moved from the midline to the left, back to midline, to the right, and back again to midline. The hierarchical structure of upper lip tissue was focused and observed in ultrasonic images and the superficial and deep layer of orbicularis oris muscle were identified. The superficial and deep layers thickness values were measured in the five points. The above operation was repeated while pouting. A single trained individual performed all of the ultrasounds.

Statistical analysis

Statistical analysis was performed using commercially available statistical software (SPSS version 14.0). All measured quantitative data were expressed in mean \pm standard deviation ($\bar{x} \pm s$). Student t test (paired, two tailed) was performed to compare the means of the same person. Student t test (independent, two tailed) was performed to compare means between different crowds. $P < 0.05$ was considered as inspection standards of statistically differences.

Results

The high quality ultrasonic images of upper lip orbicularis oris muscle

In 106 youth controls the upper lip tissue could be clearly divided into five layers: The first layer

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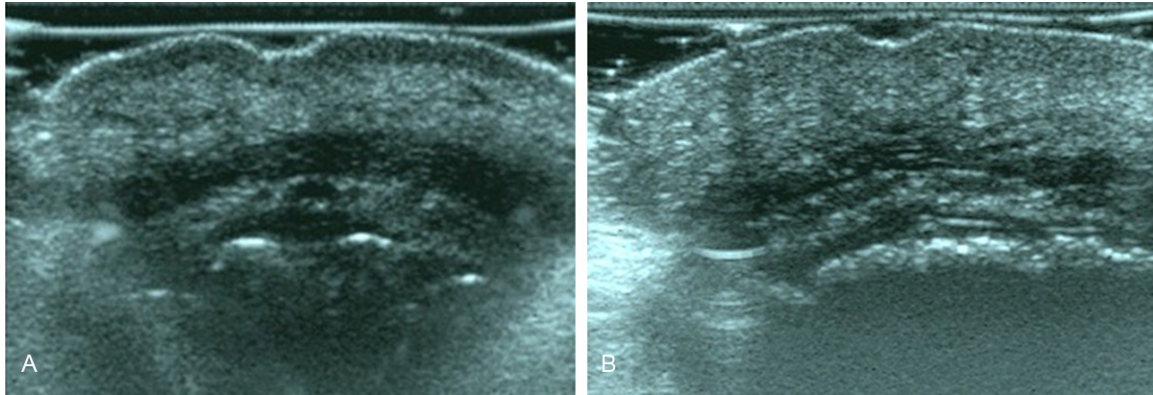


Figure 2. The ultrasonic images of upper lip orbicularis oris muscle. A. The ultrasonic image of the normal upper lip tissue could be clearly divided into five layers in natural closure. B. In pouting, the hierarchical structure of upper lip tissue was still clearly visible. Both sides of the orbicularis oris muscle gathered toward the middle and became thicker, causing philtrum dimple depression significantly.

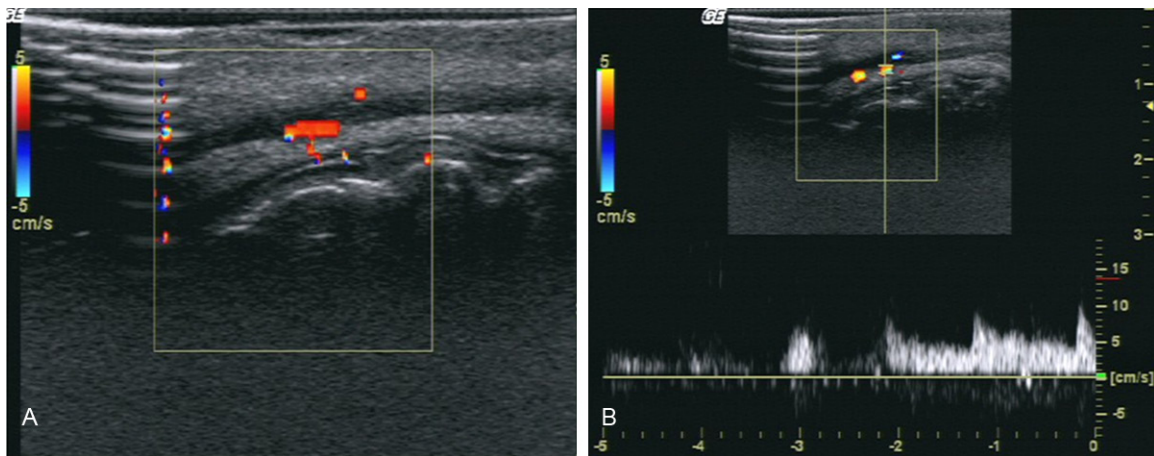


Figure 3. The ultrasonic image of the normal upper lip, upper lip artery crossed by submucosa (A), and measured the arterial spectrum (B).

was continuous dense hyperechoic line generated by ultrasonic coupling agent and the thickening skin epidermis (**Figure 2A**). The second layer was slightly hyperechoic area generated by skin connections, philtrum dimple, the left and right philtrum columns, and superficial layer muscle fibers of the upper lip orbicularis oris muscle. The third layer was consistent horizontal cordlike hypoechoic area generated by deep layer muscle fibers of the upper lip orbicularis oris muscle, with a gently curved contour of average thickness. The fourth layer was slightly hyperechoic area generated by submucosa of the upper lip tissue and upper lip artery (**Figure 3**). The fifth layer was slightly hyperechoic line generated by the mucous layer of the upper lip tissue. The deep part of the mucous layer was gap between the upper lip

tissue and gums, which was extremely hypoechoic. The hyperechoic gums was visible in the deepest part. In pout state, both sides of the orbicularis oris muscle gathered to the middle and became thicker, leading to gathering of left and right philtrum columns to the middle and obviously depressed philtrum dimple (**Figure 2B**).

In postoperative unilateral cleft lip patients, the radian of left and right philtrum columns was obviously asymmetric but displayed clearly and showed better skin continuity in ultrasonic images. Using philtrum dimple as the boundary, the hierarchical structure of the uninjured side upper lip tissue can still be clearly distinguished in ultrasonic images (**Figure 4A**). In the place equivalent to philtrum column of postoperative

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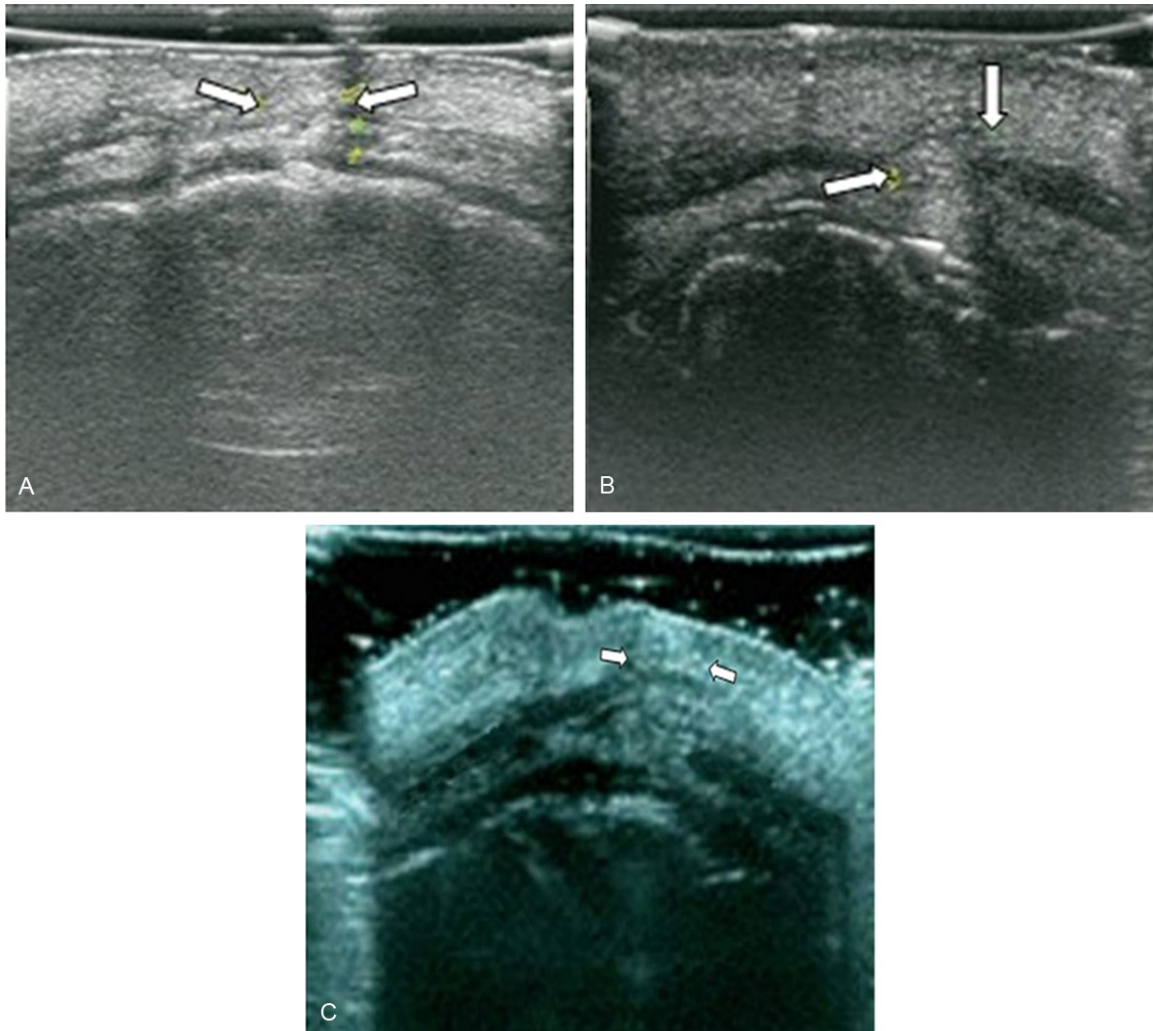


Figure 4. The ultrasonic image of postoperative unilateral cleft lip. A. In natural closure state, the radian of left and right philtrum columns was obviously asymmetric but displayed clearly and showed better skin continuity. B. In the cleft lip side, upper lip orbicularis oris muscle shows discontinuity and the hierarchical structure was unclear, replaced by hyperechoic scar tissue. C. When pouting, the upper lip orbicularis oris muscle shows discontinuity and ends dislocation obviously.

cleft lip, the upper lip tissue showed discontinuity and the hierarchical structure was unclear, replaced by hyperechoic scar tissue. Some patients' upper lip orbicularis oris muscle were obviously interrupted and misplaced with hyperechoic scar tissue obviously (**Figure 4B**). When pouting, the superficial and deep layer of upper lip orbicularis oris muscle showed discontinuity dislocation obviously (**Figure 4C**).

The ultrasonic measured values of normal upper lip orbicularis oris muscle

The upper lip orbicularis oris muscle thickness was measured both in the natural closure and pout state. No statistically significant differ-

ence was found in ultrasonic measured thickness values at the same point between male and female ($P>0.05$) (**Table 1**). The deep layer thickness of the orbicularis oris muscle was thinner than the superficial layer thickness at the same measured point ($P<0.01$). In the natural closure or pout state, there were no statistically significant difference in deep layer thickness values among five different measured points were ($P>0.05$), and no statistically significant difference in the superficial layer thickness between left and right philtrum columns or left and right paramedial philtrum dimple (1 cm) ($P>0.05$). In nature closure and pout state, there were statistically significant difference in the superficial layer thickness values of phil-

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Table 1. The ultrasonic measured values of upper lip orbicularis oris muscle from 106 normal youth in the age of 19-25 ($\bar{x} \pm s$, mm)

Sex	n	State	Layer	CR	BR	A	BL	CL
Male	48	closure	Superficial	4.80±0.58Δ,☆	5.02±0.72Δ	3.70±0.60	5.02±0.66Δ	4.63±0.70Δ,☆
			Deep	1.68±0.23■	1.64±0.32■	1.58±0.22■	1.60±0.23■	1.68±0.24■
		Pout	Superficial	6.30±0.51Δ◆	6.56±0.71Δ◆	4.53±0.34◆	6.88±0.61Δ◆	6.38±0.43Δ◆
			Deep	1.75±0.22■	1.77±0.22■	1.70±0.25■	1.78±0.21■	1.76±0.28■
Female	58	closure	Superficial	4.45±0.61Δ,☆	5.08±0.73Δ	3.85±0.54	5.08±0.70Δ	4.34±0.65Δ,☆
			Deep	1.42±0.26■	1.46±0.25■	1.42±0.24■	1.45±0.24■	1.43±0.31■
		Pout	Superficial	6.23±0.42Δ◆	6.66±0.46Δ◆	4.48±0.25◆	6.77±0.55Δ◆	6.12±0.39Δ◆
			Deep	1.65±0.30■	1.61±0.31■	1.65±0.21■	1.64±0.19■	1.62±0.26■

ΔP<0.01 VS philtrum dimple; ☆P<0.01 VS philtrum column; ◆P<0.01 VS closure; ■P<0.01 VS superficial (n-the number of participants).

Table 2. The 36 19-25 years old postoperative patients of unilateral cleft lip ultrasonic measured values of upper lip orbicularis oris ($\bar{x} \pm s$, mm)

Layer	State	Philtrum dimple	Philtrum	Column	Paramedial philtrum	Dimple 1cm
			Uninjured side	Cleft lip side	Uninjured side	Cleft lip side
Superficial	Closure	2.61±0.31Δ	3.29±0.41Δ	discontinuity, unclear and	4.16±0.28	2.98±0.16Δ
	Pout	3.63±0.47Δ	4.34±0.18Δ	replaced by scar tissue	5.87±0.57	3.66±0.11Δ
Deep	Closure			discontinuity, unclear and		
	Pout	1.54±0.21	1.56±0.13	replaced by scar tissue	1.58±0.23	1.48±0.16

ΔP<0.01 VS normal upper lip orbicularis oris muscle.

trium dimple with philtrum column or with paramedial philtrum dimple (1 cm) ($P<0.01$). The differences in superficial layer thickness values between philtrum column and paramedial philtrum dimple (1 cm) were statistically significant in nature closure state ($P<0.01$) and were not statistically significant in pout state ($P>0.05$). The superficial layer thickness was thinnest in philtrum dimple and thickest in philtrum column, shaping a radian of “low in middle side, high in both sides”, like “M”. There were statistically significant differences in superficial layer thickness values between the nature closure state and the pout state ($P<0.01$). When pouting, the superficial layer became thicker.

The ultrasonic measured value of upper lip orbicularis oris in postoperative unilateral cleft lip

In the natural closure state or pout state of postoperative unilateral cleft lip, the superficial layer thickness values of philtrum dimple, philtrum column in uninjured side, paramedial philtrum dimple (1 cm) in cleft lip side were significantly thinner than in normal upper lip orbicularis oris muscle ($P<0.01$) (Table 2). In the paramedial philtrum dimple (1 cm) of uninjured side,

there were no statistically significant differences in superficial layer thickness values between unilateral cleft lip patients and healthy controls ($P>0.05$). The superficial layer thickness of upper lip orbicularis oris muscle was thinner in areas closer scar tissue. There were no statistically significant differences in deep layer thickness values between patients and healthy controls ($P>0.05$).

The reference range of ultrasonic measured values from normal upper lip orbicularis oris muscle

The upper lip orbicularis oris muscle was thin and its measured thickness value had important clinical significance, so we took the unilateral lower limit value as the reference value range. It showed that the 95% reference value range of normal upper lip orbicularis oris muscle were ≥ 2.89 mm in superficial layer thickness of philtrum dimple, ≥ 3.92 mm in philtrum column and ≥ 1.12 mm in deep layer thickness (Table 3). When the superficial layer thickness of the upper lip orbicularis oris muscle was less than 2.89 mm, and deep layer thickness was less than 1.12 mm, we could diagnose dysplasia of upper lip orbicularis oris muscle.

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Table 3. The 106 19-25 years old youth's ultrasonic measured values of normal upper lip orbicularis oris muscle and its reference value range ($\bar{x} \pm s$, mm)

	n	Thickness ($\bar{x} \pm s$, mm)	Lower limit of the reference value (mm)
The superficial layer of philtrum dimple	106	3.81±0.56	2.89
The superficial layer of philtrum column	212	5.06±0.70	3.92
The deep layer	318	1.49±0.25	1.12

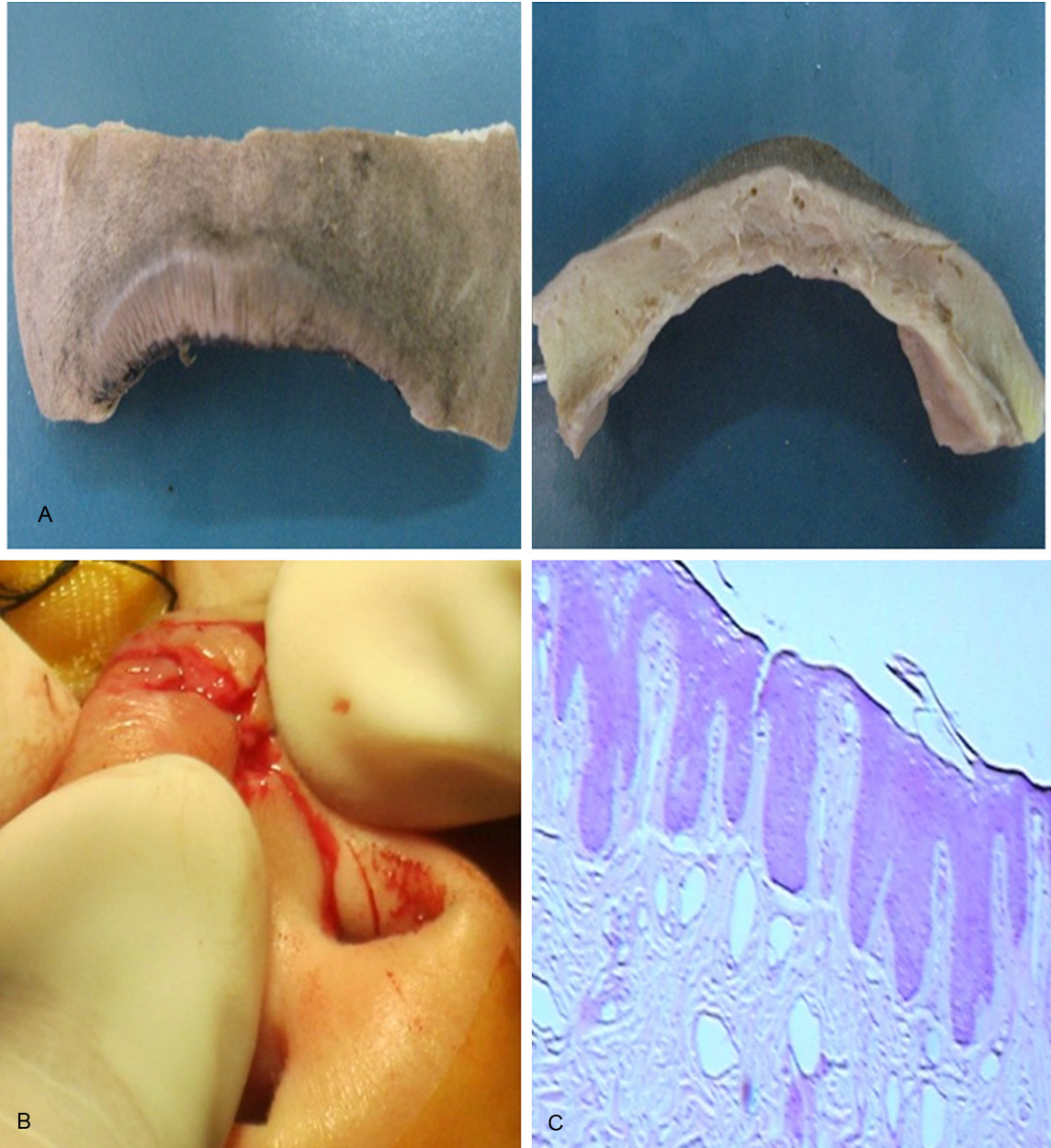


Figure 5. The gross and microscopic anatomy of upper lip orbicularis oris muscle. A. Normal upper lip orbicularis oris muscle of adult cadaver specimens. The radians formed by philtrum dimple and left and right philtrum columns were disappearing. B. Cleft lip during surgical repair. The superficial and deep layer of orbicularis oris muscle could be distinguished by naked eye, while the superficial layer and skin layer could not be distinguished. C. The histopathologic sections of upper lip orbicularis oris muscle on the midpoint horizontal section between the nose and upper lip. The demarcation between superficial and deep layer orbicularis oris muscle was clear.

The gross and microscopic anatomy of upper lip orbicularis oris muscle in adult cadaver specimens

In order to better understand the ultrasonic image of upper lip orbicularis oris muscle, we observed the general anatomy of normal upper lip orbicularis oris muscle of adult cadaver specimens (**Figure 5A**) and cleft lip during surgical repair (**Figure 5B**) and contrasted to the ultrasonic images. In cadaver specimens, the radians formed by philtrum dimple and left and right philtrum columns were disappearing. During unilateral cleft lip repair, the superficial and deep layer of orbicularis oris muscle could be distinguished by naked eye, while the superficial layer and skin layer could not be distinguished. Through observing the specimens on the midpoint horizontal section between the nose and upper lip (**Figure 5C**), we found that the upper lip tissue was composed by skin, superficial layer orbicularis oris muscle, deep layer orbicularis oris muscle, submucosa and mucosa from superficial to deep layer. The demarcation between superficial and deep layer orbicularis oris muscle was clear. The superficial layer orbicularis oris muscle was closely linked with skin and uneasily distinguished. On the fixed specimens of tissue sections, the color of superficial layer orbicularis oris muscle fiber was slightly lighter than that of deep layer muscle fiber. The demarcation was clear between deep layer fiber and submucosa, and deep layer muscle fiber is rich in glands.

Discussion

Orbicularis oris muscle is one of the important three sets of ring-shaped muscle of the body, and plays sucking, chewing and other motor functions, and it also forms the important part of the facial muscles. The dysplasia and/or discontinuity of orbicularis oris muscle would affect normal facial morphology and movement, leading to sucking and chewing movement disorders [17]. Therefore, mastering the anatomical knowledge of orbicularis oris muscle would be the theoretical basis to repair the orbicularis oris muscle.

Currently, most scholars study the orbicularis oris muscle mainly through gross observation and microscopic anatomy of the human specimens [9-13]. Through a large number of studies, the scholars agreed that the orbicularis

oris muscle is composed by different muscle fibers and could be divided into deep and superficial layer muscle fibers [18, 19]. One function of orbicularis oris muscle is facial expression and the precise movements of the lips such as speaking, which is supported by complex superficial network of muscle fibers. The other function is mastication with general sphincter activity, which is supplied by deep layer muscle fibers. The superficial fibers consist of upper and lower bundles. These bundles are inserted into the skin and form philtrum column, and short fibers end in the ridge on one side and long fibers cross the midline to enter the opposite side [9, 11, 20]. The philtrum dimple originates from lesser attachment of muscles to surfaces [11]. Briedis and Jackson also confirmed the interdigitation of the superficial layer of muscle with an insertion into the dermis and the continuity of a deeper layer across the midline [10]. Superficial fibers of the orbicularis oris muscle have a crosswise pattern. Philtrum columns are composed of superficial fiber insertions from each side. Because of this pattern, philtrum columns showed an increase in thickness in a static position and came closer to each other and move forward in dynamic mode [19].

Currently, ultrasound technology is used to examine more and more superficial tissues such as skin, subcutaneous fat, muscle, and so on. It could be not only used to diagnose disease, but also provide the complete anatomic atlas. In the ultrasonic image of superficial tissues, skin layer took on continuous dense hyperechoic line, subcutaneous layer (superficial fascia) being rich in fat tissue was hyperechoic, and muscles fiber shows hypoechoic streak [21]. Rogers CR et al concluded that combination of ultrasound and histology is capable of visualizing upper lip anatomy, thereby validating the use of ultrasound for the assessment of orbicularis oris muscle status [14]. His study provided compelling evidence that discontinuities of the orbicularis oris muscle identified by ultrasound have an anatomical and structural basis. van Hees NJM et al showed that with the use of ultrasound imaging, the various anatomical structures of the upper lip can be easily identified and distinguished [15]. It was additionally illustrated by the in vitro image when compared with the corresponding histological slice.

In this study, normal upper lip tissues from 106 young adults were examined by ultrasound technology. In ultrasonic images, the curvature shaped by philtrum dimple and left and right philtrum columns was clearly visible. According to the ultrasound image characteristics of skin, subcutaneous tissue and muscle, the normal upper lip tissues of 106 youth could be divided into five layers from superficial to deep layer. The first layer was continuous dense hyperechoic line generated by ultrasonic coupling agent and the epidermis of the skin. The second layer was slightly hyperechoic and composed by skin connection, philtrum dimple, the left and right philtrum columns, superficial layer muscles fibers of the upper lip orbicularis oris muscle. The third layer was consistent cord-like hypoechoic area generated by deep fibers of the upper lip orbicularis oris muscle. The fourth layer was slightly hyperechoic area generated by submucosa tissue of the upper lip orbicularis oris muscle, with glandular tissue and upper lip artery. The fifth layer was slightly hyperechoic line generated by the mucous layer of the upper lip tissue. In the pout state, the hierarchical structure of upper lip tissue was clearly visible in ultrasonic image, and two sides of upper lip orbicularis oris muscle gathered to the middle and became thicker, leading to the gathering of left and right philtrum columns to the middle and obvious philtrum dimple.

When getting better ultrasonic images, we measured the superficial and deep layer thickness of orbicularis oris muscle in philtrum dimple (A point), philtrum columns (BL, BR points), and paramedial philtrum dimple (1 cm) (CL, CR points). The orbicularis oris muscle thickness values had no significant difference between men and women. The deep layer thickness of the orbicularis oris muscle was significantly thinner than the superficial layer thickness. The superficial layer showed symmetry and its thickness values were the same between left and right philtrum columns, or between left and right paramedial philtrum dimple (1 cm). The superficial layer thickness was thinnest in philtrum dimple and thickest in philtrum columns, shaping like "M". The superficial layer thickness of upper lip orbicularis oris muscle became thicker when pouting.

Some scholars considered that in unilateral cleft lip, deep layer muscle fiber was only

interrupted in fissures but not distorted [9, 22]. However, superficial layer muscle fiber shows not only interruption, dislocation and distortions, but also obvious ultrastructural variation, including sparse muscle fiber, myofibrillar and mitochondrial variation, and the closer fissure, leading to more obvious muscle variation [23]. Until now, there is not unified objective standard in assessing the effect of repair and reconstruction of cleft lip. At present, clinicians mainly use subjective aesthetic vision and some objective inspection techniques to assess the postoperative effect [2-8]. Subjective evaluation is simple, but persons had different esthetic sense, therefore make a clear judgment to postoperative effect is difficult. Objective evaluation does not show the detailed conditions of orbicularis oris muscle in postoperative reconstructed cleft lip.

Every surgical intervention, however, inevitably led to scar formation. The amount of scar tissue and its position had both functional and aesthetic consequences [24]. Scar tissue contains a low density of cells and blood vessels and a higher density of arranged collagens. Areas of scar tissue show a lower echo level (hypoechoic, dark zones) in ultrasonic images within a healthy tissue layer. The echo level is dependent, among other factors, on the angle of the ultrasound with respect to the proximal surface of the scar [15].

In this study, abnormal upper lip tissues of 36 young adults postoperative unilateral cleft lip were examined by ultrasound technology, and the radian of left and right philtrum columns displayed clearly and showed better continuity. The radian of left and right philtrum columns was obviously asymmetric. Taking philtrum dimple as the boundary, the hierarchical structure of the uninjured side of upper lip tissue could be clearly distinguished in ultrasonic images. In the cleft lip side, orbicularis oris muscle of the place equivalent to philtrum column showed discontinuity and unclear hierarchical structure, and was replaced by hyperechoic scar tissue. Compared with the measured values of normal upper lip tissue, the superficial layer thickness was thinner in places adjacent to scar tissue. The superficial layer thickness of paramedial philtrum dimple (1 cm) in uninjured side had no difference compared with the normal lip tissue. The deep thickness value also has no difference compared with the normal lip

tissue. In this study, we concluded that the width of scar tissue was a factor to impact unilateral cleft lip repairing effect. When the continuity of orbicularis oris muscle was better and scar tissue was narrower, the appearance evaluation was more excellent. When the continuity of orbicularis oris muscle was obviously dislocated and scar tissue was wider, the appearance evaluation was poorer [16]. It indicates that ultrasonic image has important clinical significance in guiding cleft lip repair and reconstruction and assessing the postoperative effects.

Ultrasound imaging may be a promising method in evaluating the morphological structure of the orbicularis oris muscle and postoperative effects of cleft lip repair and reconstruction. The defect of this method is that ultrasound technology would not be very clear to display the complex directions of muscle fiber. Furthermore, in some individual, the upper lip is so narrow that the transducer is difficult to place. Because the upper lip surface is rugged, the transducer would not contact with it thoroughly and sometimes results in a fuzzy ultrasonic image. If we press the transducer, it would lead to the deformation of upper lip orbicularis oris muscle and affect the accuracy of measured values.

Because of the limitation of time and conditions, this study is not comprehensive enough. In subsequent study, increased sample size is needed and cases of different ages and body weight will be collected. The correlation of orbicularis oris muscle's thickness with age and weight should be investigated. The reference value of upper lip orbicularis oris muscle will be established. The patients of cleft lip were mostly young children and the optimal time of surgical treatment was early childhood, so the normal thickness reference value range of children's upper lip orbicularis oris muscle had important clinical significance in particular.

In conclusion, ultrasound imaging is able to clearly show the hierarchical structure of upper lip orbicularis oris muscle and acquire the reference value range of healthy upper lip orbicularis oris muscle. This will provide the clinical evidence for repair and reconstruction surgery of upper lip.

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Disclosure of conflict of interest

None.

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References

- [1] Endriga MC, Kapp-Simon KA. Psychological issues in craniofacial care: state of the art. *Cleft Palate Craniofac J* 1999; 36: 3-11.
- [2] Dion MA, Parenteau J. Rotation-advancement technique in unilateral cleft lips. *Can J Surg* 1968; 11: 177-178.
- [3] Holtmann B, Wray RC. A randomized comparison of triangular and rotation-advancement unilateral cleft lip repairs. *Plast Reconstr Surg* 1983; 71: 172-179.
- [4] Sykes JM, Tollefson TT. Management of the cleft lip deformity. *Facial Plast Surg Clin North Am* 2005; 13: 157-167.
- [5] Amaratunga NA. A comparison of Millard's and LeMesurier's methods of repair of the complete unilateral cleft lip using a new symmetry index. *J Oral Maxillofac Surg* 1988; 46: 353-356.
- [6] Qiu WL. Treatment of cleft lip and cleft palate. *Chin Med J (Engl)* 1991; 104: 432-436.
- [7] Dalston RM, Marsh JL, Vig KW, Witzel MA, Bumsted RM. Minimal standards for reporting the results of surgery on patients with cleft lip, cleft palate, or both: a proposal. *Cleft palate J* 1988; 25: 3-7.
- [8] Hood CA, Hosey MT, Bock M, White J, Orth M, Ray A, Ayoub AF. Facial characterization of infants with cleft lip and palate using a three-dimensional capture technique. *Cleft Palate Craniofac J* 2004; 41: 27-35.
- [9] Nicolau PJ. The orbicularis oris muscle: a functional approach to its repair in the cleft lip. *Br J Plast Surg* 1983; 36: 141-153.
- [10] Brieds J, Jackson IJ. The anatomy of the philtrum: observations made on dissections in the normal lip. *Br J Plast Surg* 1981; 34: 128-132.
- [11] Lathan RA, Deaton TG. The structure basis of the philtrum and the contour of the vermilion border: a study of the musculature of the upper lip. *J Anat* 1976; 121: 151-160.

- [12] Nairn RI. The circumoral musculature: structure and function. *Br Dent J* 1975; 138: 49-56.
- [13] Neiswanger K, Weinberg SM, Rogers CR, Brandon CA, Cooper ME, Bardi KM, Deleyiannis FW, Resick JM, Bowen A, Mooney MP, de Salamanca JE, González B, Maher BS, Martin RA, Marazita ML. Orbicularis oris muscle defects as an expanded phenotypic feature in nonsyndromic cleft lip with or without cleft palate. *Am J Med Genet A* 2007; 143A: 1143-1149.
- [14] Rogers CR, Weinberg SM, Smith TD, Deleyiannis FW, Mooney MP, Marazita ML. Anatomical basis for apparent subepithelial cleft lip: a histological and ultrasonographic survey of the orbicularis oris muscle. *Cleft Palate Craniofac J* 2008; 45: 518-524.
- [15] van Hees NJ, Thijssen JM, Huyskens RW, Weijers G, Nillesen MM, de Korte CL, Katsaros C. Quantitative ultrasound imaging of healthy and reconstructed cleft lip: a feasibility study. *Cleft Palate Craniofac J* 2007; 44: 261-268.
- [16] Chen BF, Wei Q, Mo CL, Liao XH. Application of the high frequency ultrasound in evaluation postoperative unilateral cleft lip. *Chinese J Aesthetic Medicine* 2012; 21: 49-51.
- [17] Hall BK, Precious DS. Cleft lip, nose, and palate: the nasal septum as the pacemaker for midfacial growth. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2013; 115: 442-447.
- [18] Fara M. Anatomy and arteriography of cleft lip in stillborn children. *J Plast Reconstr Surg* 1968; 42: 29-36.
- [19] Baris C, Kaan G, Mithat A, Gaye T, Tayfun A. Jack-like eversion by splitting the orbicularis oris muscle for reconstruction of the philtral column in secondary cleft lip. *Scand J Plast Reconstr Surg Hand Surg* 2009; 43: 8-15.
- [20] Tan O, Atik B. Triangular with ala nasi (TAN) repair of unilateral cleft lips: a personal technique and early outcomes. *J Craniofac Surg* 2007; 18: 186-197.
- [21] Abu-Hijleh MF, Roshier AL, Al-Shboul Q, Dharap AS, Harris PF. The membranous layer of superficial fascia: evidence for its widespread distribution in the body. *Surg Radiol Anat* 2006; 28: 606-619.
- [22] Stoll C, Opitz C, Bauer S, Petzold D. The soft-tissue facial profile of patients with unilateral clefts of the lip, alveolus, and palate compared with healthy adults. *J Orofac Orthop* 2002; 63: 179-189.
- [23] Zheng PH, Chang Q, Lin ZY. An electron-microscopic observation on the lip muscle of unilateral cleft lip. *J Med Imaging* 2004; 14: 300-301.
- [24] Cash C, Set P, Coleman N. The accuracy of antenatal ultrasound in the detection of facial clefts in a low-risk screening population. *Ultrasound Obstet Gynecol* 2001; 18: 432-436.