Ex vivo biomechanical stability of 5 cricoid-suture constructs for equine laryngoplasty*

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Abstract
Objective: To determine the biomechanical properties of 5 suture constructs in the equine cricoid under cyclic loading and load to failure testing.

Study design: Ex vivo study.

Samples: Seventy-five equine cadaver larynges.

Methods: Each larynx was implanted with 1 of 5 cricoid-suture constructs. The standard laryngoplasty, where a suture is passed once through the cricoid, including its caudal edge, was used in 2 constructs: 1 with 5 USP Ethibond (ES) and 1 with 2 mm Fibertape (FS). In the third construct, the 2 mm Fibertape was passed twice through the cricoid including its caudal edge (Double Loop—DL). Constructs 4 and 5 used 2 mm Fibertape in a U-shaped loop passed through the cricoid but excluding its caudal edge. One construct was supported with a metallic button (MB) on the caudo-ventral aspect of the cricoid while the other included only the U-shaped loop (U). Constructs were subjected to cyclic loading and to single cycle to failure. Reduction of the left-to-right arytenoid angle quotient (LRQ), suture migration, and load at failure were compared.

Results: LRQ reduction after cyclic loading was lower in MB and U than ES constructs. During cyclic loading, suture migration was reduced in MB, U, and DL compared to ES constructs. Mean load at failure was lower in FS and U than in ES constructs.

Conclusion: Loss of abduction after equine laryngoplasty may be reduced and pull-out forces increased by applying a MB construct in the cricoid cartilage. In vivo testing is required to verify these results.

1 | INTRODUCTION

Although prosthetic laryngoplasty¹ remains the treatment of choice for recurrent laryngeal neuropathy in horses, its success rate is highly variable with only a 45%-70% improvement in racing performance of Thoroughbreds.²–⁴ Loss of abduction during the first 6 weeks after surgery is suggested to be one of the main reasons for laryngoplasty failure.⁵–¹⁰ The cause of this abduction loss remains unclear, and seems multifactorial,¹¹ involving factors such as loosening of the suture construct due to the suture
slipping, or the suture cutting through tissues associated with the arytenoid and cricoid cartilages.\textsuperscript{5,12-14} Most equine laryngeal biomechanical research has focused on suture retention on the muscular process of the arytenoid cartilage.\textsuperscript{10,15-19} Dahlberg et al reported considerable variability in the shape of the caudal border of the cricoid cartilage based on helical CT scans of 15 Thoroughbred larynges,\textsuperscript{13} a factor that may influence suture retention at the cricoid cartilage.\textsuperscript{2,10,12,13,15,20,21} The most commonly cited laryngoplasty (referred to as “standard laryngoplasty”)\textsuperscript{1,2,22} requires placement of a single 5 USP Ethibond suture through the cricoid cartilage, rostral to the palpable notch between the 2 lateral prominences of the cartilage, prior to wrapping it around the caudal edge. However, the suture can slip off the caudal edge of the cricoid, especially if the lateral prominences are not present.\textsuperscript{13} In addition, the suture can cut into the variably thick caudal cricoid cartilage. This suture slipping and cutting into the cartilage (hereafter called “suture migration”) loosens the construct and leads to loss of abduction of the arytenoid cartilage.\textsuperscript{10,11,13} Only 2 publications report the biomechanical properties of laryngoplasties tested in cyclic loading at the cricoid cartilage. The first study reported less distraction when 5 USP Ethibond suture was used for standard laryngoplasty compared to 2 USP Ethilon and 5 USP Fiberwire constructs.\textsuperscript{23} In the second study,\textsuperscript{11} an alternative technique relying on a metallic anchor resulted in less distraction than the standard laryngoplasty with 5 USP Ethibond.

The aims of this study were to determine the biomechanical stability of 4 alternative cricoid-suture constructs compared to the standard laryngoplasty described above. We hypothesized that these alternative constructs would reduce suture migration and sustain higher load at failure than the standard laryngoplasty in an ex vivo equine model.

2 | MATERIALS AND METHODS

2.1 | Specimen preparation and surgical implantation

Seventy-five grossly normal larynges of horses aged between 2 and 18 years were collected at an abattoir. Larynges with gross atrophy of the left dorsal cricoarytenoid muscle were excluded. The larynges were labeled, vacuum-sealed, and frozen at $-20^\circ\text{C}$ and randomly assigned to 1 of 5 cricoid-suture construct groups. Within 3 months of harvesting, batches of 5 larynges were thawed overnight at room temperature ($19-21^\circ\text{C}$). Using careful sharp dissection, all of the hyoid bones, trachea, and extrinsic laryngeal muscles on the left side including the lateral cricoarytenoid muscle were removed, leaving the caudal third of the dorsal cricoarytenoid muscle intact.\textsuperscript{11,16,24} The intrinsic muscle attachments on the arytenoid cartilage were cut, and these muscles were removed. The palpable presence or absence of a notch along the left caudal aspect of the cricoid cartilage (from midline to the most lateral aspect of the cricoid cartilage) was recorded. Larynges were kept moist by covering them with gauze soaked in saline (0.9% NaCl) solution and testing commenced within 5 hours after thawing.

Left-sided prosthetic laryngoplasty was performed using 5 different cricoid-suture constructs by the same experienced surgeon (FR). The control group consisted of a standard laryngoplasty (ES), where a 5 USP braided polyester suture coated with polybutylate (Ethibond, EXCEL, 7.0 metric, V-40, Ethicon, Issy les Moulineaux, France) was passed through the cricoid cartilage, 2 cm cranial to the caudal edge and 1 cm lateral to the dorsal ridge, using a taper point needle (Mayo Cattgut 1/2 circle Taper PT 1824-3D, Anchor Products Company, Addison, Illinois). Such placement resulted in the suture resting in the palpable notch on the caudal edge of the cricoid cartilage, when present (Figure 1). If the notch was not palpable, the tensioned suture was positioned at the shortest distance from the needle insertion to the caudal edge of the cricoid cartilage. A 2 mm Fibertape (Ref AR-7237, Arthrex, Karlsfeld, Germany) was used for the 4 other constructs. In the Fibertape standard construct (FS), suture placement and needle selection were identical to those of the ES construct. In the double loop construct (DL), the suture was passed twice through the cricoid cartilage with a taper point needle, 2 cm cranial to its caudal edge. After the first pass, placed 15 mm lateral to the dorsal ridge, the suture was wrapped around the caudal aspect of the cricoid cartilage prior to placing a second pass, 5 mm lateral to the dorsal ridge. This technique resulted in a suture loop engaging the caudal edge of the cricoid cartilage (Figure 1). In the U-shaped loop construct (U), the cricoid cartilage was passed through twice with the Scorpion device (Scorpion Multifire, “Humpback” Ref AR-13995, Arthrex, Germany), with the first pass placed 5 mm lateral to the midline and the second pass placed 15 mm lateral to the midline.\textsuperscript{25} For each pass, a different end of the suture was grabbed, in order to obtain a U-shaped loop passing ventrally on the cricoid cartilage. This suture conformation bypassed the caudal edge of the cricoid cartilage (Figure 1). In the metallic suture button construct (MB), the suture was passed through the cricoid cartilage as in the U construct but a metallic suture button (Metallic Suture Button Dog Bone, Ref AR-2270, Arthrex, Germany) was set in the loop passing ventrally on the cricoid cartilage (Figure 1). Inadvertent penetration of the laryngeal mucosa at the cricoid was visually controlled in all constructs.

Sutures were placed in the muscular process of the arytenoid cartilage in an identical fashion for all 5 constructs. A 13G 17 cm Jamshidi needle\textsuperscript{16,26} (PBN medicals, Stenløse, Denmark) was inserted perpendicular to the arcuate crest (“spine” of the muscular process), 10 mm cranially and 10 mm ventrally to the insertion of the CAD tendon. A 1.5 mm crochet-style hook\textsuperscript{21} was passed through the hole created by the needle and the dorsal (leading) thread of the
suture was grabbed and passed through the hole in a medial to lateral direction.

On the cricoid cartilage, the following measurements were taken of the suture insertion sites after implantation and before tying: the lateral distance to the dorsal ridge and the rostral distance to the caudal edge of the cricoid cartilage. On the muscular process, the rostral distance to the insertion of the CAD muscle on the muscular process and depth through the muscular process were measured after implantation and before tying. In the case of 2 passes through the cricoid cartilage (DL, U, MB), the average of the lateral distance between the 2 bites from the dorsal ridge and the rostral distance to the caudal edge of the cricoid cartilage was noted.

2.2 | Biomechanical testing

The larynges were fixed on a customized stand with a digital camera set up 30 cm above. Two holes were drilled through the cricoid cartilage using a 5 mm drill bit, one 4 cm lateral to the midline and one 1 cm lateral to the midline on the right side, with both holes 2 cm cranial to the caudal edge of the cricoid cartilage (Figure 2A,B). A 4 mm diameter “S” shaped metal hook 5 cm in length (S-shaped hook, Mottez SAS, Erquinghem-Lys, France) was inserted in each hole (Figure 2C). After this instrumentation, the laryngoplasty constructs were tied using 1 single throw, which was tightened progressively until no further abduction of the arytenoid cartilage could be obtained (maximal abduction, $F_{\text{max}}$). In the ES and FS constructs without a palpable lateral notch, the tail end of the suture that was wrapped around the caudal edge of the cricoid cartilage tended to slide rostro-ventrally as the suture was tightened. The first throw was secured with a small needle-holder with tungsten carbide tips prior to tightening a second single throw. The knot was completed by placing 2 additional square knots. After tying the sutures, the level of adduction of left arytenoid reached a maximum grade. In all larynges, an ES technique was performed on the right side in order to obtain the same maximal abduction grade in the right arytenoid and standardize this angle. In all constructs, the dorso-medial suture thread was hooked by an “S” shaped hook, pulled cranially until it reached the muscular process (Figure 2C). The rima glottis was photographed before cyclic loading. The constructs were then subjected to cyclic loading tests, using the same technique and equipment recently described by our group.16 Briefly, the larynges were removed from the customized stand and mounted vertically into the mechanical testing machine (Bâti manuel avec règle numérique, BAT 750 R, Andilog, Vitrolles, France). The 2 cricoid cartilage hooks were connected to the S-typed load cell (Capteur de force type S 50 kg RB Phi 120, Robotshop Inc, Gonesse, France) and the 2 arytenoid hooks were connected to the 1 Hz oscillator. The S-typed load cell recorded the tension of the suture on the cricoid cartilage. It was connected to a computer and calibrated using a currently published technique.16,27 Calibration was confirmed using a 10 and 50 N weight at the beginning of each testing day. An S-shaped hook was added to the lateral cricoid cartilage hook to adjust the position of the larynx and maintain the prosthesis in a vertical position (Figure 2D-F). Using a customized software (Python Software Foundation, Beaverton, Oregon), distraction was applied on the construct during 3000 cycles (50 minutes), maintaining the oscillating load between 5 and 50 N over time at 100 Hz. With advanced suture migration, the construct loosened and the distraction (mm) required to maintain the 50 N tension was recorded using a digital height ruler. This distance represented the combined rostroventral slipping and cutting of the suture in the cricoid cartilage and was termed the suture migration distance in this study. Larynges were kept moist during cyclic testing by regular spraying with saline (0.9% NaCl) solution. After cyclic testing, the larynges were dismounted from the testing machine and, in constructs ES, FS, and DL, the cutting of the suture into the caudal edge of the cricoid cartilage was manually measured with a ruler. The larynges were then mounted on the stand to obtain a photograph of the rima glottis. The left and right
arytenoid angles on each picture of the rima glottis, taken before and after cyclic loading, were calculated by the same, blinded assessor using ImageJ, (Version 1.46r, Wayne Rasband, National Institutes of Health, Bethesda, Maryland) and the technique described by Herholz and Straub and Jansson et al. Briefly, a line was drawn from the most ventral aspect of the vocal fold fornix to the junction of both corniculate processes of the arytenoid cartilages and measured. The line was then extended dorsally by one-third of its original length and the angle between the tip of this line and the most dorso-lateral aspects of the corniculate process was measured bilaterally (Figure 3). The left angle was divided by the right angle to obtain the arytenoid left-to-right angle quotient (LRQ) for each larynx before and after cyclic loading. The Dixson abduction grade of all larynges before and after cyclic loading was determined by a blinded observer. Mean arytenoid angles were calculated for each Dixson abduction grade. The mean LRQ reduction in all cases with a Dixon abduction grade loss of 0, 1, or 2 was calculated.

After cyclic loading, the constructs were loaded to failure at a rate of 1 mm/s, as recently described by our group. Failure was defined as the first drop in the force/time curve. This drop could be due to partial or complete cartilage failure, or to breakage of the suture or knot. The load (N) at failure was measured, and the mode of failure was recorded for each larynx.

2.3 | Statistical analysis

Three main parameters (dependent variables) were measured during the biomechanical tests: the LRQ reduction after cyclic loading (LRQ before–LRQ after), the suture migration distance during cyclic loading, and load (N) at failure. The means and 95% CIs of these 3 parameters were calculated,
and the data were tested for normality using a 2-sample Kolmogorov-Smirnov test. An ordinary least-squares regression analysis was performed for each of the 3 dependent variables, including multiple control variables (such as age, size [height of the withers], sex, lateral distance of the suture to the dorsal ridge of the cricoid cartilage, rostral distance to the caudal edge of the cricoid cartilage, rostral distance to the insertion of the CAD muscle on the muscular process, depth through the muscular process, length of the cricoid cartilage, suture, and needle type) using the ES construct as a baseline. A Welch Two Sample t-test was performed with each construct to compare the loss of abduction and suture migration of cricoid cartilages with or without a palpable notch. Statistical significance was set at $P < .05$. All statistical analyses were performed with the R software package (Version 0.97.551; Rstudio Inc, Boston, Massachusetts) and Stata (Version 11; StataCorp LP, College Station, Texas).

3 | RESULTS

3.1 | Population

Data were available for 15 larynges per construct, resulting in 75 datasets. The mean age of horses was 10 years ($\pm 3.5$ years), ranging from 3 to 18 years. There were 56 females and 19 males. Thirty-eight larynges (51%) had a palpable notch between 2 prominences from midline to the lateral aspect of the cricoid cartilage on the left side. The data for LRQ reduction and load at failure were normally distributed. Suture migration distances were logarithmically transformed (base 10) prior to analysis.

3.2 | Loss of abduction

LRQ reduction was lower in MB and U constructs than with ES ($P = .003$ and $P = .002$, respectively, Table 1). No significant difference was apparent when FS and DL were compared to ES ($P = .12$ and $P = .8$, respectively). Overall model fit was good (Adjusted $R^2 = .61$). The mean (SD) angles for each Dixon abduction grade were as follows; $47.5^\circ (\pm 3.8^\circ)$ for grade 1; $41.4^\circ (\pm 4^\circ)$ for grade 2; $35.3^\circ (\pm 3.2^\circ)$ for grade 3; $28.5^\circ (\pm 3.8^\circ)$ for grade 4; and $23.1^\circ (\pm 2.6^\circ)$ for grade 5. Mean (SD) of LRQ reduction after cyclic loading for all constructs with a loss of 0 Dixon abduction grade was 0.07 ($\pm 0.07$), for constructs with a loss of 1 Dixon abduction grade was 0.13 ($\pm 0.07$) and for constructs with a loss of 2 Dixon abduction grades it was 0.23 ($\pm 0.14$).

3.3 | Suture migration

All constructs completed the cyclic loading test without evidence of failure. All mean suture migration distances for the DL, U, and MB constructs were lower than in control construct ES ($P = .035$, $P < .001$, and $P < .001$, respectively). The suture migration distance in FS did not differ statistically from that of ES ($P = .15$). Overall model fit was good (Adjusted $R^2 = .51$). During cyclic loading, the suture cut into the caudal edge of the cricoid cartilage by $1.8 \pm 0.45$ mm in ES, FS, and DL. Ventral slippage of the lateral thread was noted with the ES and FS constructs but only in cases where the suture was not blocked by the notch. In the ES and FS constructs, the difference in suture migration distance between cricoid cartilages with or without a notch was
greater if the notch was absent \((P = .004\) and \(P = .038\), respectively). This effect was not observed in the DL, U, and MB constructs \((P = .96, P = .18, P = .98)\).

### 3.4 | Load at failure

The load at failure was reduced in FS and U compared to ES \((P < .001, P = .003\), respectively). There was no significant difference between DL and MB, when compared to ES \((P = .3, P = .26\), respectively). Overall model fit was good \((\text{Adjusted } R^2 = .57)\). Three out of 15 sutures in ES broke, each time far away from the knot, and at about 300 N \((296, 300,\) and \(305\) N). The mode of failure differed between constructs. In the ES and FS constructs, the cricoid cartilage started to bend around \(200\) N and the suture was torn out in a caudal direction, when the edge of the cricoid cartilage had bent to a horizontal plane. In the FS and DL constructs, a thinning of the suture was observed with increasing force. In the DL construct, the piece of cartilage embedded in the loop broke out as a whole piece of cartilage in all constructs. In the U construct, 7 out of 15 constructs failed because a piece of cartilage had broken loose. In the remaining 8 specimens, the suture cut through the cartilage between the holes and was torn out, as soon as the 2 cuts joined each other. In the MB construct, the button was torn through the cartilage by rupturing a hole in the cricoid cartilage (Figure 4). The suture did not cut through the cricoid cartilage in a rostral direction in any of the constructs.

### 3.5 | Implantation variability

None of the constructs at the cricoid penetrated the laryngeal mucosa. The mean distance from the suture lateral to the dorsal ridge was \(8.3 \pm 2.8\) mm and the mean distance rostral to the caudal edge was \(12.7 \pm 2.7\) mm.

### 4 | DISCUSSION

Suture migration and LRQ reduction did not differ between ES and FS constructs under cyclic loading. In a similar

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**TABLE 1** Means and 95% CI of reduction of left to right arytenoid angle quotients (LRQ) after cyclic loading of different cricoid-suture constructs, suture migration distance after cyclic loading, and load to failure for the 5 constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>LRQ reduction</th>
<th>Suture migration distance (mm)</th>
<th>Ultimate failure load (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs. Mean 95% CI</td>
<td>Obs. Mean 95% CI</td>
<td>Obs. Mean 95% CI</td>
</tr>
<tr>
<td>ES</td>
<td>14 0.15 0.04</td>
<td>15 4.5 0.9</td>
<td>15 278 25.9</td>
</tr>
<tr>
<td>FS</td>
<td>12 0.13 0.05</td>
<td>15 3.5 1.0</td>
<td>15 220* 29</td>
</tr>
<tr>
<td>DL</td>
<td>15 0.17 0.04</td>
<td>15 2.7* 0.4</td>
<td>15 283 23.6</td>
</tr>
<tr>
<td>U</td>
<td>14 0.07* 0.05</td>
<td>15 1.7* 0.3</td>
<td>15 248* 28.7</td>
</tr>
<tr>
<td>MB</td>
<td>14 0.04* 0.05</td>
<td>15 1.1* 0.5</td>
<td>15 342* 21.8</td>
</tr>
</tbody>
</table>

Abbreviations: DL, double loop construct; ES, standard technique with 5 USP Ethibond suture; FS, standard technique with 2 mm Fibertape; MB, U-shaped loop construct not wrapped around the caudal edge of the cricoid cartilage with a metallic button placed ventrally on the cricoid cartilage; U, U-shaped loop construct not wrapped around the caudal edge of the cricoid cartilage. *Denotes differences from the standard technique ES \((P < .05)\).

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**FIGURE 4** Representative photographs of different modes of failure during load to failure testing for each type of cricoid-suture construct. Arrows indicate the site of rupture. ES and FS: caudal fissuring of the suture through the cricoid cartilage. DL: piece broken out of the cricoid cartilage by the loop. U: connection of the 2 holes in the cricoid cartilage. MB: hole ruptured in the cricoid cartilage.
study, less suture migration was detected during cyclic loading, when 5 Ethibond rather than 2 Ethilon and 5 Fiberwire sutures were placed in standard laryngoplasties. The authors attributed the improved holding strength of the 5 Ethibond suture to its larger diameter. Two millimeter Fiber-tape is a broad suture and this might explain the comparable results obtained with these 2 sutures during cyclic loading in the present study. Conversely, we measured lower loads at failure when constructs used 2 mm Fibertape rather than 5 USP Ethibond suture. During this testing, the Fibertape laid initially flat against the cartilage, but folded onto itself with increasing tension, resulting in a thinner diameter. Load to failure testing has traditionally been used in biomechanical studies of suture-cartilage interaction in equine laryngoplasty. However, this mode of testing may not accurately reflect the cyclic stresses physiologically placed on the suture, thereby limiting its clinical relevance.

Based on the results of our cyclic loading tests, 2 mm Fibertape may be a comparable alternative to 5 USP Ethibond suture material for cricoid-suture constructs in equine laryngoplasty.

Placing a double loop on the cricoid cartilage reduced rostroventral slipping and suture migration during cyclic loading compared to the standard laryngoplasty in our study. Some suture still cut into the cartilage, which may explain the greater suture migration noted in DL compared to U and MB constructs. The double loop technique in equine laryngoplasty was first described to involve the muscular process of the arytenoid cartilage. In this study, the authors implanted a Lycra-Mersilene (0 USP) prosthesis using either the double loop or standard technique on isolated arytenoid cartilages and measured the load to failure. The double loop increased the load at failure, an effect attributed by the authors to improved distribution of suture tension through the cartilage. In our study, we were unable to detect a difference in load at failure between the double loop with 2 mm Fibertape and the standard technique with 5 USP Ethibond. The discrepancy between studies may be due to differences in suture material. Placement of a double loop of 2 mm Fibertape on the arytenoid cartilage has recently been compared in cyclic loading to the standard laryngoplasty and a screw fixation technique. Use of a double loop resulted in the greatest distraction, which was attributed to the potential slack remaining in the loop of the DL construct. This slack is also present in the DL construct at the cricoid cartilage in this study, where the suture passes twice around the caudal edge of the cricoid. When exposed to repeated force (swallowing, coughing) the slack in the loop may tighten and loosen the construct and this may explain the higher suture migration of DL compared to the U and MB constructs in our study. The double loop construct with 2 mm Fibertape combines slack in the suture loops and cutting of the 2 loops into the cartilage as 2 main risk factors for suture migration on the cricoid cartilage.

Both cricoid-suture constructs that were not wrapped around the caudal edge of the cricoid cartilage (U, MB) sustained less suture migration and loss of abduction than the standard laryngoplasty (ES). In a study using the Alternate Laryngoplasty System (ALPS), a metallic anchor (screw) in the cricoid cartilage decreased suture migration compared to the standard technique with 5 USP Ethibond. The authors concluded that the caudal edge of the cricoid cartilage should not be included in the laryngoplasty construct. The U and MB constructs in the present study did not include the caudal edge of the cricoid cartilage and resulted in comparable suture migration distances to the ALPS construct, thereby confirming their conclusion. The reduced suture migration obtained with the ALPS was attributed to the ability of this fixation to palliate the variability in the shape of the cricoid cartilage and the thinning of the cartilage caudally. This concept also applies to our U and MB constructs and the impact of the anatomical variability and thickness of the caudal edge of the cricoid cartilage on the suture construct could be minimized by excluding this region from the prosthesis.

Use of a suture button improved stability over U constructs, especially when tested to failure. The use of a cricoid-suture construct with a metallic button on the cricoid cartilage has been described in an ex vivo load to failure testing of 80 isolated Warmblood cricoid cartilages. Two cricoid-suture constructs were compared, identical to our U and MB constructs, using a 3 USP Mersilene suture. Loads at failure were increased in constructs using a metallic suture button compared to U constructs without a suture button. The authors postulated that the addition of a metallic suture button eliminated the risk of the suture cutting through the cartilage and increased the surface area for dissipation of force on the cartilage. This concept was confirmed in our study, where higher forces were required to tear out the complete MB construct compared to the U construct. Suture cut through tissues between the 2 holes of the U construct during failure testing, as postulated by Robertz et al. This tearing occurred in 8/15 constructs at low loads and decreased load to failure compared to ES. In the present study, the 2 holes in the U constructs were 10 mm apart. Further testing is required to evaluate whether a larger distance between holes would improve stability. Adding a metallic suture button increases the amount of foreign material and associated risk of infection and foreign body reaction. The U construct might be an alternative if the surgeon chooses not to apply a metallic suture button on the ventral aspect of the cricoid cartilage.

The models tested in the present study were slightly modified with the inclusion of angle measurements and Dixon abduction grading of pictures of the rima glottis taken.
before and after cyclic loading. This step illustrated the loss of abduction and improved the visual interpretation of the results of cyclic loading. The LRQ reduction before and after cyclic loading in ES, FS, and DL corresponded to the loss of 1 Dixon abduction grade. In comparison, LRQ reduction in U and MB constructs corresponded to the loss of 0 Dixon abduction grade. However, LRQ reduction in this ex vivo study was measured on isolated larynges and with an initially hyper-abducted left arytenoid. This condition differs from clinical cases undergoing laryngoplasty, where the left arytenoid is preferably opened to Dixon abduction grade 2 or 3. \(^5,22\) LRQ measurements should be measured in in vivo cases to draw more precise clinical conclusions.

The most stable construct in our ex vivo study was a U-shaped construct including a ventral metallic button at the cricoid cartilage. Placing a metallic button on the ventral aspect of the cricoid cartilage, makes this construct completely independent of the shape of the caudal edge of the cricoid cartilage. This construct offers 3 advantages over the standard technique: the construct can be consistently placed at a planned distance from the sagittal ridge of the cricoid cartilage, through a thicker portion of cricoid cartilage, and result in a constant angle of tension in relation to the muscular process. Further in vivo testing is required to assess the safety and efficacy of this construct during equine laryngoplasty.

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