



# Preoperative assessment of depressor anguli oris to prevent myectomy failure: An anatomical study using high-resolution ultrasound

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## KEYWORDS

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**Summary** *Background:* Myectomies of the lower lip depressor muscles have unexplained high failure rates. This study aimed to examine the depressor anguli oris (DAO) muscle using high-resolution ultrasound to identify potential anatomical explanations for surgical failures and to determine the accuracy of utilizing preoperative ultrasound assessment to improve myectomies.

*Methods:* Anatomical features of DAO and the surrounding anatomy were examined in 38 hemifaces of human body donors using high-resolution ultrasound and dissection.

*Results:* The ultrasound and dissection measurements showed the DAO muscle width to be  $16.2 \pm 2.9$  versus  $14.5 \pm 2.5$  mm, respectively, and the location of the lateral muscle border  $54.4 \pm 5.7$  versus  $52.3 \pm 5.4$  mm lateral to the midline. In 60% of the cases, the facial artery was either completely covered by lateral DAO muscle fibers or was found to be in direct contact with the lateral border. Significant muscle fiber continuity was present between the DAO and surrounding muscles in 5% of cases, whereas continuity between the depressor labii inferioris and surrounding muscles was considerably more common and pronounced.

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**Conclusions:** High-resolution ultrasound can accurately reveal important preoperative anatomical information in myectomies. Two potential explanations for the surgical failures were discovered: an overlap of lateral DAO muscle fibers over the facial artery could lead to inadequate resections and continuity with the surrounding muscles might lead to muscle function takeover despite adequate resections. Both can be uncovered preoperatively by the surgeon through a brief, directed ultrasound examination, which may allow for modification of the surgical plan to reduce surgical failure.

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Myectomy of the depressor anguli oris (DAO) muscle can restore symmetry in patients with facial paralysis and post-paralytic facial imbalance.<sup>1,2</sup> The procedure effectively re-establishes facial function and balance by releasing the pull exerted by a hyperkinetic DAO on the affected side or, in a patient with flaccid paralysis, by the healthy muscle on the contralateral side. However, despite being a straightforward procedure, approximately one in five myectomies of the lower lip depressor muscles fails.<sup>3,4</sup> Thus, patients with intact depressor function are forced to undergo repeated surgeries or alternative treatments such as chemodenervation using botulinum toxin.

Surgical failure is defined as the unexpected return of muscle function following resection and can be categorized into two distinct groups: early failure and delayed failure. A potential explanation for early failures could be that the lateral most muscle fibers of the lower lip depressor muscles are difficult to define and resect during surgery, which might result in these fibers, and thus lateral muscle function, being left intact.<sup>4-6</sup> Delayed failures could be explained by scar formation, leading to gradual recurrence of muscle function over time, possibly due to an inadequate resection length.<sup>5,6</sup>

Currently, preoperative assessment of the location and boundaries of the DAO muscle is performed through clinical visual assessment of muscle movement and palpation, which is then confirmed intraoperatively.<sup>4</sup> The clinical assessment, even though reliable in experienced hands, is subjective. Furthermore, it is subject to several factors of unreliability, such as difficulty in defining the muscles in patients with trouble activating the correct fibers, in combination with muscle atrophy in older individuals. These difficulties in preoperative assessment, together with the intraoperative difficulty in determining the lateral muscle border, could contribute to the high failure rate of the procedure.

High-resolution ultrasonography has shown potential as a perioperative adjunct in plastic surgery. In preoperative vessel mapping prior to flap harvesting, for example, ultrasound assessment has been shown to be able to supplement or even supplant the gold-standard tools of today.<sup>7-14</sup> In facial paralysis, the use of ultrasound for diagnosis, prognostication, and treatment is being explored.<sup>15-21</sup> It has also been used to objectify DAO dysfunction in synkinetic patients.<sup>22,23</sup> When the ultrasound examination is performed bedside by the surgeon, it can provide a simple and quick evaluation tool to improve the preoperative assessment, with benefits such as increased anatomical awareness, the possibility of mapping individual anatomical variants, and improved patient satisfaction.<sup>24,25</sup>

The authors hypothesized that preoperative ultrasonographic assessment of the DAO muscle and surrounding anatomy, performed by the surgeon, might reduce the proportion of surgical failures in lower lip depressor myectomies by increasing anatomical awareness. This study aimed to discover anatomical explanations for the high failure rates in lower lip depressor myectomies using ultrasound and dissections and to assess the clinical feasibility and accuracy of examining the DAO muscle using ultrasound to improve myectomies.

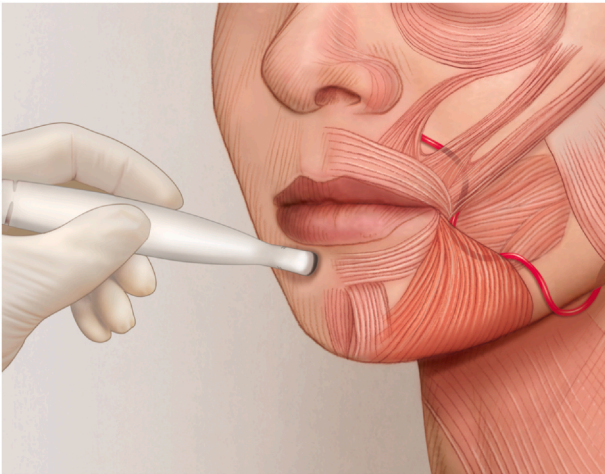
## Materials and methods

The study was performed in accordance with local rules and regulations and was approved by the ethical institutional committee in Austria (EC-number: 1402/2020 and amendment). Written consent was obtained from all donors during their lifetimes.

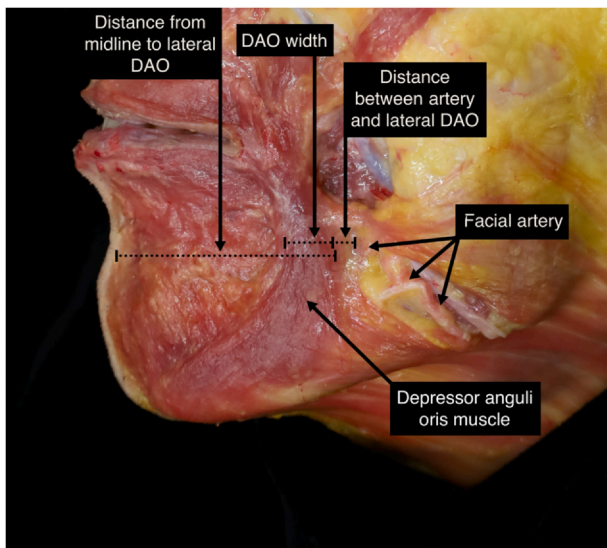
This study included 38 hemifaces from 19 non-embalmed fresh cadavers. The average age was  $83.5 \pm 8.7$  years (range 67-100), with 10 female and 9 male body donors. With a standard clinical ultrasound system and a high frequency (22 MHz) hockey stick probe (Aplio i800 and i22LH8, Canon Medical Systems Europe B.V., Zoetermeer, The Netherlands), the DAO muscle and its relation to the surrounding anatomy (the facial artery and surrounding anatomical structures) was studied by a radiologist specialized in ultrasonography.

## Sonographic measurements

With the skin intact, the DAO muscle width was measured using the built-in 2D ultrasound machine caliper. Next, the lateral border of the DAO was identified using ultrasound and marked on the skin, and the horizontal distance from the midline of the mandible to this point was measured using measuring tape. DAO muscle depth was measured from the skin surface to the superficial surface of the middle part of the muscle. Sonographic images of each measurement and muscle were stored. The location of the facial artery was determined in relation to the lateral border of the DAO muscle by measuring the distance from the lateral DAO border to the medial wall of the facial artery using an ultrasound caliper (positive values if the medial arterial wall was found lateral to the lateral DAO border and negative values if found medial to it). See [Figure 1](#) for an illustration of the procedure and [Figure 2](#) for an example



**Figure 1** Illustration of preoperative ultrasound examination of the depressor anguli oris muscle. The facial artery can be seen lying beneath the lateral DAO muscle fibers, which might theoretically lead to an increased risk of surgical failure.



**Figure 2** Example image from the dissections. The depressor anguli oris (DAO) muscle can be observed with the facial artery lying laterally to it. The dotted lines mark the measurements that were performed: the distance from the midline of the mandible to the lateral DAO border, the DAO width, and the distance between the lateral DAO border and the medial wall of the facial artery.

of the dissections of the measurements. In addition, the presence and degree of muscle fiber continuity between the DAO and the surrounding muscles were graded. The focus of this study was the DAO muscle; nonetheless, as the depressor labii inferioris (DLI) muscle is part of the depressor complex, it was also briefly evaluated for the presence of muscle fiber continuity.

### Dissection measurements

Dissections were performed within 24 h of the ultrasound measurements and were carried out by two senior plastic

surgeons and an anatomist. Using standard surgical instruments and loop magnification, the skin and adipose tissue were removed down to the muscle layer. The DAO muscle and the surrounding anatomy were completely exposed. The previously measured distances of the DAO width and distance to the lateral DAO border were measured again with a physical measuring tape and compared with the ultrasound assessments.

To ensure corresponding measurement sites during ultrasound and dissection measurements, a vertical line was drawn along the midline of the mandible on each face from the anteroinferior mandibular border to the lower vermilion border. All the measurements were performed at the same relative height in each hemiface. Specifically, one-third down along this line from the lower vermilion border (a height illustrated in [Figure 2](#) by the line marked with “DAO width,” approximately where myectomies are generally performed). A suture was placed to ensure equivalent measurement heights. The ultrasound-measured distances were always measured with the ultrasound probe held at a strictly horizontal angle, with an assistant double-checking the probe position before each measurement.

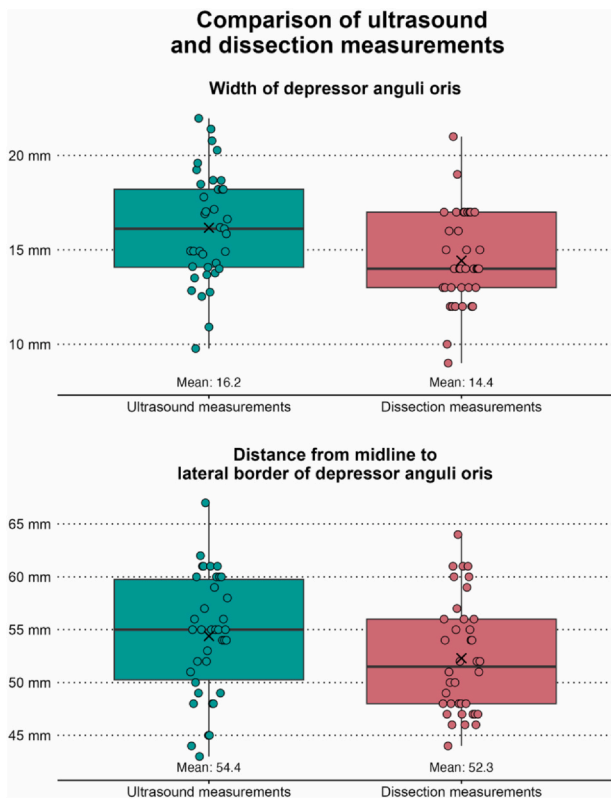
Descriptive statistics were used, and the data are presented as means with corresponding standard deviations (mean  $\pm$  SD). The plot was produced using R version 2023.03.0 + 386.

### Results

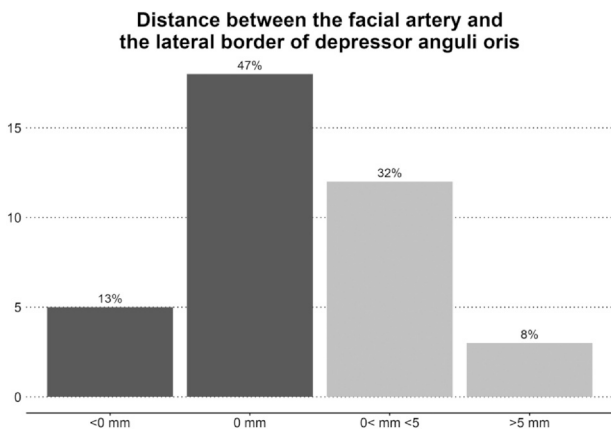
The ultrasound measurements showed that the DAO muscle width was  $16 \pm 3$  mm (range: 9.8-22), compared to  $14.5 \pm 2.5$  mm (range: 9-21) according to the dissections. The distance from the mandible midline to the lateral DAO border was  $54.4 \pm 5.7$  mm (range: 43-67) compared to  $52.3 \pm 5.4$  mm (range: 44-64) according to the dissection measurements. A comparison of the ultrasound and dissection measurements is shown in the boxplots in [Figure 3](#). The superficial surface of the DAO muscle was found lying at a depth of  $2.2 \pm 0.6$  mm (range: 1.3-3.3).

In 18 of the 38 cases, the facial artery was found exactly at the lateral DAO border. In 5 of 38 cases, the artery was found medial to the lateral DAO border and was thus completely covered by lateral DAO muscle fibers, with a mean distance of  $-2.2 \pm 1.3$  mm in the subgroup (range: -4 to -1). In 15 of 38 cases, the artery was found lateral to the lateral DAO border, with a mean distance of  $3.3 \pm 2.6$  mm (range: 0.5-9). In the whole cohort, the mean distance between the artery and lateral DAO border was  $1.0 \pm 2.6$  mm ( $n = 38$ , range: -4 to +9). [Figure 4](#) shows the relative distribution of the distances between the facial artery and the lateral DAO border.

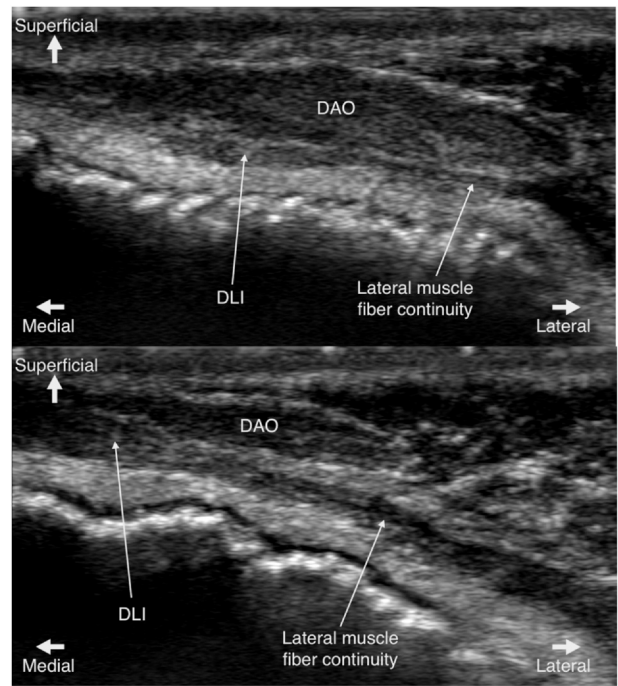
In addition, both the DAO and DLI muscles were assessed for muscle fiber continuity with the surrounding muscles, which was less frequently observed in the DAO muscle than in the DLI muscle. When evaluating the DAO muscle using ultrasound, most muscles showed no continuity with the surrounding muscles. However, two hemifaces had pronounced continuity with the platysma muscle laterally, which made defining the borders of the muscles more difficult than usual because it was difficult to determine where



**Figure 3** Boxplots comparing the ultrasound measurements and the dissection measurements of the “DAO width” and “Distance from the midline to the lateral DAO border.” Each point represents a single measurement of a single hemiface. The black crosses represent mean values, and the horizontal black lines represent median values.



**Figure 4** Bar chart showing the relative distribution of the distances between the facial artery and lateral border of the depressor anguli oris muscle in the hemifaces in the current study. The darker columns, which constitute approximately 60% of the cases, indicate the number of hemifaces where the distance was at or below 0 mm; thus, where the artery was either directly adjacent to or completely covered by the lateral DAO muscle fibers. Theoretically, these cases might have an increased risk of inadequate DAO resections, and thus, surgical failure.



**Figure 5** Two examples of lateral muscle fiber continuity from the depressor labii inferioris in two different hemifaces were seen on ultrasound. The muscles are hypoechoic (darker) and surrounded by hyperechoic (brighter) connective tissue. The mandible can be seen as a sloping hyperechoic white irregular line in the middle of the image. Figures 5 and 6 were subtly modified to remove the identifying features attributable to the manufacturer of the ultrasound machine.

the muscle belly ended. In comparison, the DLI muscle had some form of muscle fiber continuity in all cases; in 11 of the 38 cases, the continuity was so marked that the medial and lateral borders of the muscle were deemed impossible to define using ultrasound. In one of the DLI measurements, defining the borders of the muscle was deemed difficult but not impossible. Furthermore, the DLI muscle was very thin in many hemifaces and thus often difficult to locate using ultrasound. In contrast, the DAO muscle was thicker and easier to locate across all the hemifaces. Examples of lateral muscle fiber continuity in DLI are shown in Figure 5.

## Discussion

This anatomical study in body donors showed that preoperative high-resolution ultrasound assessment of the DAO muscle is feasible and accurate. Moreover, it can provide important anatomical information before myectomy of the lower lip depressor muscles to hopefully reduce the incidence of common surgical failure. To the best of the knowledge of the authors, this is the first study to investigate the potential anatomical reasons for surgical failure.

## Comparing the ultrasound and dissection measurements

The dissection measurements showed that the distance from the mandible midline to the lateral DAO border was

$52.3 \pm 5.4$  (range: 44-64), whereas the DAO width was  $14.5 \pm 2.5$  mm (range: 9-21). These measurements correlated well with the ultrasound measurements, as demonstrated by the boxplots in Figure 3. These measurements should be considered during surgery to ensure a complete DAO resection. The small variability between the two can probably be explained by tissue movement during measurements and dissections, which will inevitably lead to some imprecision when measurements are performed at different times by different operators. Furthermore, the high mean age of the body donors in this study was associated with reduced skin elasticity, which might have further affected the results.

### Anatomical reasons for surgical failures in myectomies of the lower lip depressor muscles

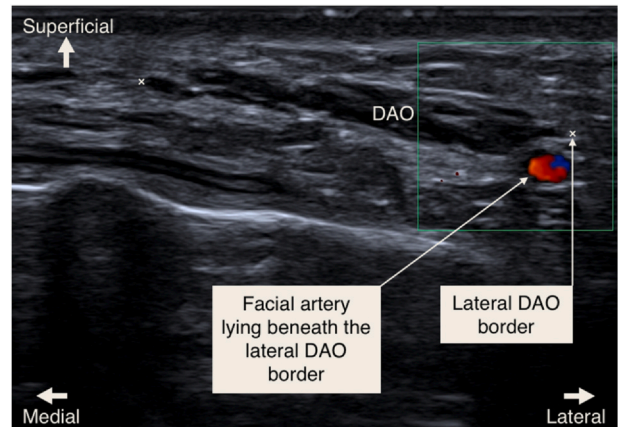
The study revealed two new potential anatomical explanations for the early surgical failures in myectomies of DAO, both of which can be uncovered through preoperative evaluations using high-resolution ultrasound. First, the facial artery was found either below or directly bordering the lateral margin of the DAO muscle in a large majority of the cases. Previously, Lee et al. described the course of the facial artery in a cadaver setting and showed that the main trunk of the facial artery may run beneath the lateral DAO muscle.<sup>26</sup> However, further details on the relationship between the facial artery and the DAO muscle were not presented. The current study showed that, in approximately 60% of the cases (Figure 4), the distance between the facial artery and the lateral DAO border was  $\leq 0$  mm ( $n = 23/38$ ,  $-0.48 \pm 1.08$  mm, range:  $-4$  to  $0$  mm), meaning that the artery was either completely covered by the lateral DAO fibers ( $n = 5/38$ ) or was in direct contact with the lateral border ( $n = 18/38$ ). The authors believe this finding could be a potential explanation for the failure rates of the procedure, as surgeons might see the artery as the lateral border of the surgical field, thus not crossing it to avoid the risk of vessel injury. This might prevent surgeons from extending their resection to the full lateral length of the DAO muscle, resulting in the lateral muscle fibers accidentally remaining intact. The importance of defining and including the lateral border of the depressor muscles in the resection to avoid surgical failure has been stated previously, but it is difficult to achieve because of the nature of the surrounding connective and adipose tissue.<sup>5,6</sup> The current study suggests that the DAO muscle fiber overlap over the facial artery might further exacerbate these difficulties.

Second, the presence and degree of muscle fiber continuity between the DAO and surrounding muscles were assessed in each hemiface. This analysis was based on the hypothesis that substantial continuity could provide a second explanation for the common surgical failures in lower lip depressor myectomies, as the adjoined surrounding muscles might uphold the original function of the resected muscle fibers. When examining DAO using ultrasonography, most cases had no muscle fiber continuity with the surrounding muscles. However, 5% of the cases had pronounced continuity, which was so distinct that the muscle borders were difficult to discern on ultrasound imaging. The DLI was also briefly evaluated for muscle fiber

continuity. Interestingly, compared with the DAO muscle, all DLI muscles had some degree of muscle fiber continuity with the surrounding muscles. The degree of continuity was also significantly more pronounced. In 32% of cases, the continuity from the DLI was so significant that the muscle borders were difficult or impossible to define using ultrasound. This continuity could explain why the borders of the muscles can be difficult to define during surgery,<sup>5,6</sup> which can potentially make complete and successful surgical excision of the muscle more challenging. This could explain the surgical failures in some cases of myectomies of the DAO, and perhaps to a greater extent when resecting the DLI, where continuity was more common.

For myectomies, the authors suggest that high-resolution ultrasonography be performed by the surgeon perioperatively. This would enable defining the location of the lateral DAO border and facial artery to uncover cases with muscle fiber overlapping over the artery and assess muscle fiber continuity with the surrounding muscles. In cases with sonographically confirmed muscle fiber overlap, care should be taken to include the entire width of the muscle in the resection, including the fibers lying above and lateral to the artery. The artery can also be used as a reliable intraoperative landmark for increased surgical precision after determining the exact distance between the lateral DAO border and the facial artery. Clinically, the degree of continuity could be used to tailor the treatment plan. Examples of lateral DAO muscle fibers overlapping the facial artery can be seen in Figure 1 and in the ultrasound image of a living person in Figure 6. Figure 5 shows sonographic examples of muscle fiber continuity.

Another important implication of the finding of proximity between the DAO muscle and facial artery is the risk of vessel injections during botulinum toxin treatment for DAO.



**Figure 6** Example of an ultrasound image where the lateral DAO muscle fibers can be seen covering the facial artery in a living person. This overlap might lead to inadequate resections and residual lateral muscle fibers and could thus be an explanation for the common surgical failures. The facial artery is visible with red/blue Doppler flow in the right part of the image. The DAO is hypoechoic (darker) and surrounded by hyperechoic (brighter) connective tissue, and the white crosses mark the medial and lateral DAO borders. The mandible can be seen as a sloping hyperechoic white line in the middle of the image.

In a previous study using an anatomical model, the authors compared the injection accuracy of landmark-guided and ultrasound-guided injections in the face for treating facial synkinesis and gustatory hyperlacrimation.<sup>18</sup> The study showed that when the DAO muscle was injected without ultrasound guidance, 23% of the injections accidentally stained the facial artery. This finding could be explained by the generally low injection accuracy when ultrasound was not used. Interestingly, 15% of these injections completely missed the DAO muscle, and in most injections, the majority of the injectate was found outside the muscle in the surrounding tissue. The current study showed that the facial artery can lie within the field of injection underneath the DAO muscle body by up to 4 mm, further highlighting the reasons for the risk of vessel injections. Botulinum toxin injections into the DAO muscle can be difficult to perform and are associated with side effects; however, efforts to improve the treatment are ongoing.<sup>1,27-30</sup> The findings of the current study further emphasize the potential benefits of using ultrasound for procedures and surgery in the area.

The authors believe the DAO muscle is perfectly suited for preoperative evaluation using ultrasound. It was simple to visualize sonographically, and the borders of the muscle were easy to see and correlate to the adjacent anatomy, such as the facial artery. However, the DLI muscle was generally more difficult to assess due to the thinner muscle body, a finding supported by previous studies.<sup>15</sup> In addition, the difficulties were further exacerbated by continuity with the surrounding muscles.

Two ultrasound probes were used for tissue examination during the initial phases of data collection (18 MHz and 22 MHz). After initial testing, superior image quality was observed with the 22 MHz probe which was chosen for this study. Although the 18 MHz probe could outline the muscle borders, the 22 MHz probe could also clearly identify the individual interconnecting muscle fibers between the lower lip depressors and surrounding muscles, such as the platysma muscle, which were not visible with the lower resolution probe.

## Limitations

Ultrasound assessment of muscles is easier to perform in living patients than in cadavers, as dynamic evaluation can be accomplished during muscle movement. This could allow for more accurate ultrasound assessments in living patients and, thus, an even better correlation between ultrasound and dissection findings than demonstrated in the current study. The same is true when evaluating blood vessels, such as the facial artery, as color Doppler imaging can be used to highlight blood flow in real time, which makes vessels easier to see. The ultrasound assessments in the current study were performed by a radiologist to provide a gold standard and demonstrate the achievable results. Future clinical studies should be performed, in which plastic surgeons perform ultrasound assessments. The study's limitations also include a demographically narrow cadaver donor pool consisting of older individuals, which may affect the generalizability of the results given age-related anatomical changes. Furthermore, the unknown medical history of donors could introduce unanticipated variables into assessments. Finally, although the study employed unembalmed cadavers, post-mortem changes might have influenced the measurements of the study.

## Conclusions

This anatomical study showed that preoperative assessment of the depressor anguli oris muscle using high-resolution ultrasound is accurate and can provide valuable anatomical information before myectomy. Two potential anatomical explanations for the common early myectomy failures were identified. First, the overlap of the lateral depressor anguli oris muscle fibers over the facial artery could lead to inadequate resection and residual lateral muscle fibers. Second, continuity between the lower lip depressor muscles and the surrounding muscles might lead to muscle function takeover despite adequate resections and make the borders of the muscles difficult to define during surgery. This study showed that both phenomena can be discovered preoperatively through a brief ultrasound examination. If revealed bedside by the surgeon, adjustment of the surgical plan could be performed to hopefully reduce the proportion of surgical failures.

## Ethical approval

The study was performed in accordance with local rules and regulations and was approved by the ethical institutional committee in Austria (EC-number: 1402/2020 and amendment).

## Financial disclosure statement

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## Declaration of Competing Interest

The authors declare that they have no financial conflicts of interest.

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