

# Comparison of skin elasticity and stiffness of the thoracodorsal artery perforator flap and commonly used flaps in head and neck reconstruction

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## Research article

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# Abstract

**Background** Reconstruction of oral and maxillofacial defects requires soft and ductile flaps. Thoracodorsal artery perforator flap (TDAP) has good plasticity, but it is not widely used in the repair of oral and maxillofacial defects. The main aims of this study are to compare the skin elasticity and hardness of various free flaps commonly used in reconstructive surgery, and to explore the advantages and disadvantages of TDAP. **Methods** The elasticity and stiffness of the most commonly used free flaps in our department were measured by ElastiMeter and SkinFibroMeter. The elasticity and stiffness values of TDAP, anterolateral thigh flap, anterior medial femoral flap and forearm flap were measured respectively. **Results** The elasticity of TDAP was the lowest among all flaps, and the difference was statistically significant, except for the forearm flap ( $p = 0.000$ ;  $p = 0.000$ ;  $p = 0.06$ ). The stiffness of TDAP was the lowest among all skin flaps, and the difference was statistically significant ( $p = 0.000$ ;  $p = 0.000$ ;  $p = 0.000$ ). **Conclusions** TDAP is indeed suitable for reconstruction of head and neck defect, especially oral and oropharyngeal defect. Due to the ductile texture of TDAP, it is very conducive to the recovery of the morphology and function of oral and oropharyngeal organs.

## Introduction

Oral and oropharyngeal cancers are among the most common cancers of the head and neck, accounting for nearly 4% of all cancer cases <sup>1</sup>. Surgical treatment is common for such cancers, and repair of tissue defects following tumour resection is critical. For both aesthetic and functional reasons, the oral, maxillofacial-head and neck areas are extremely important. If defects in these regions are not promptly repaired, adverse effects may include impaired speech, chewing and swallowing disorders and psychological problems due to disfigurement.

With the development of microsurgical techniques, free flaps are commonly used as a tissue source for the repair of oral, maxillofacial-head and neck defects <sup>2-4</sup>. As there are more than a dozen free flaps that can be used, choosing the correct flap is important for successful reconstruction <sup>5</sup>. The ideal free flap for reconstructing head and neck defects should have a high success rate, simple preparation, constant vascular anatomy, few donor site complications, sufficient diverse tissues and a vascular diameter similar to that of the neck and maxillofacial vessels. Investigators around the world have made great efforts to determine the most appropriate free flaps for repairing head and neck defects <sup>6</sup>.

The aims of this study are threefold: (i) to share our experience using thoracodorsal artery perforator flaps (TDAPs) to repair oral and maxillofacial defects, (ii) to compare the skin elasticity and hardness of various free flaps commonly used in reconstructive surgery and (iii) to explore the advantages and disadvantages of TDAPs.

## Methods

The study was approved by the Ninth People's Hospital Institutional Review Board and all participants signed an informed consent agreement. Between June 2017 and June 2018, 38 oral or oropharyngeal cancer patients underwent reconstruction using TDAPs. The population included 32 male patients and 6 female patients. Patient ages range from 30 to 75 with a mean of 57.7 years. The largest size among the flaps was  $7.5 \times 15 \text{ cm}^2$  and the smallest was  $4 \times 5 \text{ cm}^2$ . Postoperative follow-up was performed for all patients. Follow-up time varied from 2 to 14 months with a mean of 6.6 months. Basic information for all patients, including flap size, recipient vessel processing method, donor complications and postoperative quality of life, were recorded and statistically analysed. Patient characteristics are presented in Table 1. Post-surgery, aesthetic result, swallowing function and speech function were assessed by two surgeons. Aesthetic result for the oral and maxillofacial region was rated as 1 = unsatisfactory, 2 = satisfactory or 3 = excellent. Swallowing function was rated as 1 = unable to swallow, 2 = liquid or soft food or 3 = normal. Speech function was rated as 1 = slurred speech, 2 = intelligible speech or 3 = normal speech. These ratings are presented in Table 2.

### **Surgical technique**

Patients were placed in the supine position. The incision line was parallel to the latissimus dorsi muscle surface projection line, and in front of the latissimus dorsi muscle surface projection line about 2–4 cm (Figure 1). The position and distance of the incision line were adjusted according to the width of the prepared flap. If a narrow flap was needed, the incision line was moved back; if a wide flap was needed, the incision line was moved forward. Retrograde anatomy was assessed to determine the appropriate vessel and vascular pedicle. A different amount of vascular pedicle muscle tissue or adipose tissue was used to fill the dead space. When repairing complicated defects, separate fat flaps and muscle flaps can be prepared. The donor wound was closed by direct suture after preparation of the complete flaps. If the wound tension was too large, a local random skin flap was used for repair. Ren's anastomosis<sup>3</sup> was used for microscopic artery anastomosis, and end-to-end or end-to-side anastomosis was used for microscopic venous anastomosis.

### **Measurement of flap elasticity and stiffness**

The elasticity and stiffness of the flaps were measured by ElastiMeter (Supplement Figure 1) and SkinFibroMeter (Supplement Figure 2), respectively. The ElastiMeter and SkinFibroMeter probes were briefly (0.8 and 0.5 s, respectively) pressed perpendicularly against the skin. Each elasticity and stiffness value was calculated as the mean of five successful consecutive measurements at the same site. Previous readings were listed under the most recent value, and the values were mathematically modelled using 3D computational finite element analysis, with the final value displayed on the main screen. If the force applied or duration of measurement was incorrect, the message 'USER ERROR' was displayed and the measurement was repeated. We measured the skin elasticity and stiffness of the most commonly used free flaps (anterolateral thigh flap, anterior medial femoral flap and forearm flap) and TDAPs.

### **Statistical analysis**

Data were analysed using SPSS 19.0 software (SPSS, Inc., Chicago, IL, USA). The  $\chi^2$  test or Fisher's exact test were used to analyse the data, as appropriate. A  $p$ -value  $< 0.05$  was considered to indicate a statistically significant difference.

## Results

Of the 38 TDAPs transferred, all 38 survived; 1 showed postoperative vascular crisis, but completely survived after treatment. The overall survival rate was thus 100%. Of the 38 flaps, the largest single flap area was  $7.5 \times 15 \text{ cm}^2$ , whereas the smallest was  $4 \times 5 \text{ cm}^2$ . The perforator vessels of 86.8% (33/38) flaps were derived from the thoracic dorsal artery and 13.2% (5/38) from the lateral thoracic artery. The arterial vascular diameter was 0.8–2.5 mm, the venous vascular diameter was 1.5–2.2 mm and the vascular pedicle length ranged from 6 to 12 cm, with an average of 8.5 cm. The vascular pedicle most commonly comprised one artery and one vein (32 cases), followed by one artery and two veins (6 cases). The number of perforations ranged from 1 to 3, with an average of 1.8. The skin flaps were between 0.8 and 3 cm thick, averaging 1.6 cm. Of the 38 flaps, 12 were used to repair the tongue, 9 to repair the oropharynx, 8 to repair the bucca area, 8 to repair the floor of the mouth and 1 to repair the mandible (Table 1). TDAP can be a perforator flap, one pedicle double island flap (Figure 2) or it can include fat and muscle tissue.

Postoperative follow-up was performed for all patients. Follow-up time ranged from 2 to 14 months with a mean of 8.6 months. Questionnaires, oral evaluation or other methods were used to assess patients' quality of life and obtain information about their speech, swallowing, chewing and appearance. Chewing, swallowing, speech, appearance and other oral maxillofacial functions were perfectly recovered in 90% of patients with tongue, cheek, floor of the mouth and other oral and oropharyngeal cancers following TDAPs reconstruction. No cases showed limited shoulder or upper arm movement, spinal scoliosis or other serious complications. All patients said that the surgical scars under their armpits had no effect on their quality of life.

The 38 patients were tested for skin elasticity and stiffness. The elasticity values of TDAPs, anterolateral thigh flap, anterior medial femoral flap and forearm flap were  $41.2 \pm 12.9 \text{ N/m}$ ,  $77.6 \pm 23.3 \text{ N/m}$ ,  $62.6 \pm 17.7 \text{ N/m}$  and  $51.7 \pm 8.6 \text{ N/m}$ , respectively. The elasticity of TDAPs was the lowest among all flaps, and the difference was statistically significant ( $p = 0.000$ ;  $p = 0.00$ ;  $p = 0.06$ , Figure 3). The stiffness values of TDAPs, anterolateral thigh flap, anterior medial femoral flap and forearm flap were  $0.037 \pm 0.016 \text{ N}$ ,  $0.088 \pm 0.019 \text{ N/m}$ ,  $0.059 \pm 0.020 \text{ N/m}$  and  $0.062 \pm 0.016 \text{ N}$ , respectively. The stiffness of TDAPs was the lowest among all skin flaps, and the difference was statistically significant ( $p = 0.000$ ;  $p = 0.000$ ;  $p = 0.000$ , Figure 4). Complete elasticity and stiffness results are presented in Table 2.

## Discussion

Various defects may occur following radical resection of head and neck tumours, and a considerable portion of these defects requires free flap repair<sup>7-9</sup>. The quality of repair directly affects patients'

postoperative recovery and quality of life. There are two key factors that affect the quality of repair, namely, the surgical skill and clinical experience of the surgeon and the correct flap selection<sup>5, 10-12</sup>. Oral and oropharyngeal mucosa is soft, and the function of the relevant organ is very complex and sophisticated. Therefore, when repairing oral or pharyngeal defects, a ductile skin flap should be used whenever possible. Only in this way can a patient's oral oropharyngeal morphology and function be restored. This TDAPs can well meet the demand of softness for head and neck defect repair. Our study is the largest application of TDAPs to repair head and neck defects in mainland China at present. Meanwhile, we also reported a pedicle double island TDAP for the first time.

Stable, quantitative measurements of skin hardness and elasticity have long been lacking<sup>13, 14</sup>. In this study, we used the ElastiMeter and SkinFibroMeter in a novel way to measure the elasticity and hardness of the skin flap, demonstrating that these tools can quantitatively evaluate skin elasticity and stiffness. The ElastiMeter and SkinFibroMeter also have the advantages of being highly sensitive, portable and accurate. Unlike diagnostic methods based on skin biopsy and puncture, ElastiMeter and SkinFibroMeter measurements are non-invasive and do not damage skin structures, thereby reducing patient anxiety. In addition, the wireless data collection system uses DMC software, enabling real-time data acquisition and storage. The measurement process is simple, requiring only depression of the operation button and adjustment of the power and velocity of the probe. The site of measurement was the donor site of the flap, not the flap. This can avoid measurement errors between different patients. In this study, the use of these measurements revealed that TDAP donor skin is the most ductile of all commonly used skin flaps—even softer than the forearm, which is considered to be the softest flap. The use of TDAP for repair of oral or pharyngeal defects also led to full recovery of swallowing, speaking and other functions, as confirmed by patient follow-up.

When choosing a flap, scarring and other complications at the donor site are other important considerations. The surgical incision at the donor site of TDAP is concealed under the armpit, and the average surgical scar is only 14.5 cm. In addition, because the flap was prepared with retention of the important nerves, there was almost no damage to the adjacent muscles. As a result, there was no serious dysfunction in the postoperative donor site. In this study, the most common donor site complications included localised paraesthesia, muscle weakness and poor wound healing. The main causes of the above complications are intraoperative injury of the latissimus dorsi muscle motor nerve and cutaneous nerve<sup>15, 16</sup>. Therefore, during flap preparation, the latissimus dorsi muscle motor nerve and cutaneous nerve should be protected as much as possible with avoidance of large suture tension to minimise donor site complications.

In the current study, all of the transplanted flaps survived. Factors known to influence the success rate of skin flap transplantation<sup>17</sup> include the surgeon's clinical experience and a good match between the vascular diameter of the skin flap and the neck. The diameter of the arteries and veins of the TDAPs was about 2 mm, which is suitable for anastomosis with the head and neck vessels. From this point of view, TDAPs are very suitable for reconstruction and repair of head and neck defects.

Although TDAPs offer many advantages for repair and reconstruction of head and neck defects, there are two notable disadvantages. First, there may be some interference with head and neck surgery when preparing the flap. Both groups could be performed simultaneously if necessary. Second, the thickness of TDAPs is too great in some patients, and a thinning treatment may be required.

## Conclusion

In summary, TDAPs are indeed suitable for reconstruction of head and neck defects, especially oral and oropharyngeal defects. Due to the ductile texture of TDAPs, they are very conducive to the recovery of the morphology and function of oral and oropharyngeal organs. The use of this flap in the repair and reconstruction of head and neck defects is worthy of further promotion.

## Abbreviations

TDAP :Thoracodorsal artery perforator flap.

## Declarations

### Acknowledgements

Not applicable

### Ethics approval and consent to participate

This study was approved by the independent Ethics Committee of Shanghai Ninth People's Hospital affiliated with Shanghai Jiao Tong University School of Medicine. Written informed consents were obtained from all participants.

### Consent for publication

Not Applicable

### Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Competing interests

The authors declare no competing interest

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### Authors' contributions

ZHR and JZH determined the search strategy. KW and WJ Y conducted the selection of relevant studies and data extraction separately. ZHR and JZH evaluated the quality of each study independently. ZHR and YH did the analyses and outcomes. KW and ZHR drafted the manuscript. All authors revised and approved the final version of the manuscript.

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Table 1

Table 1: Basic information on 38 patients and TDAPs

SEX		
	Male	32
	Female	6
AGE		30-74
TUMOR SITE		
	Tongue	12
	Buccal	9
	Oropharynx	8
	Mouth floor	8
	Mandible	1
FLAP SIZE		4cm*5cm—7.5cm*15cm
THICKNESS OF FLAP		1cm—3cm
QUANTITY OF PERFORATE		
	1 perforate	12
	2 perforate	22
	3 perforate	4
PEDICLE LENGTH		6cm-12cm
NUMBER OF ARTRY AND VEIN		
	1 artry, 1 vein	32
	1 artry, 2 vein	6
LENGTH OF SURGICAL SCAR		13cm—20cm

Table 2

Table 2: Comparison of skin stiffness and elasticity of some common flaps



	FLAP ELASTICITY (N/m)				FLAP STIFFNESS (N)			
NUMBER	TDAP	ALT	AMT	FOREARM FLAP	TDAP	ALT	AMT	FOREARM FLAP
1	22	76	71	48	0.02	0.09	0.05	0.05
2	68	87	56	50	0.01	0.11	0.05	0.08
3	42	70	46	57	0.03	0.09	0.03	0.07
4	59	100	75	54	0.04	0.09	0.07	0.08
5	43	71	39	44	0.06	0.08	0.05	0.05
6	49	115	105	66	0.04	0.13	0.1	0.06
7	43	86	65	38	0.05	0.11	0.08	0.08
8	32	82	48	60	0.05	0.1	0.07	0.03
9	68	74	77	66	0.03	0.08	0.05	0.06
10	52	89	75	60	0.02	0.1	0.04	0.08
11	59	53	50	50	0.01	0.08	0.05	0.09
12	41	32	43	40	0.03	0.06	0.03	0.05
13	49	70	67	68	0.05	0.07	0.04	0.08
14	25	80	49	45	0.02	0.08	0.06	0.06
15	49	49	64	60	0.06	0.07	0.05	0.08
16	43	109	77	46	0.04	0.09	0.07	0.05
17	44	108	87	55	0.05	0.13	0.09	0.06
18	68	105	80	49	0.04	0.11	0.09	0.08
19	45	36	87	57	0.06	0.08	0.08	0.09
20	55	70	49	51	0.05	0.09	0.07	0.06
21	38	100	67	40	0.03	0.07	0.06	0.05
22	65	58	50	50	0.02	0.08	0.06	0.09
23	37	30	36	35	0.02	0.05	0.03	0.04
24	45	60	62	55	0.05	0.07	0.04	0.08
25	28	70	45	40	0.02	0.07	0.05	0.05
26	45	76	50	53	0.04	0.09	0.06	0.04
27	55	90	70	51	0.04	0.09	0.06	0.06
28	41	71	40	44	0.06	0.08	0.05	0.04
29	49	105	100	66	0.04	0.11	0.1	0.06
30	43	86	65	45	0.05	0.11	0.08	0.06
31	38	80	48	54	0.05	0.08	0.07	0.04
32	60	74	79	66	0.03	0.08	0.05	0.06
33	54	85	79	60	0.02	0.1	0.07	0.06
34	67	89	56	50	0.04	0.11	0.05	0.06
35	46	67	45	57	0.04	0.06	0.03	0.07

36	50	103	75	54	0.04	0.09	0.07	0.05
37	47	70	49	44	0.05	0.08	0.05	0.05
38	29	72	51	38	0.02	0.07	0.05	0.04
The average	41.2	77.6	62.6	51.7	0.037	0.088	0.059	0.062
<i>P</i>		0.000	0.000	0.06		0.000	0.000	0.000

Note: The data of elasticity and hardness of the flaps were obtained by measuring the supply area of flaps. We not only measured the TDAP supply area of 38 patients, but also measured the other flap (ALT, AMT, Forearm flap) supply area of the patients. Data from different skin flaps of the same patient were more consistent and comparable. TDAP, Thoracodorsal artery perforator flap; ALT, Anterolateral thigh flap; AMT, anteromedial thigh flap.

## Figures

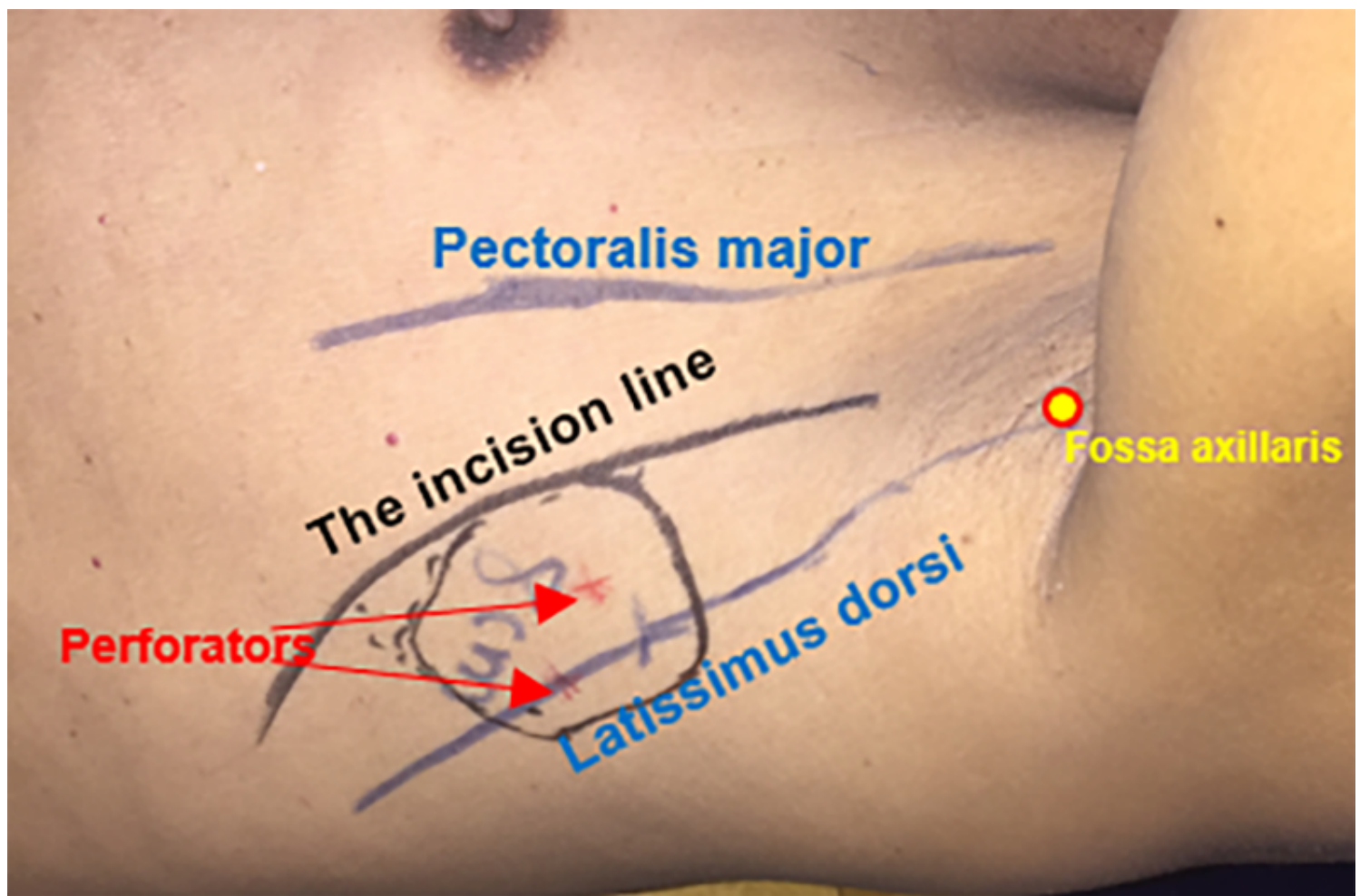


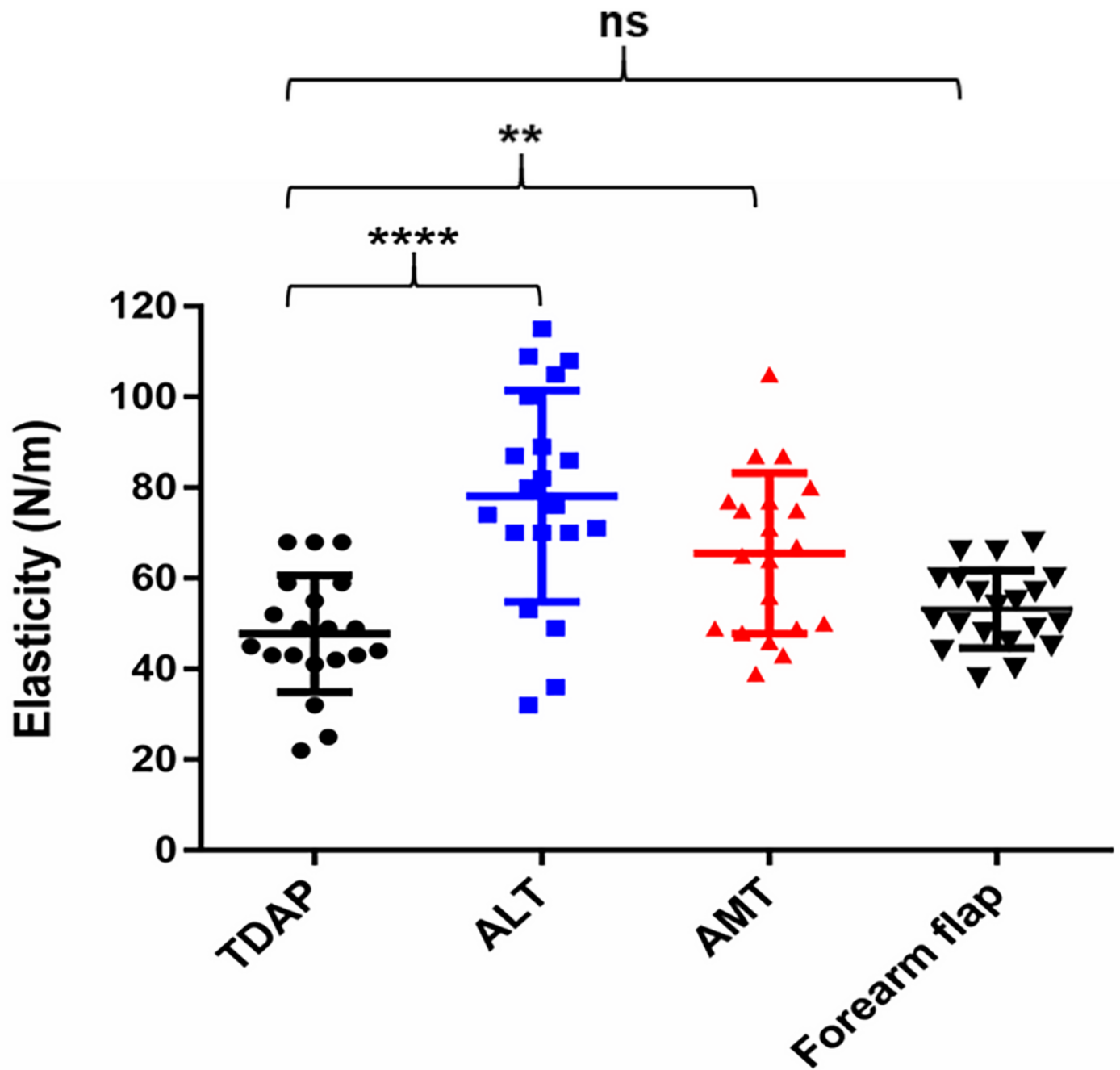
Figure 1

The incision line was parallel to the latissimus dorsi muscle surface projection line, and in front of the latissimus dorsi muscle surface projection line about 2–4 cm.



**Figure 2**

One pedicle double island flap of TDAP



**Figure 3**

Comparison of elasticity in various flaps. The elasticity values of TDAPs, anterolateral thigh flap, anterior medial femoral flap and forearm flap were  $41.2 \pm 12.9$  N/m,  $77.6 \pm 23.3$  N/m,  $62.6 \pm 17.7$  N/m and  $51.7 \pm 8.6$  N/m, respectively. The elasticity of TDAPs was the lowest among all flaps, the difference was statistically significant ( $p = 0.000$ ;  $p = 0.00$ ;  $p = 0.06$ ).

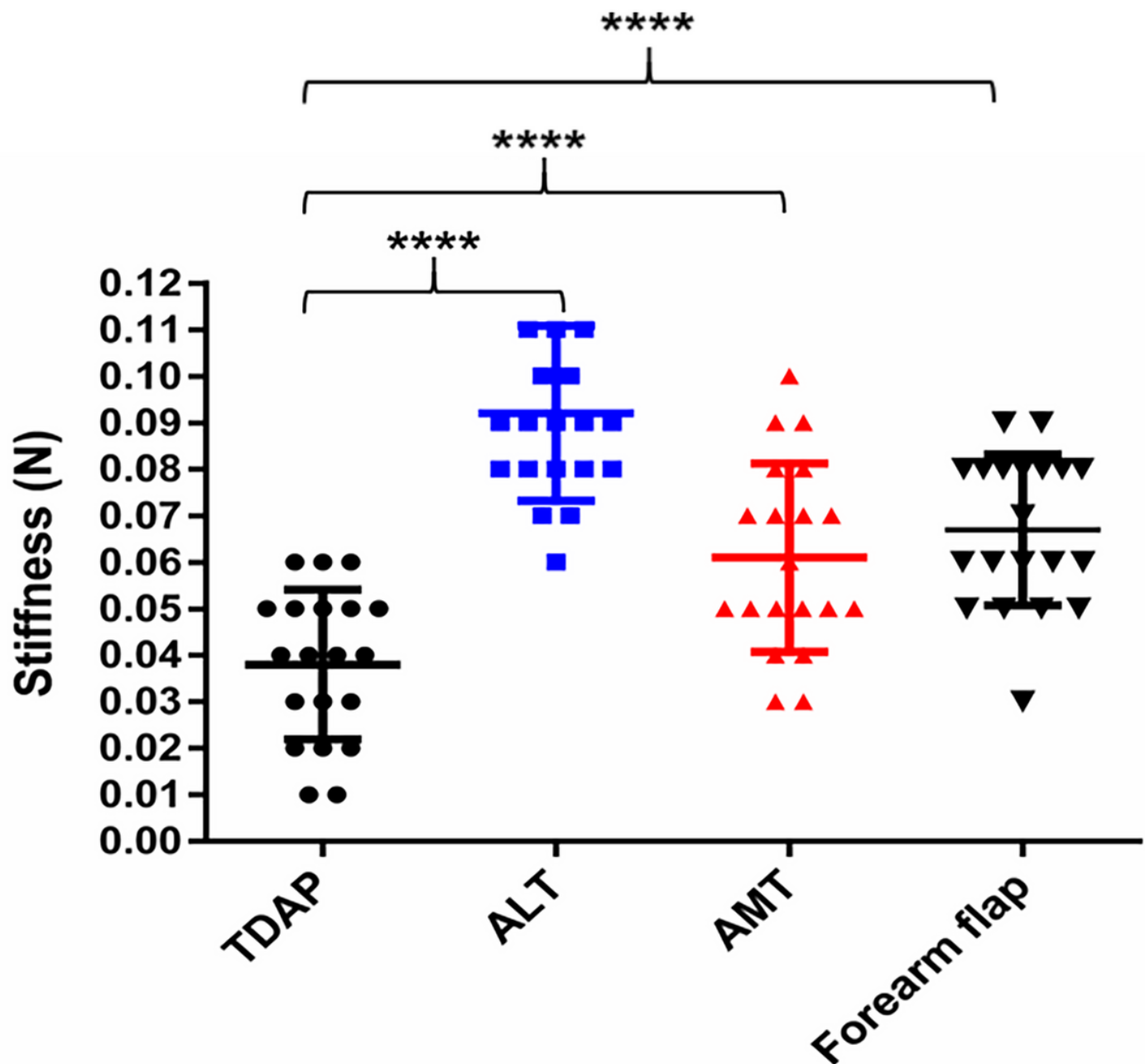


Figure 4

Comparison of stiffness in various flaps. The stiffness values of TDAPs, anterolateral thigh flap, anterior medial femoral flap and forearm flap were  $0.037 \pm 0.016$  N,  $0.088 \pm 0.019$  N/m,  $0.059 \pm 0.020$  N/m and  $0.062 \pm 0.016$  N, respectively. The stiffness of TDAPs was the lowest among all skin flaps, and the difference was statistically significant ( $p = 0.000$ ;  $p = 0.000$ ;  $p = 0.000$ ).

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