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Anatomy

Comparison Between Intralingual Suture Patterns for Prevention of Self-Suckling and Inter-Sucking in Dairy Cattle

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ABSTRACT

The current research aimed to describe seven less-invasive techniques for the prevention of self-suckling and inter-suckling, to estimate the topographical sagittally and horizontally induced dorso-lingual convexities after surgery, as well as to investigate the adverse effect of the undesirable sagittally induced dorso-lingual convexity on the prehension and licking. Four tongue specimens of apparently healthy adult slaughtered cows were collected from the local slaughterhouse in Beni-Suef province and freshly dissected for clarification of their lingual musculature. Grossly, the cow's tongue was reinforced by a complex myo-architecture of extrinsic and intrinsic muscles; the former included styloglossus, genioglossus and hyoglossus. Together with those of the intrinsic muscles, the fibers of the styloglossus muscle formed the rostral free part of the tongue (about 10-11 cm). The operated cows were classified into seven groups (n= 10 cows for each), and the recently-invented rectangular intralingual suture pattern was applied to group (A), affecting mainly the styloglossus muscle to prevent the formation of the tube-shaped tongue during self-suckling, and six modifications were applied to the other groups. After surgery, the dorso-lingual surfaces were casted, and the heights of the rostral and posterior, sagittal and horizontal convexities of these casts were measured and analyzed statistically. In the current study, we attempted to develop some grades for assessment of the prehension and licking abnormalities. Statistically, the seven groups had no significant differences in prehension normality. These patterns are advised to be used for prevention of self-suckling due to their high success rates and minimal adverse effects on normal prehension.

Keywords: Cows, Dairy, Self-Suckling, Styloglossus muscle, Tongue.

INTRODUCTION

The bovine depends mainly on the tongue for prehension of the food (Iwasaki, 2002; Konig and Liebich, 2009; Dyce et al., 2010; Nazih, 2019). However, this prehension ability of the tongue is used in self-suckling, inter-sucking and cross-sucking as behaviour disorders. Many factors may be implicated as causes of these disorders, including genetic factors (Fuerst-Waltl et al., 2010; Grobbacher et al., 2018), age (Abdel-Hamid et al., 2017), management and housing methods (Keil et al., 2000; Keil et al., 2001; Keil and Langhans, 2001; Jensen, 2003; Lidfors and Isberg, 2003; Nielsen et al., 2008; Pempek et al., 2013; Grobbacher et al., 2018; Serrapica et al., 2019). These behavioural disorders predispose to significant economic losses due to the high possibility of mastitis with subsequent reduction in milk production, the high cost of treating udder and teat infection, the high mortality in calves born with no colostrum, the cost of conservative and surgical treatments of self-suckling, hair-loss or skin infections, and culling of affected animals when treatment fails to correct the problem (Keil et al., 2000; Keil et al., 2001; Bademkiran et al., 2006; Bademkiran et al., 2007; Lidfors, 2007; Pempek et al., 2013; Abdel-Hamid et al., 2017; Kushwaha and Mohan, 2019).

Prevention of self-suckling passes through many stages, starting with conservative preventive methods that have many complications and variable success rates (Allmacher, 1998; Abou-El-Ella, 1999; Bademkiran et al., 2007). Later on, an invasive surgical lateral glossectomy technique was established with a very high success rate as it mechanically interferes with the animal's ability to curl the tongue into a complete tube shape (Tadmor and Ayalon, 1972; Berthet et al., 1981; Ducharme, 2017). The latter method is remodeled and gradually replaced by a less-invasive ventral glossectomy technique (McCormack, 1976; Silva et al., 2000; Bademkiran et al., 2006; Yong et al., 2008; Ducharme, 2017).

As researchers around the world work to improve these preventive techniques to prevent self-suckling with fewer complications and side effects (McCormack, 1976; Silva et al., 2000; El-Sherif, 2018; Seddek et al., 2019), new less-invasive techniques were developed, either via applying interrupted inverting silk stitches on the ventral aspect of the free lingual portion (El-Sherif, 2018) or by induction of convexity of the dorsal lingual surface via insertion of a rectangular intralingual silk stitch through small stabs at the dorsal lingual surface (Seddek et al., 2019). However, this technique may cause an undesirable sagittal lingual convexity that interferes with normal prehension.

The current clinical study had three main aims, including fully describing the seven less-invasive surgical methods for preventing self-sucking in dairy cows based on the morphological description of the lingual musculature, determination of the topographical changes of the dorsal surface of the tongue following application of these techniques, and investigation of the adverse effect of the sagittal convexity on prehension.

MATERIALS AND METHODS

Anatomical study

Four tongue specimens of apparently healthy adult cows (3–4 years old) were collected from the local slaughterhouse in Beni-Suef province. These specimens were cleansed using tap water and freshly dissected for clarification of their lingual musculature and related major blood vessels and nerves; dorsal and lateral aspects (Figure 1), ventrolateral aspect (Figure 2), and ventral aspect (Figure 3).

Clinical study

The subjects of the study were 70 dairy cows that had self-suckling and inter-sucking behavior, and they were classified blindly into seven groups (n = 10 cows for each). Prior to surgery, the seven techniques were thoroughly explained to the owners, who were then free to the technique of treatment. After the owners' agreement, the affected cows were sedated with a reduced dose of xylazine HCl 2% (0.1 mg/kg body weight) and prepared for surgery in either a standing or recumbent position according to their weights and pregnancy status. The tongue was prepared for aseptic surgery, and then a tourniquet was applied to the root of the tongue, and finally, local infiltration analgesia was induced by using 10 ml of lidocaine HCl 2%.

Group (A): This group was operated by the recently-invented intralingual suture pattern (Seddek et al., 2019) in the form of a rectangular intralingual silk stitch that was applied through four stabs on the dorsal aspect of the tongue. Each stap extended 1 cm medial to the lateral border of the tongue, where there were no major blood vessels or nerves. The two rostral stabs were made about 4 cm caudal to the lingual tip, and the two posterior stabs were made at the level of the lingual frenulum, about 10-11 cm caudal to the lingual tip. A sterile silk No. 2 was threaded onto a long round needle and inserted from the right-posterior stab and then it advanced ventrally towards the left-posterior one, passing through the ventral border of the styloglossus muscle about 1 cm from the ventral aspect of the tongue to avoid the lingual artery, branches of the hypoglossal and the lingual branch of the mandibular nerves without penetration of the ventral lingual mucosa. The needle was exited from the left-posterior stab to be re-introduced through it towards the left-rostral stab, parallel to the long axis of the tongue and deeper into the dorsal lingual mucosa between the superficial intrinsic lingual musculature where there were neither major blood vessels nor nerves. When the needle exited the left-rostral stab, it was re-inserted into the same stab and directed to the right-rostral one perpendicular to the long axis of the tongue, passing through the ventral border of the styloglossus muscle. After the needle exited, it was re-introduced into the right-rostral stab and directed towards the right-posterior one, and then the two ends of the silk were pulled to induce the desirable dorsal lingual convexity, and then it was knotted.

Group (B): The same technique used in group (A) was applied to this group with slight modification, as about 4 cm was left from the tip of the tongue and the rest of the free lingual length (about 6 cm) was divided into three equal thirds, the caudal one being extended caudally till the level of the lingual frenulum. The intralingual silk stitch technique was applied to the rostral (Figure 4A) and the posterior thirds of this lingual length, so that the two applied rectangular stitches had widths greater than their lengths.

Group (C): This group was operated by the intralingual eight-figure stitch via four stab incisions on the dorsal lingual surface, and the needle passed from the right-posterior stab to the left-rostral one, ventral to the tongue, then from the left-rostral stab to the left-posterior one dorsal to the tongue, then from the left-posterior to the right-rostral one ventral to the tongue, and finally from the right-rostral to the right-posterior one dorsal to the tongue. So, it gave an eight-figure appearance, and the two horizontal arms of the intralingual rectangular stitch crossed each other under the tongue.

Group (D): These cows were operated by the same technique that was used for group (C), but two shorter eight-figure stitches were buried rostrally (Figures 4B & 4C) and posteriorly (Figure 5) at locations similar to group (B).

Group (E): The same technique was used as in group (B), but the anterior intralingual stitch was replaced by a purse-string silk stitch buried at the ventral aspect of the anterior third of the tongue until it reached the styloglossus muscle, about 4 cm caudal to the lingual tip. This technique aimed to tighten both the styloglossus muscles, resulting in a narrowing of the ventral aspect of the free part of the tongue. The Stab incisions were rowed in a circle-manner on the anterior third of the ventral lingual surface, and the needle was inserted through one stab and advanced deep about 1 cm within the styloglossus muscle to avoid the lingual artery, branches of the hypoglossal and lingual branch of the mandibular nerves, and then it was exited from the next stab incision to be re-inserted into it to exit through the next stab incision. When a complete circle of the purse-string was finished, the two free silk ends were pulled and tied, inducing retraction of the ventral lingual surface.

Group (F): These cows were operated by a rostral ventral purse-string stitch as in group (E), and a short eight-figure stitch was applied to the posterior third of the tongue as in group (D).

Group (G): These cows were operated by one rostroventral intralingual purse-string silk stitch as in groups (E and F) and another posterior intralingual purse-string silk stitch on the posterior half of the ventral lingual surface (Figure 6). Both of the purse-string stitches were buried on the ventral lingual surface through small stabs.

After application of these techniques in the seven groups, the stab incisions were sutured in a cruciate mattress pattern using polyglactin 910 No. 0. The tongue was rendered analgesic and slightly flaccid under the effect of local infiltration analgesia, and then its tip was grasped gently and two aluminium foil pieces, lined with clay, were wrapped around the tongue to take a print of its dorsal aspect. The two aluminium casts were filled with gyps to form casts of the tongue, and then one of them was cut sagittally, and a 6-cm straight line was used to measure the rostral and posterior sagittal convexities, respectively. These straight lines connected two points on the dorsal surface of the cast by centering the sagittal dorso-lingual convexity's summit on the straight radius as much as possible, and then the height of the sagittal lingual convexity was measured by a caliper. The second cast was cut in transverse sections at the summits of the rostral and posterior horizontal convexities, and a 4 cm straight line was used as a radius to assess the height of the horizontal lingual convexities in the same manner as the first cast. The collected data were analyzed statistically using IBM SPSS statistics.

After-care involved intramuscular injection of meloxicam 0.5 mg/kg body weight for two conjunctive days, one intramuscular dose of oxytetracycline (200 mg/ ml) 1 ml/10 kg body weight, and the owners were asked to flush the oral cavity with diluted povidone iodine mouthwash three times per day for three days.

Three days post-surgery, in the light of the absence of any surgical complications after clinical examination, prehension abnormalities were assessed by putting the food at a level higher than the animal's head, while licking abnormalities were assessed by moistening the muzzle and nostril with molasses. In the current study, we attempted to develop some grades of prehension and licking abnormalities to be scored as follows: Grade I: difficult prehension and muzzle licking (score 1); Grade IIa: normal prehension with difficult muzzle licking (score 2); Grade IIb: difficult prehension with normal muzzle licking (score 2); Grade III: normal prehension and licking of the muzzle with slight curving of the lingual tip (score 3); Grade IV: normal prehension and licking of the muzzle without curving of the lingual tip (score 4)

For six months, the operated cows were followed up on via phone calls or visits to nearby cases for the presence of any short- or long-term complications of these techniques.

RESULTS

Anatomical findings

The tongue of the cow had an apex, body and root. The lingual apex is characterized by a pointed tip, while the body had a dorsal large prominence, the lingual torus, which was defined rostrally by a traverse lingual fossa (Figure 1A). The lingual body was anchored to the floor of the oral cavity by a fold of mucous membrane, the lingual frenulum, which was found about 10–11 cm caudal to the lingual tip (Figure 1B).

Furthermore, the tongue was supported by two groups of muscles: intrinsic and extrinsic. The former group constituted the dorsolateral part of the lingual musculature (Figure 2/im). The extrinsic group included three muscles, the styloglossus, genioglossus and hyoglossus, which formed the ventral part of the lingual musculature, and their fibers fused dorsally with the intrinsic muscles.

1- Styloglossus muscle

The styloglossus muscle had two parts; major and minor. The latter was a short flat muscle that originated from the lateral aspect of the stylohyoid process of the hyoid bone. It was covered partially by the origin of the major styloglossus muscle, and it was directed dorsally to be terminated at the root of the tongue (Figure 2/msg). The major styloglossus muscle was the longest extrinsic lingual muscle which originated by a flat tendon from the ventrolateral aspect of the stylohyoid process of the hyoid bone. The fibers of this muscle ran in a sagittal manner parallel to the long axis of the tongue, and they were directed rostroventrally toward the ventral aspect of the lingual apex (Figure 2/sg). Both major styloglossus muscles fused about 2.5 cm rostral to the lingual frenulum and their fibers were fused with the intrinsic muscles, forming the musculature of the ventrolateral aspect of the lingual apex (Figure 3/sg). The major lingual blood vessels and nerves were located near the origin of this muscle (Figure 2). The terminal part of the lingual artery, the hypoglossal nerve, and the lingual branch of the mandibular nerve could be observed within the fibers of the styloglossus muscle about 2 cm from the ventral aspect of the tongue (Figure 3). Consequently, the ventral surgical stitches should be operated 1 cm from the ventral lingual mucosa.

2- Genioglossus muscle

It was the largest extrinsic lingual muscle that originated from the medial aspect of the mandible, just caudal to the mandibular symphysis. The fibers of this muscle were directed caudodorsally in a fan shape to be insinuated between the two major styloglossus muscles. The rostral part of this muscle was terminated in the lingual body and lingual torus (Figure 2/rgg), while the caudal one terminated in the lingual root (Figure 2/cgg).

3- Hyoglossus muscle

This muscle was found at the root of the tongue and originated from the lingual process, basihyoid, and thyrohyoid bones. The fibers of this muscle were directed rostrally and dorsally to be fused with the intrinsic muscles at the lingual torus and root of the tongue (Figure 2/hg).

Surgical findings

The obtained results revealed the absence of short- and long-term serious post-operative complications, and most animals started to eat directly after surgery. Moreover, there were no complaints of silk exposure or lingual abscess formation when lingual ulcerations occurred during foot and mouth disease (FMD) outbreaks in our localities.

The current techniques limited the ability of the operated cows to self-suck directly post-surgery, but these cows tried to self-suck for about three weeks after surgery, and this abnormal behavior changed gradually until it ceased.

Regarding the sagittal convexities in the different groups (Table: 1 and Charts: 1 & 2), group (B) had the highest undesirable rostral sagittal convexity followed by group (E), while group (D) showed less sagittal convexity followed by groups (E, F & G), which had the same suture pattern at that level and nearly the same convexities. It should be noted that groups (A & C) had no intralingual stitches at that rostral level and their recorded convexities corresponded to the normal sagittal convexity in this area. Posteriorly, group (A) had the highest undesirable sagittal convexity, followed by groups (E & B), which had the same rectangular suture pattern posteriorly as group (A). On the other hand, group (D) showed the highest desirable horizontal convexity rostrally, followed by groups (G & B), while posteriorly, group (C) showed the highest horizontal convexity followed by groups (A, D & F).

Statistical analyzes of the prehension and licking abnormalities scores (Table 2 and Chart 3) revealed the absence of significant differences among the different groups.

Chart 1: Rostral and posterior heights of sagittal dorsal lingual convexities in groups (A-G) in millimeter (mean ± SD).

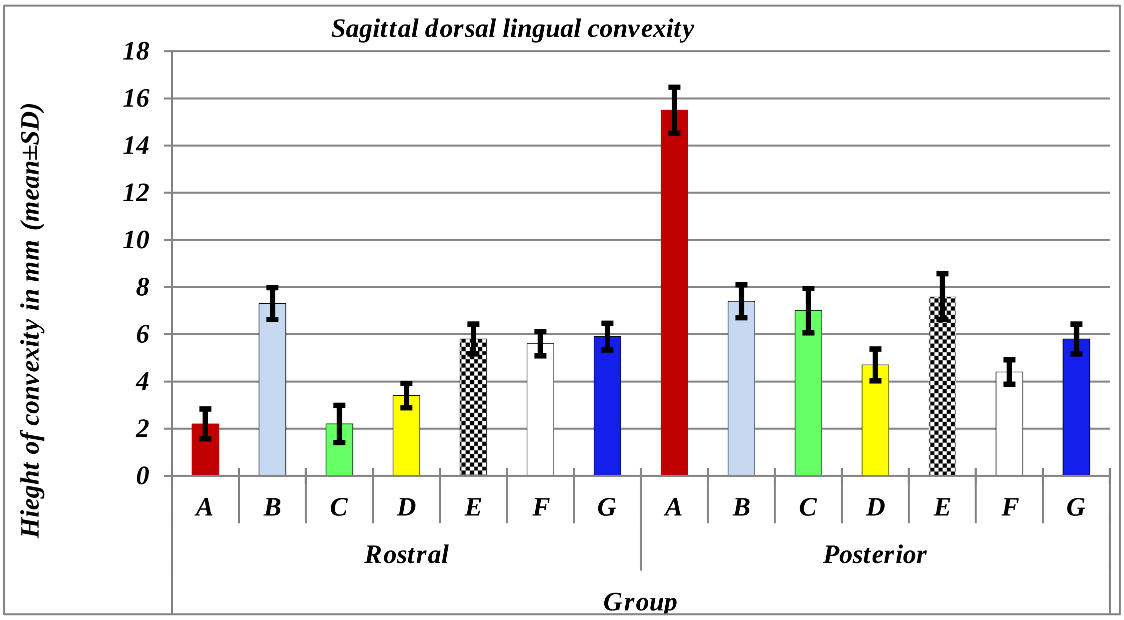


Chart 2: Rostral and posterior heights of horizontal dorsal lingual convexities in groups (A-G) in millimeter (mean ± SD).

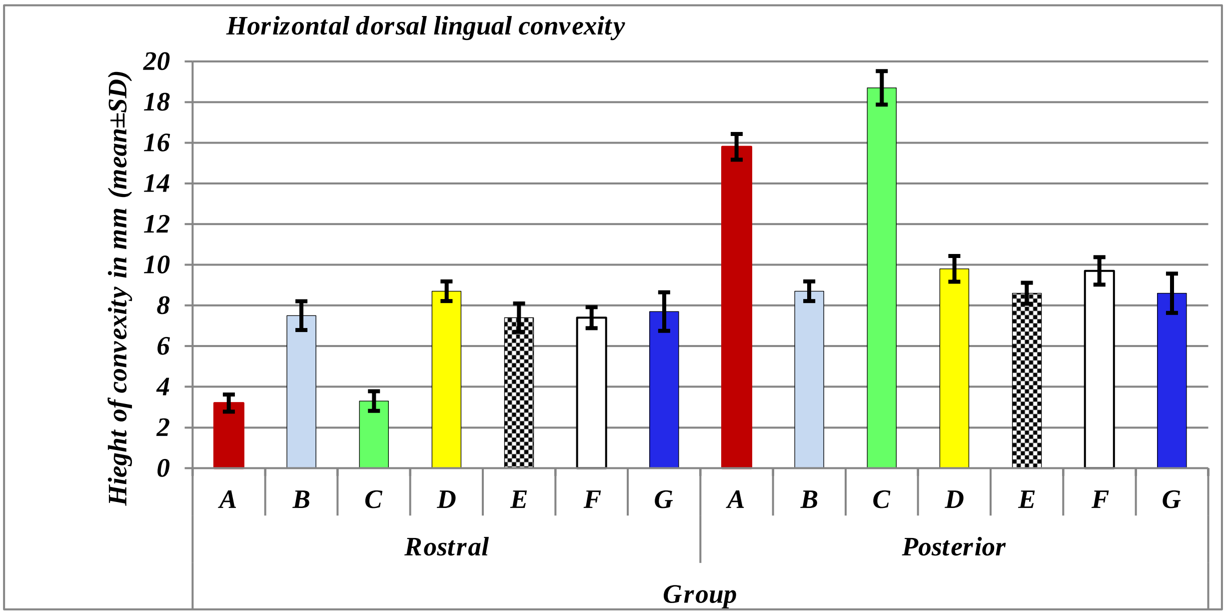
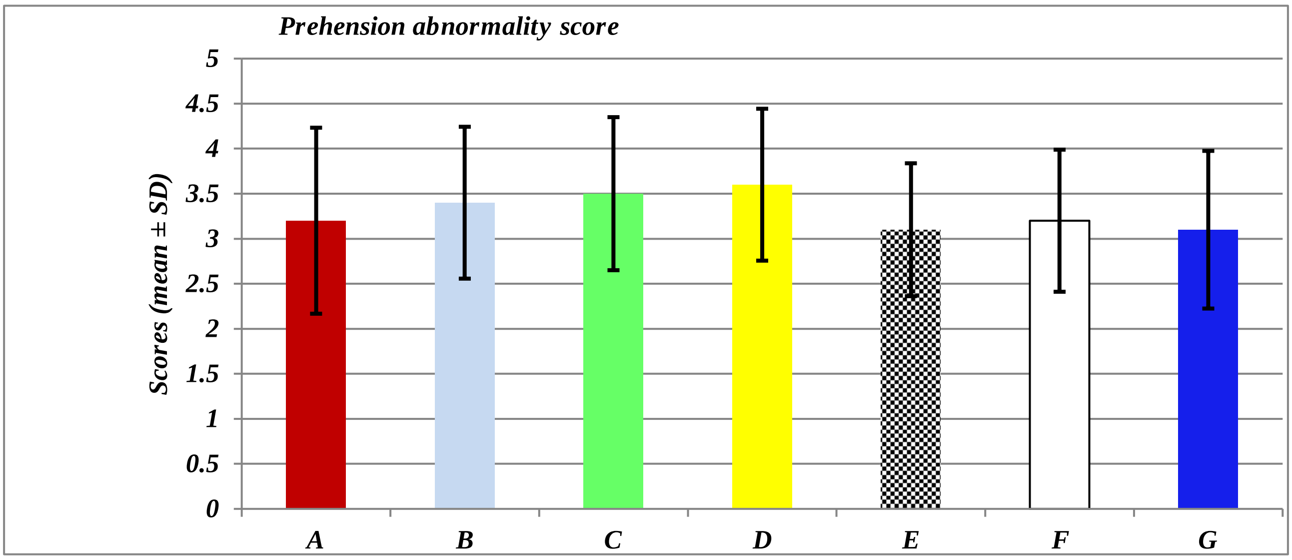


Chart (3): Prehension abnormality scores in groups (A-G) (mean ± SD)



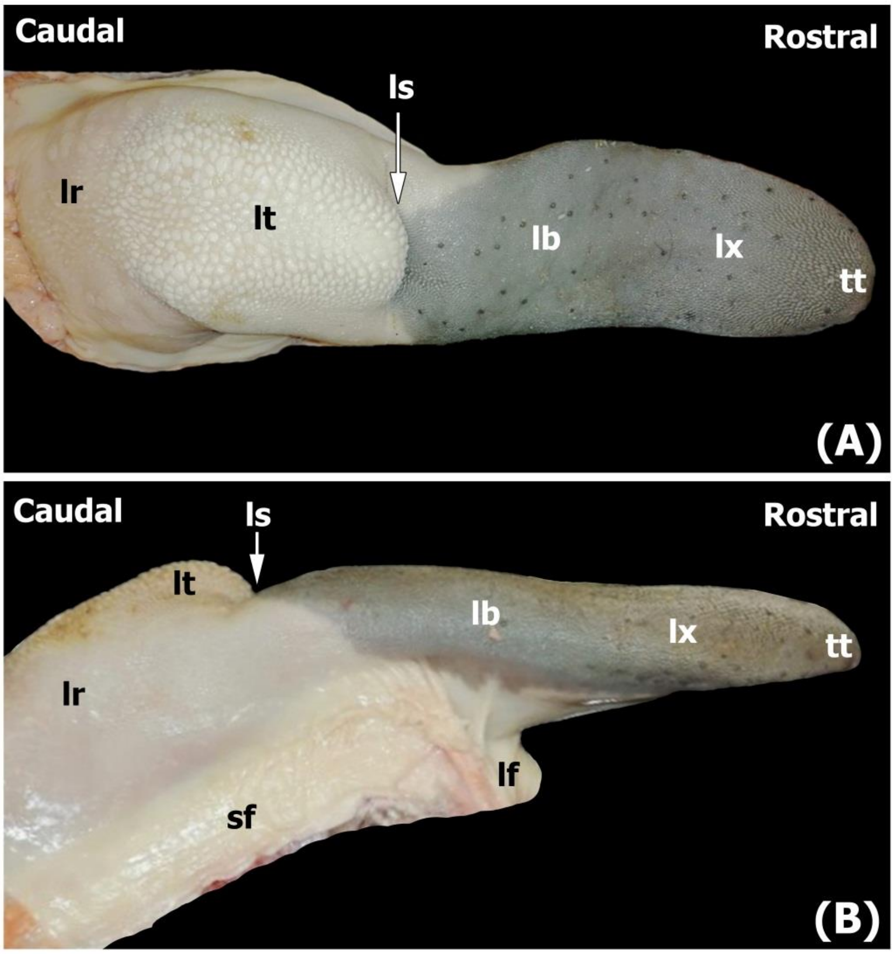


Figure 1: Dorsal (A) and lateral (B) aspects of the cow's tongue: fl- lingual frenulum, lb- lingual body, lr- root of the tongue, ls- lingual sulcus, lt- lingual torus, lx- lingual apex, sf- sublingual fold, tt- tip of the tongue.

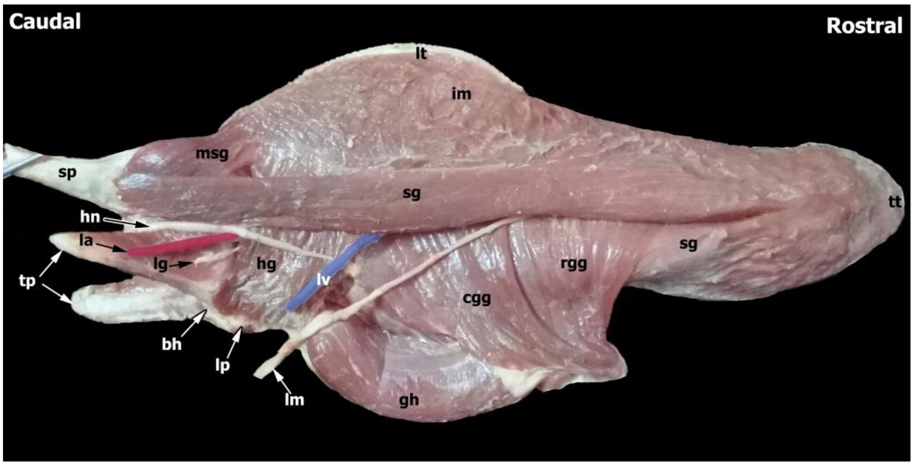


Figure 2: Dissected ventrolateral aspect of the cow's tongue: bh- basihyoid bone, cgg- caudal part of the genioglossus muscle, gh- geniohyoid muscle, hg- hyoglossus muscle, hn- hypoglossal nerve, im- intrinsic muscles, la- lingual artery, lg- lingual branch of glossopharyngeal nerve, lm- lingual branch of the mandibular nerve, lp- lingual process of the hyoid bone, lt- lingual torus, lv- lingual vein, msg- minor styloglossus muscle, rgg- rostral part of the genioglossus muscle, sg- major styloglossus muscle, sp- styloid process of the hyoid bone, tp- thyrohyoid bone, tt- tip of the tongue.

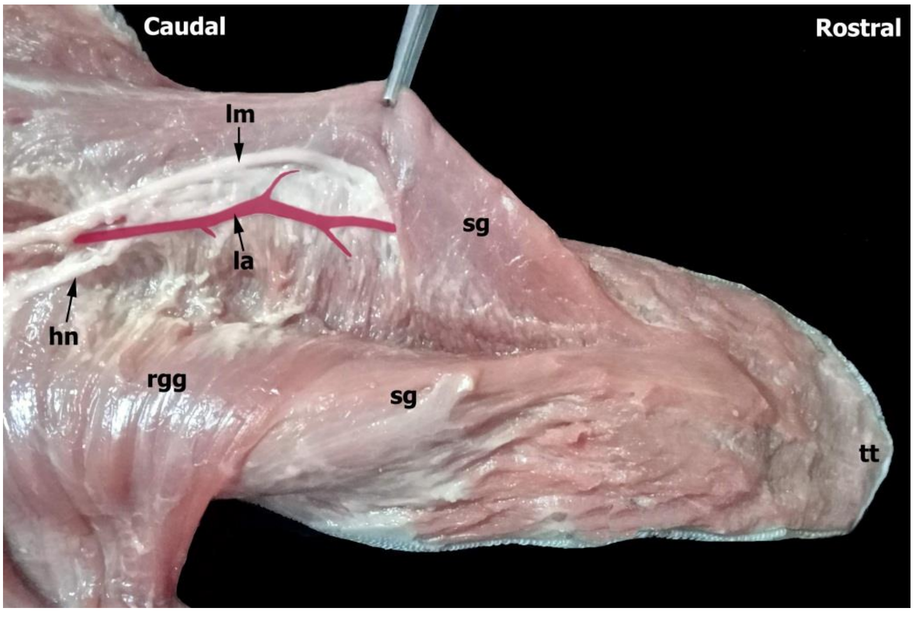


Figure 3: Dissected ventral aspect of the cow's tongue: hn- hypoglossal nerve, la- lingual artery, lm- lingual branch of the mandibular nerve, rgg- rostral part of the genioglossus muscle, sg- major styloglossus muscle, tt- tip of the tongue.

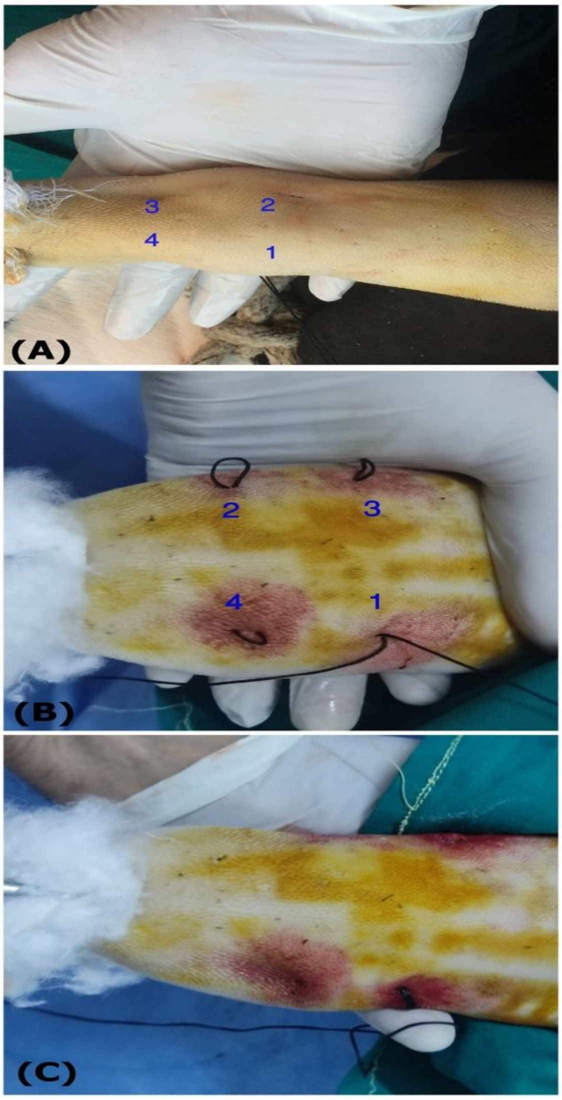


Figure 4: Rostral intralingual rectangular suture pattern (A): 1-2-3 and 4 denote the dorso-lingual stab incisions arranged according to the passage of the thread. Rostral intralingual eight-figure suture pattern (B): 1-2-3 and 4 denote the dorso-lingual stab incisions arranged according to the pass of the stitch, the needle passed from stab 1 to 2 crossly and from 2 to 3 parallel to the tongue and from 3 to 4 crossly. Rostral intralingual eight-figure suture pattern after knotting of silk (C): Note the induced dorsal lingual horizontal convexity.

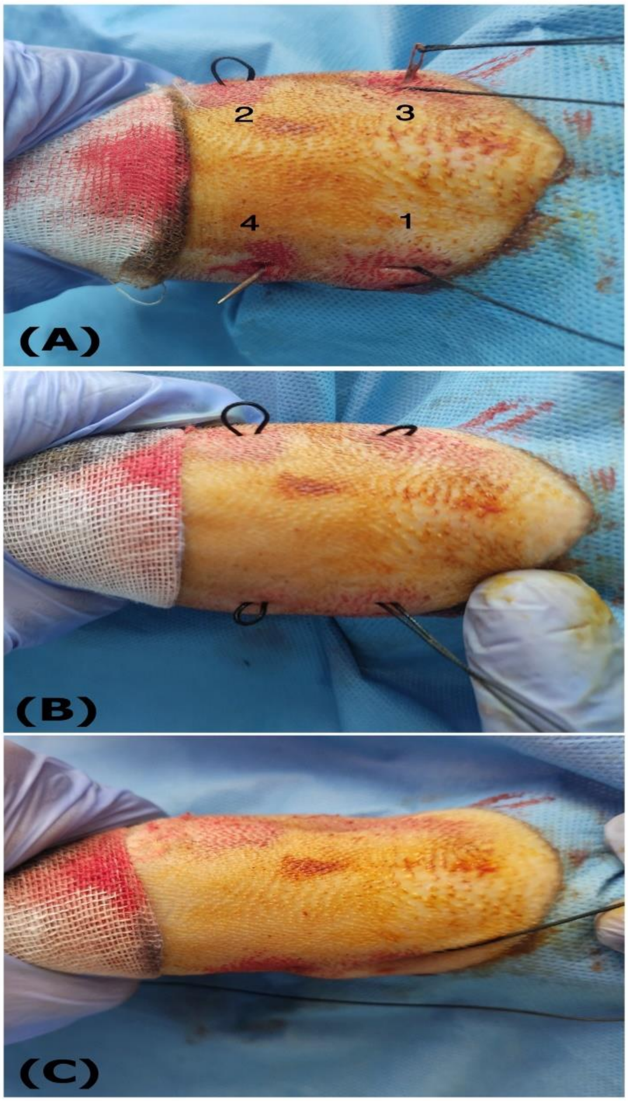


Figure 5: Posterior intralingual eight-figure suture pattern (A): 1-2-3 and 4 denote the dorso-lingual stab incisions arranged according to the passage of the thread, the needle passed from stab 1 to 2 crossly and from 2 to 3 parallel to the tongue and from 3 to 4 crossly. Posterior intralingual eight-figure suture pattern before knotting of silk (B). Posterior intralingual eight-figure suture pattern after knotting of silk (C): Note the induced horizontal dorso-lingual convexity

Figure 6: Rostral ventral purse-string pattern showing the stabs rowed in a circle-manner (A). Rostral ventral purse-string showed knotting of the silk and retraction of the ventral lingual aspect rostrally (B). Directly after completing the rostral and posterior ventral purse and suturing of stabs by cruciate mattress by using polyglactin 910 No. 0 (C): Note the retraction of ventral lingual aspect rostrally and posteriorly.

Table (1): Rostral and posterior heights of the sagittal and horizontal dorsal lingual convexities in millimeter (mean ± SD)

			Height of sagittal convexity	Height of horizontal convexity
Groups	Rostral	(A)	2.2 ± 0.63 [a]	3.2 ± 0.42 [a]
		(B)	7.3 ± 0.67 [c]	7.5 ± 0.71 [b]
		(C)	2.2 ± 0.79 [a]	3.3 ± 0.48 [a]
		(D)	3.4 ± 0.52 [d]	8.7 ± 0.48 [c]
		(E)	5.8 ± 0.63 [b]	7.4 ± 0.70 [b]
		(F)	5.6 ± 0.52 [b]	7.4 ± 0.52 [b]
		(G)	5.9 ± 0.57 [b]	7.7 ± 0.95 [b]
	Posterior	(A)	15.5 ± 0.97 [c]	15.8 ± 0.63 [c]
		(B)	7.4 ± 0.70 [a]	8.7 ± 0.48 [a]
		(C)	7 ± 0.94 [a]	18.7 ± 0.82 [d]
		(D)	4.7 ± 0.67 [b]	9.8 ± 0.63 [b]
		(E)	7.6 ± 0.97 [a]	8.6 ± 0.52 [a]
		(F)	4.4 ± 0.52 [b]	9.7 ± 0.67 [b]
		(G)	5.8 ± 0.63 [d]	8.6 ± 0.97 [a]

Values with different small letters indicate statistically significant difference between groups ($p \leq 0.05$). SD means standard deviation. (A-G) are the seven operated groups.

Table (2): Prehension abnormality scores (mean ± SD)

Group	Scores of prehension Abnormality (mean ± SD)
(A)	3.2 ± 1.03
(B)	3.4 ± 0.84
(C)	3.5 ± 0.85
(D)	3.6 ± 0.84
(E)	3.1 ± 0.74
(F)	3.2 ± 0.79
(G)	3.1 ± 0.88

Values with different small letters indicate statistically significant difference between groups ($p \leq 0.05$). SD means standard deviation. (A-G) are the seven operated groups.

DISCUSSION

Self-sucking and inter-sucking had received attention as early as the seventies of the past century due to their high economic losses in dairy farms. Unfortunately, early surgical trials are very invasive and associated with many disadvantages and complications, in addition to the low-quality scores of treated cows in markets (Tadmor and Ayalon, 1972; Reinheckel, 1975; McCormack, 1976; Dietz and Ludwig, 1979; Steenhaut et al., 1983; Kersjes et al., 1984; Seddek et al., 2019). The highly invasive nature of these techniques, their complications, and their variable success rates (Tadmor and Ayalon, 1972; Dietz and Ludwig, 1979; Berthet et al., 1981; Steenhaut et al., 1983; Bademkiran et al., 2006) force veterinary surgeons to find new, less invasive techniques with fewer complications and better humanity (El-Sherif, 2018; Seddek et al., 2019).

The anatomical findings in the current investigation revealed that the major styloglossus muscle with its associated intrinsic muscles formed the free rostral part of the tongue, extending about 10-11 cm from the lingual tip to the lingual frenulum. Contraction of this muscle unilaterally curls the tip of the tongue caudodorsally (Getty, 1975). During self-suckling, the tongue is curled backward to form a complete tube shape (Tadmor and Ayalon, 1972; Berthet et al., 1981; Ducharme, 2017). Consequently, the suggested techniques in the current study were operated in the rostral free part of the tongue, affecting mainly the styloglossus muscle inducing sagittal and horizontal dorso-lingual convexities to prevent the formation of the complete tube-shaped tongue. Moreover, the given anatomical data restricted the area of surgical interference to be about 1 cm from the ventral lingual mucosa to avoid the terminal branches of the lingual artery, the hypoglossal nerve, and the lingual branch of the mandibular nerve.

Although the use of silk material in a wet, contaminated oral environment is not recommended by the oral surgery specialists due to its high capillary ascension and thus higher potential for bacterial transportation through it, leading to glossitis and abscess formation (Geiger et al., 2005; Silver et al., 2016), the burying of sterile silk suture materials inside the tongue under aseptic conditions overcame this problem and caused a minor inflammatory reaction (Cutler and Dunphy, 1941; Chung et al, 2006; Kikuchi et al., 2012 Seddek et al., 2019), and minimal complications as foreign body granuloma around the silk material without signs of suppuration (Chung et al, 2006; Takahara et al., 2013; Ollivere et al., 2014; Seddek et al., 2019). Encircling the silk by fibrous connective tissue (Secil et al., 2015; Seddek et al., 2019) may prevent the tongue from curling to facilitate self-sucking (Seddek et al., 2019). This could explain the cows' early return to normal eating and the lack of short- and long-term post-surgical complications in the current study.

Regarding animal behavior, all of the current techniques precluded the self-sucking ability directly post-surgery, and the abnormal animal behavior was changed gradually over three weeks after surgery, the same as reported in a previous study (Seddek et al., 2019). The existence of such non-productive trials after surgery may be due to the presence of that motivation for self-suckling, as the surgery prevents the animal from self-sucking, but it has no effect on correcting animal behavior (Motsch et al., 1975). So, some cows showed these non-productive self-sucking trials to satisfy their sucking motivation, but the elicited motivation to suck decreased gradually as a result of the lack of self-sucking ability after the surgical intervention (De Passille, 2001).

Geometrically, the rectangular intralingual suture pattern had nearly equal four sides, and on pulling the silk to tie the knot, equal pulling and pushing forces were placed on the two sagittal and horizontal sides, respectively, and this might predispose to equal sagittal and horizontal convexities of the dorso-lingual surface. The horizontal convexity was desirable to prevent the animal from turning the tongue into a tube to suck himself, and controversial to the undesirable sagittal convexity that had no adverse effect on self-sucking and might theoretically conflict with the normal movement of the tongue during prehension, licking and swallowing. Therefore, this potentiality was investigated in the current study for the seven applied techniques.

The recorded higher rostral sagittal convexity in the group (B) than in the group (D), rostrally and posteriorly, might be due to the differences in the geometrical pulling in the eight-figure suture patterns of the group (D), as the parallel rostral and posterior sides of the rectangular stitch pattern in the group (B), crossed each other in the group (D) pattern, leading to a reduction of the pushing effect of the stitch sagittally and diverting it towards the horizontal pulling. The same phenomenon was observed at the posterior sagittal convexity, with group (A) having a higher posterior sagittal convexity than group (C), and it should be noted that these two groups were operated by a single posterior intralingual stitch, which explains why they had a greater effect on the posterior sagittal convexity than the rostral one. Moreover, the rectangular pattern in the group (A) had an equal pulling effect on both lingual axes, while the group (C) pattern had a lesser effect on the sagittal and more pulling effect on the horizontal axis.

Concerning the ventral lingual purse-string pattern rostrally in groups (E, F, and G) and posteriorly in the group (G), higher horizontal convexities were observed, controversial to the geometrical fact that pulling the circumference of the circle in the purse-string pattern placed equal pulling on the periphery towards the center, and it should have nearly equal pulling effect in all directions. This could be explained in the light of our anatomical findings that the fibers of the major styloglossus muscles were sagittally oriented, similar results are observed in the previous studies (Wedeen et al., 2001; Nazih, 2019). Furthermore, the superficial ventral location of these patterns lowered their adverse effect on the dorso-glossal sagittal convexity. Accordingly, this suture pattern tended to retract the ventral lingual surface, inducing a horizontal lingual convexity rather than the sagittal one. Consequently, modifying the rectangular intralingual stitch to cruciate or purse-string patterns diverted the stitch pulling effect from the undesirable sagittal to the desirable horizontal one.

Regarding the desirable horizontal lingual convexity rostrally in groups (D and G) had the highest ability to induce horizontal lingual convexity, while posteriorly in groups (C, A, D and F) induced the highest posterior horizontal lingual convexity. In the same line, it seems that crossing the two arms of the rectangular stitch or its replacement by a purse-string had a positive effect on horizontal convexity and a negative effect on the sagittal one. Surprisingly, the significant high sagittal convexity of the rectangular intralingual suture pattern had no adverse effect on the normality of prehension and licking in the operated cows. Despite the significant differences among groups in the sagittal and horizontal lingual convexities, our results revealed the absence of significant differences in prehension and licking normality among the different groups and the highest non-significant normality was observed in the group (D), while the lowest non-significant normality occurred in groups (E and G). These findings indicated that the induced sagittal geometric changes in the tongue using these current techniques had minimal effects on the prehension and licking normality.

Conclusion

It can be concluded that the seven techniques, which operated based on the anatomical configuration of the lingual muscles, were associated with no major complications, less-invasive nature than lateral and ventral partial glossectomy, similar efficacy and success rates in preventing self-sucking in dairy cows, and their sagittal lingual convexities had minimal adverse effects on the normal prehension. Such advantages encourage using these less-invasive methods instead of the traditionally used invasive surgical preventive techniques. It should be noted that the intralingual eight-figure or purse-string patterns induced higher horizontal dorsal lingual convexity. However, further studies are required to assess their adverse effects on swallowing.

Conflict of interest statement

None of the mentioned products played a role in the study design or in the collection, analysis, and interpretation of data, nor in the decision to submit the manuscript for publication. Moreover, none of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

Ethical statement

All procedures and techniques used in the current study followed the instructions of the Institutional Animal Care and Use Committee of Beni-Suef University.

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