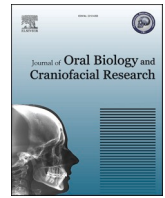




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Knotless barbed suture versus conventional polydioxanone suture material for intraoral surgical incisions - A randomized controlled trial

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ABSTRACT

Purpose: To evaluate and compare the perioperative wound management and healing of intraoral surgical incisions between the conventional and knotless barbed Polydioxanone suture materials.

Materials and methods: A Randomized Controlled Trial was conducted with well-constructed inclusion and exclusion criteria. 46 participants were allotted into the control and test groups based on a computer-generated randomization sequence. The materials used were 3–0 Stratafix™ knotless barbed PDS suture and conventional 3–0 Ethicon PDS™II suture materials. Parameters assessed included intraoperative time taken for closure and assessment with Early Wound Healing Score (EHS) on postoperative day 1 and Landry, Turnbull, and Howley (LTH) Healing index on postoperative days 3 and 7. Statistical analyses were done using the Chi-square test and student's *t*-test with a *p*-value less than 0.05 indicating statistical significance.

Results: 32 patients had surgical intervention for maxillofacial fracture management and 14 patient for orthognathic osteotomies. Surgical sites (*n* = 60) included maxillary and mandibular vestibules. Intraoperative closure time was better in the test group with statistical significance (*p*-value = 0.0472). The healing scores on the 3rd and 7th postoperative days were compared between the control and test groups exhibiting statistical significance favouring the test group. The *p*-values were 0.0479 and 0.0393 respectively.

Conclusion: To conclude, our study concurred with the existing literature in terms of reduced operating time, and better wound healing observed with the knotless barbed suture. Along with statistical significance, all the variables exhibited clinical relevance and better wound management in the test group.

1. Introduction

The outcome of any surgical procedure depends largely on skilful wound closure. An inadequate closure can lead to the separation of wound margins, leading to a potential pathway for bacterial contamination resulting in surgical site infection (SSI), delayed healing, and scar formation. Although other methods such as staples and tissue adhesives are reasonable alternatives, sutures are to date the mainstay in achieving a watertight closure.

The suture threads are secured to the tissues employing various surgical knots. These knots lead to a reduction of the tensile strength of the suture thread by stretching and thinning the material. The primary weakest portion in a suture line is the knot and the next weakest point is the portion adjacent to the knot.¹ This can lead to a breach of the thread leaving the wound exposed. These areas lead to the accumulation of

food debris and become a nidus for bacterial growth and the development of infection.

To overcome these surgical difficulties, the knotless barbed suture was introduced and patented in 1964, by John H Alcamo.¹ The knotless suture is said to be self-securing without the need for any additional adhesive for the suture anchorage. This suture has had good clinical success in various surgical specialties such as the closure of donor leg wounds in coronary artery bypass grafting, breast surgery, laparoscopic hysterectomy, and myomectomy.^{2–4}

In Maxillofacial practice, barbed sutures have been used for aesthetic procedures, such as brow lifting, face, and neck lifting. Although knotless suture material has a good track record in other surgical specialties, the description of its intraoral applications reported is minimal in the contemporary Maxillofacial literature.^{5,6} The Oral and Maxillofacial Surgery community is still in search of the ideal and most suitable suture

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material for the closure of challenging anatomical areas intraorally.

Our study aims to compare perioperative wound management, and healing between conventional Polydioxanone and knotless barbed Polydioxanone suture materials using various clinical parameters at timed intervals.

2. Patients and methods

2.1. Design

A prospective randomized clinical trial was performed in adaptation to the Declaration of Helsinki. The study was approved by the Institutional Ethics Committee (Ethics Clearance Number: 1853/IEC/2019). Informed written consent was obtained from each participant.

2.2. Selection criteria

Individuals requiring full-thickness labio-buccal sulcular incisions in the maxillary vestibule for maxillofacial fracture reductions and osteotomy procedures were included in the study. Participants with any local conditions such as infection, inflammation, ragged, lacerated tissues, or systemic conditions, and individuals not willing to participate were excluded from the study.

2.3. Randomization

Participants were sequentially numbered in an order of enrolment and were allocated into two groups according to a computer-generated randomization table. The CONSORT 2010 guidelines and checklist were followed while designing the study. Three investigators were involved in this randomized clinical trial. The first investigator allocated the individuals into groups, the second investigator performed the procedure, and the third investigator carried out the postoperative evaluation thereby avoiding any potential bias.

2.4. Interventions

A total of 60 participants were randomly allocated into two equal groups –

Group A – Wound closure was done with conventional 3–0 Polydioxanone suture material. (It is 70 cm long with a round-bodied needle, and is 20 mm $\frac{1}{2}$ c in dimension.); the control group.

Group B – Wound closure was done with knotless barbed 3–0 Polydioxanone suture material. (Ethicon™ Stratafix™ spiral PDS™ plus) (30 cm long, reverse cutting needle, 19 mm $\frac{3}{8}$ circle in dimension, 3–

0 size); the test group (Fig. 1).

2.5. Surgical technique

All the participants underwent a thorough clinical examination and an appropriate surgical procedure was planned individually. All the procedures were performed under general anesthesia. The site and length of the incision to be made were recorded and standardized for every participant. The incision line was marked with a sterile marker. A clear and clean cut was made in the tissues with electrocautery and a subperiosteal flap was reflected exposing the field of interest. The planned surgical procedure was carried out following which the closure of the tissues commenced.

The closure was done with either conventional or knotless barbed Polydioxanone suture material according to the randomization into the study groups. Both the suture materials were applied in a simple continuous suturing fashion. During placement of the knotless suture, after taking the first bite with the needle through either side of the wound margin, the suture material is passed through the loop on the distal end of the suture length which secured the suture material in the tissues. Closure of the entire length of the incision was carried out. After reaching the end of the incision, the material is terminated without the placement of any knot.

In case of closure with conventional Polydioxanone material, it was secured to the tissues at the beginning and end of the incision line with surgical knots. The time taken for closure from the beginning of introducing the needle into the tissues till the termination of the suture material was also recorded.

2.6. Postoperative oral hygiene protocol

- Pressure was applied to the surgical wound during the immediate postoperative period by positioning gauze for 30 min at least.
- Rinsing mouth or using mouthwash was avoided for 24 h postoperatively.
- Spitting was prohibited to avoid disrupting blood clots.
- The surgical wound was manually inspected and irrigated with saline solution from 1st postoperative day till the time of discharge.
- Individuals were instructed to brush gently around the surgical site and rinse two to three times daily to maintain a hygiene routine.
- Mouthwash such as Chlorhexidine were recommended.
- Smoking and alcohol consumption was discouraged.

2.7. Assessment

All the patients were evaluated with healing indices postoperatively. Early Wound Healing Score (EHS)⁷ was used on postoperative day 1, and the Healing index of Landry, Turnbull, and Howley (LTH) was used on postoperative days 3, and 7.⁸

2.8. Statistical analyses

The data were collected and statistically analyzed for both groups. Time taken for wound closure, EHS score of postoperative day 1, and Healing index of LTH on postoperative days 3, and 7 were assessed and documented. The mean and standard deviation of all the parameters were calculated and compared using paired student's t-test and Chi-square test. A P-value less than 0.05 was considered statistically significant.

3. Results

During our study period, 60 participants were enrolled. 45 participants were treated for road traffic accidents (RTA), and 15 were operated on for orthognathic surgery. The age range of our study groups ranged from 20 to 59 years with the mean being 36 years. Of the 60

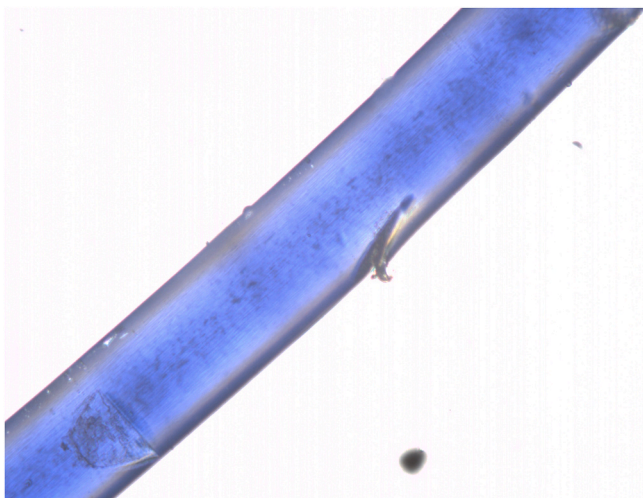


Fig. 1. Magnified view of the knotless barbed suture.

participants, 37 (60.8%) were male, and 23 (39.2%) were female. The most common etiology was RTA. The detailed demographic data are presented in Table 1. P value was calculated for the demographic parameters between the groups. For age comparison, the p-value was 0.79 and etiology was 0.29, while the site of incision had a value of 0.56. None of the parameters presented any statistical significance.

The sites of the incision were the maxillary buccal vestibule, right and left sides. Intraoperative time taken for surgical incision closure was calculated in both groups. The mean and standard deviation of the time taken for group A was 5.65 ± 2.15 min, and for group B was 4.33 ± 1.20. The statistical analysis performed suggested that the time taken for group B was lower with a p-value of 0.0472. Statistical significance was seen (Table 2).

On the 1st postoperative day, an assessment was made with the EHS scale. The mean and standard deviation of the EHS for group A was 7.13 ± 2.10, and for group B was 7.13 ± 1.90. The results were analyzed and the p-value for POD - 1 was 0.8178. The results were not statistically significant (Table 2).

On the 3rd and 7th postoperative days, the healing was assessed with the Healing index of Landry, Turnbull, and Howley (LTH). The mean and standard deviation of the 3rd postoperative day for group A was 3.75 ± 0.89 and for group B was 4.4 ± 0.83. The values for the 7th postoperative day for group A were 4.63 ± 0.52 and for group B were 4.98 ± 0.35. The p-value was 0.0479 and 0.0393 respectively. Both the parameters showed statistical significance at the given time interval (Table 2).

4. Discussion

This prospective randomized clinical trial was performed to evaluate and compare the perioperative wound management and healing in surgical incisions between the conventional and knotless barbed Polydioxanone suture materials.

The inception and evolution of the concept of suturing and various suture materials used began Before the Common Era (BCE) period as described in Samhita.⁹ The suture materials are broadly classified into absorbable and non-absorbable sutures based on the material of origin.

A suture is called absorbable when the tensile strength is lost within 60 days of suture placement.¹⁰ The absorbable suture materials further are natural or synthetic in origin. The catgut is the only naturally available absorbable suture. The synthetic suture materials which are in practice now are derivative of surgical experience from 3000 years BCE.¹¹

Surgical knots are necessary to anchor the smooth structure of the suture material to the tissues. Other than securing the suture to the tissues, the knots present no other significant function. The suture material is stretched at the area of the knots which leads to thinning of the material and a reduction in the tensile strength. This thinning of the material often leads to suture breakage and knot displacement.¹²

The knots also act as a nidus for infection, and food debris collection, and promote the colonization of bacteria.^{13,14} Other associated complications include localized tissue ischemia and loss of wound strength. Overtightening of the knots to prevent slippage can also impair fibroblast proliferation.^{15,16} These complications were persistent and

encountered by many surgeons which led to the search and innovation of the knotless barbed suture.

The barbed suture contains a central smooth structure with small barbs arising and organized in a spiral fashion.¹⁷ The design of a barbed suture was patented by John H Alcamo in 1964 and he characterized it as a suture so formed that it prevents slippage within sutured incisions or wounds. Later in 1967, Dr. A. R. McKenzie reported using the barbed suture in cadavers and dogs for repairing long flexor tendons.¹

There is extensive literature from the 20th and, 21st centuries reporting the use of the knotless barbed suture in various surgical specialties such as Orthopaedics in procedures such as total knee arthroplasty (TKA), tendon repairs, and lateral ankle ligament repair. In the field of Gynaecology and Obstetrics for procedures such as uterine repair following caesarean delivery, and vaginal cuff closure. In Neurosurgery for dural closure, Reconstructive surgery following breast reconstruction, body contouring, abdominoplasty, bariatric anastomoses, and many more.^{18–26}

The head and neck applications for the barbed suture listed include various cosmetic procedures such as Rhytidectomy, Facial rejuvenation, and face, brow, and neck lifting.^{27–29} The reports of the intraoral application of the barbed suture are minuscule.

The first report on the intraoral application of the knotless barbed suture was in 2018, by Kasi Ganesh et al.⁶ They reported using the suture material for the management of Lefort and the angle of mandible fractures. The author reports minimal complications and ease of access and suturing in restricted areas such as the retromolar region. The reported complications included tissue reaction to due erythema on the first operative day. It was observed to be painless and subsided spontaneously. In the case of extraoral application of the suture, micro-hematoma was observed from the barbs and tissue reaction to the material.

Crosetti E et al., 2019³⁰ reported using the barbed knotless suture for closure of the reconstruction flap where resection of oral squamous cell carcinoma of the tongue was performed. They observed a decrease in complications related to knot-tying such as breakage, wound dehiscence, or fistula incidence. The use of knotless barbed suture was reported to allow the distribution of the force and tension along the wound length uniformly. They reported easier placement of sutures in areas of restricted access such as the base of the tongue, and the retromolar region. This relevant clinical advantage was observed in our study while performing wound closure following maxillary osteotomy. It provided better ease of operation and faster wound closure with minimal injury to the tissues. It also aided in easier maintenance of hygiene post-operatively without any evidence of wound breakdown or accumulation of debris.

The time taken for wound closure was compared between the study and test groups intraoperatively. It was observed that closure with the knotless barbed PDS material was faster by at least 3 min. This was in accordance with the literature where Sharma AK et al.,¹³ reported a mean difference of 8.1 min with closure being faster in the knotless barbed suture group. Smith et al.²⁹ conducted an extended review comparing the wound closure time between barbed and conventional sutures in hysterectomy procedures. They reported an average reduction of 15.6 min in wound closure time with barbed sutures compared to conventional sutures, for vaginal cuff closure.

Table 1
Demographic details.

S. No	Data	Group A (Control group)		Group B (Test group)		Total			
		n	%	n	%	n	%		
1	Gender	Males	18	60	19	63.3	37	61.6	
		Females	12	40	11	36.7	23	38.4	
2	Etiology	Road traffic accidents	25	80.6	20	68.9	45	75	
		Maxillary osteotomies	6	19.4	9	31.1	15	25	
3	Site of incision	Maxillary vestibule	Right	16	47.1	21	53.4	37	61.6
		Left	18	52.9	18	46.1	36	60	

Table 2

Comparison among the groups using the mean and standard deviation of the variables showing statistical significance.

Parameters	Group A		Group B		P - value	Statistical significance
	Mean	Standard deviation	Mean	Standard deviation		
Closure time taken	5.65	2.15	4.33	1.20	0.0472	Yes
EWB Score Postoperative day 1	7.13	2.10	7.30	1.90	0.8178	No
LTH score Postoperative day 3	3.75	0.89	4.4	0.83	0.0479	Yes
LTH score Postoperative day 7	4.63	0.52	4.98	0.35	0.0393	Yes

The reduction in the time taken can be attributed to the elimination of time taken for the placement of knots. A statistically and clinically significant difference was seen among the groups in our study.

Postoperatively, all the surgical sites sutured with either conventional or knotless barbed PDS materials were subjected to an evaluation of the wound healing on the 1st, 3rd and 7th days with various wound healing assessment scales.

On 1st postoperative day, an assessment was made with the EHS scale.⁷ Though statistically insignificant, the clinical difference was seen in both groups with better wound healing in the test group (Figs. 2 and 3). As reported in the literature,^{6,14} the barbs deliver an equal distribution of tension along the wound in the initial postoperative period. Similarly in our study, there was passive maintenance of closure with uniform distribution of the tension along the length of the wound. This led to minimal discomfort to the individual, allowing easy hygiene maintenance and restitution of function.

The wound assessment was done on the 3rd and 7th postoperative days using the Healing index of LTH.⁸ Sharma AK et al.,¹³ reported better-wound healing in the study group on 1st, the 3rd, and 7th postoperative days (Figs. 4 and 5). They reported better wound apposition and less inflammation in the test group. Likewise, in our study, there was a significant clinical difference in the healing scores between the groups with better healing in the test group. This can be attributed to the minimal inflammation, which was painless and resolved spontaneously without causing any limitation of function to the participant. There was minimal inflammation postoperatively with the barbed suture, causing less irritation and faster wound healing.

Comparable results were obtained between the control and test groups clinically and statistically. Statistical significance was seen in three parameters (Table 2).

Crosetti E et al.,³⁰ reported healing without complications in 90% of the knotless barbed suture population. Likewise in our study, minimal complications were reported in the test group. The knotless barbed



Fig. 2. Immediate postoperative picture of the knotless barbed suture in the left buccal vestibule.



Fig. 3. Immediate postoperative picture of conventional polydioxanone suture in left buccal vestibule.



Fig. 4. Postoperative day – 7, closure is done with conventional PDS suture in the left buccal vestibule.

suture offered better patient comfort by reducing the tissue reaction, and less incidence of inflammation, and irritation allowing for good wound maintenance and healing.

To conclude, our study concurred with the existing literature in terms of reduced operating time, and better wound healing observed with the knotless barbed suture. Along with statistical significance, all the variables exhibited clinical relevance and better wound management in the test group. As reported in the literature^{6,13,14,30} the knotless barbed suture can be considered an effective alternative to the conventional suture materials in intraoral wound closure by minimizing the associated limitations. Contrary to the literature reported, our study also maintains the homogeneity in the type of suture materials compared, belonging to the same material (PDS). In literature, most of the studies reported conducted analyses between Vicryl and Polydioxanone materials of different sizes.

In the future, conducting studies with a larger sample population,



Fig. 5. Postoperative day – 7, closure is done with knotless barbed PDS suture in the left buccal vestibule.

and a longer follow-up period are required which can then provide information regarding the long-term effects of the barbed suture material in various anatomical sites.

5. Clinical significance

The knotless barbed suture is an inventive solution to the issues faced quite often with conventional suture materials and the benefits of this are seen successfully across all surgical specialties. They provide the benefit of accelerated closure while maintaining wound tension equally along the entire length. It eliminates the need for an assistant to follow and taut the suture while providing better cosmesis. The knotless suture also provides the benefit of easy water-tight closure for incisions in a deep plane and areas with restricted access. In case of wounds and incisions on the tongue, the barbed suture is more comfortable for the patient and easier in hygiene maintenance as the knots are eliminated.

Compliance with ethical standards

The authors have no conflicts of interest to declare that are relevant to the contents of this article. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the University (Ethics Clearance Number: 1853/IEC/2019). Informed consent was obtained from all participants included in the study.

References

- Greenberg James A, Goldman Randi H. Barbed suture: a review of the technology and clinical uses in obstetrics and gynecology. *Rev Obstet Gynecol.* 2013;6(3/4): 107–115. <https://doi.org/10.3909/riog0231>.
- Minozzi F, Bollero P, Unfer V, Dolci A, Galli M. The sutures in dentistry. *Eur Rev Med Pharmacol Sci.* 2009;13(3):217–226.
- Einarsson JI, Vellinga TT, Twijnstra AR, et al. Bidirectional barbed suture: an evaluation of safety and clinical outcomes. *J Soc Laparoendosc Surg.* 2010;14:381.
- Niu Q, Zheng J, Han X. No incision and tension-free vaginal sling for stress urinary incontinence: the role of knotless barbed suture. *Med Hypotheses.* 2018;111:8–11. <https://doi.org/10.1016/j.mehy.2017.12.012>.
- Pippi R. Post-surgical clinical monitoring of soft tissue wound healing in periodontal and implant surgery. *Int J Med Sci.* 2017;14(8):721–728. <https://doi.org/10.7150/ijms.19727>.
- Kasi Ganesh S, Panneerselvam E, Sharma AK, Raja Vb K. Knotless Suture for Wound Closure in Intraoral Surgery-A Report of 2 Cases. *J Oral Maxillofac Surg.* 2018 Sep;76(9):1954.e1–1954.e4. <https://doi.org/10.1016/j.joms.2018.03.017>. Epub 2018 Mar 21. PMID: 29654780.
- Ganesh Kasi, et al. Knotless suture in intraoral surgery – a report of 2 cases. *J Oral Maxillofac Surg.* 2018;76:1954.e1–1954.e4.
- Marini L, Rojas MA, Sahrman P, Aghazada R, Pilloni A. Early Wound Healing Score: a system to evaluate the early healing of periodontal soft tissue wounds. *Journal of periodontal & implant science.* 2018;48(5):274–283. <https://doi.org/10.5051/jpis.2018.48.5.274>.
- Pippi R. Post-surgical clinical monitoring of soft tissue wound healing in periodontal and implant surgery. *Int J Med Sci.* 2017 Jul 18;14(8):721–728. <https://doi.org/10.7150/ijms.19727>.
- Schiappa J, Van Hee R. From ants to staples: history and ideas concerning suturing techniques. *Acta Chir Belg.* 2012;112(5):395–402. <https://doi.org/10.1080/00015458.2012.11680861>.
- Chellamani K, Veerasubramanian D. *Surgical Sutures: An Overview.* 2013.
- Muffy TM, Tizzano AP, Walters MD. The history and evolution of sutures in pelvic surgery. *J R Soc Med.* 2011;104(3):107–112. <https://doi.org/10.1258/jrsm.2010.100243>.
- Greenberg JA, Goldman RH. Barbed suture: a review of the technology and clinical uses in obstetrics and gynecology. *Rev Obstet Gynecol.* 2013;6(3-4):107–115.
- Sharma AK, Thulasi Doss GP, Panneerselvam E, Ganesh SK, Krishna Kumar Raja VB. Use of knotless barbed sutures for closure of intraoral incisions for maxillofacial trauma: a randomized controlled trial. *Br J Oral Maxillofac Surg.* 2020. <https://doi.org/10.1016/j.bjoms.2020.08.015>. S0266-4356(20)30402-2.
- Ramkumar Ceyar KA, Thulasidoss GP, Raja Sethupathy Cheeman S, Sagadevan S, Panneerselvam E, Krishna Kumar Raja VB. Effectiveness of knotless suture as a wound closure agent for impacted third molar - A split mouth randomized controlled clinical trial. *J Craniomaxillofac Surg.* 2020 Oct;48(10):1004–1008. <https://doi.org/10.1016/j.jcms.2020.07.014>. Epub 2020 Aug 1. PMID: 32873466.
- Gowtham K, Anandh B, Srinivasan K, Umar M. Suture materials in dental surgeries: a review. *Ann SBV.* 2020;9(1):30–32.
- Nutt LK, Wilson ML, Sakals S. Comparison of surgical time and complication rate of subcutaneous and skin closure using barbed suture or traditional knotted suture in dogs. *Can Vet J.* 2017;58(12):1281–1286.
- Faour M, Khlouas A, Elmallah RK, et al. The role of barbed sutures in wound closure following knee and hip arthroplasty: a review. *J Knee Surg.* 2018;31(9):858–865.
- Malhotra R, Jain V, Kumar V, Gautam D. Evaluation of running knotless barbed suture for capsular closure in primary total knee arthroplasty for osteoarthritis-a prospective randomized study. *Int Orthop.* 2017;41(10):2061–2066.
- Massey PA, Myers M, McClary K, Brown J, Barton RS, Solitro GF. Biomechanical analysis of patellar tendon repair with knotless suture anchor tape versus transosseous suture. *Orthop J Sports Med.* 2020;8(10), 2325967120954808. <https://doi.org/10.1177/2325967120954808>. Published 2020 Oct 2.
- Ratner DA, Rogers JP, Tokish JM. Use of a knotless suture anchor to perform double-pulley capsulotenodesis of infraspinatus. *Arthrosc Tech.* 2018;7(5):e485–e490. <https://doi.org/10.1016/j.eats.2017.12.002>.
- Niu Q, Zheng J, Han X. No incision and tension-free vaginal sling for stress urinary incontinence: the role of knotless barbed suture. *Med Hypotheses.* 2018;111:8–11. <https://doi.org/10.1016/j.mehy.2017.12.012>.
- López CC, Ríos JFL, González Y, et al. Barbed suture versus conventional suture for vaginal cuff closure in total laparoscopic hysterectomy: randomized controlled clinical trial. *J Minim Invasive Gynecol.* 2019;26(6):1104–1109. <https://doi.org/10.1016/j.jmig.2018.08.030>.
- Cong Z, Wang H, Ma C. Simple dural closure using a knotless barbed suture in endoscopic transsphenoidal surgery: preliminary experience. *Acta Otolaryngol.* 2019; 139(12):1140–1144. <https://doi.org/10.1080/00016489.2019.1668570>.
- Terao Y, Taniguchi K, Tomita S. A new method for inframammary fold recreation using a barbed suture. *Aesthetic Plast Surg.* 2015;39(3):379–385. <https://doi.org/10.1007/s00266-015-0479-7>.
- Bures C, Seika P, Denecke C, Pratschke J, Zorron R. Routine use of v-lock® suture for bariatric anastomosis is safe: comparative results from consecutive case series. *Arq Bras Cir Dig.* 2019;32(3):e1452. <https://doi.org/10.1590/0102-672020190001e1452>.
- O'Connell JB. Rhytidectomy utilizing bidirectional self-retaining sutures: the bidirectional lift and the extended bidirectional lift. *Aesthetic Surg J.* 2015;35(6): 633–643. <https://doi.org/10.1093/asj/sju167>.
- Wu WT. Barbed sutures in facial rejuvenation. *Aesthetic Surg J.* 2004 Nov-Dec;24(6): 582–587. <https://doi.org/10.1016/j.asj.2004.09.007>.
- Mulholland RS, Paul MD. Lifting and wound closure with barbed sutures. *Clin Plast Surg.* 2011;38(3):521–535. <https://doi.org/10.1016/j.cps.2011.06.002>. viii.
- Smith K, Caceres A. Vaginal cuff closure in minimally invasive hysterectomy: a review of training, techniques, and materials. *Cureus.* 2017;9, e1766.17.
- Crosetti E, Caracciolo A, Arrigoni G, Delmastro E, Succo G. Barbed suture in oral cavity reconstruction: preliminary results. *Acta Otorhinolaryngol Ital.* 2019;39(5): 308–315. <https://doi.org/10.14639/0392-100X-2130>.