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Reconstructive

Thoracodorsal Artery Perforator Flap in Partial Breast Reconstruction: A Systematic Review

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Introduction: Breast conserving surgery followed by radiation therapy represents the standard of care for early stage breast cancer. Oncoplastic breast surgery includes several reconstructive techniques essentially summarized in 2 categories: volume displacement and volume replacement procedures. These latest procedures have evolved over time from the use of the entire latissimus dorsi muscle to the use of pedicled perforator flaps, namely the thoracodorsal artery perforator (TDAP) flap. The aim of this article is to provide a comprehensive review of the literature regarding the use of the TDAP flap in partial breast defects.

Methods: A literature search was performed via PubMed, Medline, and Cochrane. Studies reporting the use of the TDAP flap after breast conserving surgery were included. Patient characteristics, topography and size of breast defect, flap size and design, number of perforators, and operative time were analyzed. Moreover, aesthetic and functional (shoulder morbidity) results, patient satisfaction, postoperative complications, and donor site morbidity were registered.

Results: Twelve articles fulfilled inclusion criteria, and 337 patients were included. All articles except 1 described the use of the TDAP flap for defects in every breast quadrant. The mean weight of resected breast tissue was 97.28 g, and patients with over 20% of volume deficiency were considered eligible for TDAP flap volume replacement. The ellipse-shaped skin paddle (oriented oblique downward, transversal or oblique upward in most cases) was extended over the anterior border of the latissimus dorsi muscle to include possible septocutaneous perforator vessels. Most authors began the dissection from the anterior and caudal border of the flap to reserve the possibility to convert the TDAP to a musculocutaneous flap and check for septocutaneous perforators. Flap size ranged from 4 × 12 to 21 × 9 cm. The mean procedure time was 192.21 minutes. Mean follow-up was 17.42 months. Evaluation by way of a 5-point Likert scale reported overall mean values of over 4 points. Satisfactory outcomes were reported in 92.85%–100% of cases. Patient satisfaction ranged from 80% to 94% of cases. The incidence of seroma (1 case) and "shoulder-related" donor site morbidity was very low.

Conclusions: Despite the heterogeneity of the evaluation methods, our review suggested that the use of the TDAP flap in oncoplastic surgery allows for satisfactory aesthetic outcomes and quite high levels of patient satisfaction. The TDAP flap represents an effective and versatile tool that amplifies the oncoplastic surgeon's arsenal, which allows for satisfactory outcomes. *(Plast Reconstr Surg Glob Open 2020;8:e3104; doi: 10.1097/GOX.0000000000003104; Published online 26 October 2020.)*

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INTRODUCTION

Breast conserving surgery (BCS) followed by postoperative radiation therapy (RT) currently represents the standard of care for early stage breast cancer.[1] In fact, several prospective and randomized studies reported that BCS provides the same rate of overall and disease-free survival as do mastectomy in the early stage.[1–3] In parallel, reconstructive surgeons have developed several partial breast reconstructive techniques to improve cosmetic results as well as the quality of life of patients post-BCS.[4–9] Oncoplastic breast surgery can be defined as a tumor-specific immediate breast reconstruction approach that combines principles of surgical oncology with the aesthetically

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derived breast reduction techniques.[7,10,11] It uses volume replacement or volume displacement[7] techniques to redistribute the remaining breast parenchyma and reshape the breast after tumor excision[6] with or without contralateral breast symmetrization procedures. Many studies agree on the fact that oncoplastic breast surgery, which allows wider resections, is associated with a significantly lower positivity of surgical margins and can guarantee an overall local control of disease. The 2 different approaches (volume displacement and volume replacement) are differently indicated depending on tumor size, location, and breast characteristics.[6,12,13] On the one hand, volume displacement applies different surgical techniques to reshape the breast and to correct the defect created during lumpectomy or quadrantectomy with dermo-glandular flaps of breast tissue; on the other hand, volume replacement procedures employ autologous reconstruction techniques like the use of local flaps where volume is missing. Volume replacement procedures have evolved over time from the use of the entire latissimus dorsi (LD) muscle to the use of pedicled perforator flaps available in the thoracic region such as the thoracodorsal artery perforator (TDAP) flap, the intercostal artery perforator flaps, the lateral thoracic artery perforator flap, and the serratus anterior artery perforator flap.[14] The muscle-sparing LD (MS-LD) flap consists of a TDAP flap that includes a part of LD muscle to protect the perforators, sparing the nerves that innervate the rest of the LD muscle.

Despite the LD flap presenting several advantages such as simplicity in dissection, reliable vascularity, and high volume availability, it also presents a non-negligible morbidity rate, including seroma and limitation of shoulder movement.[15,16] Angrigiani et al[17] first described the concept of raising the cutaneous portion of the LD flap without the muscle in 1995. The use of a pedicled TDAP flap in breast reconstruction was initially reported in 2004 by Hamdi et al[18] in a series of 18 patients. The TDAP flap is a fasciocutaneous flap based on musculocutaneous or septocutaneous perforators that arise from the thoracodorsal artery. This flap has been largely used in breast reconstructive surgery for partial or total[19] breast reconstruction after oncological resection, in cases of burn breast,[20] and as implant coverage in alloplastic breast reconstruction.[21]

The aim of this article is to provide a comprehensive review of the literature regarding the use of the TDAP flap after BCS.

MATERIALS AND METHODS

A literature search was performed by utilizing the PubMed, Medline, and Cochrane databases according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis[22] guidelines to provide a comprehensive review of the literature regarding the use of the TDAP flap after BCS.

The following MeSH terms were used: "thoracodorsal artery perforator flap breast," "oncoplastic breast perforator flap," and "oncoplastic breast local flap" (period: 2004–2020; last search on May 3, 2020). Two different reviewers performed double screening and data extraction. Abstracts were examined to identify qualified papers. Reference lists of relevant articles were screened for supplementary studies.

Inclusion and Exclusion Criteria

The selection of the articles was based on the following inclusion criteria:

(1) Studies reporting the use of the TDAP flap after BCS; (2) Registration of outcomes after surgical treatment; and (3) Full text available in English.

The studies were excluded due to any one of the following criteria:

(1) Studies reporting the use of the TDAP flap combined with implant positioning; (2) Studies reporting the use of the TDAP flap for total breast reconstruction; (3) Articles including fewer than 6 cases; (4) review articles; (5) case report; (6) nonreferenced articles; and (7) expert opinion or comment (level V).

Data Collection

Extracted data included type of study, number of patients included, mean age, time of reconstruction, topography of breast defect, specimen weight, preoperative assessment [Doppler mapping or computed tomography (CT) scan, flap design], patient positioning, dissection strategy (above or below the LD fascia, perforator eligibility, possible conversion to MS-LD), flap size, number of perforators included in the flap, operative time, mean follow-up time, postoperative RT, aesthetic results, functional results (shoulder morbidity), patient satisfaction, postoperative complications, and donor site morbidity.

Statistical Analysis

Statistical analysis was performed using SPSS statistical software (version 24.0; IBM Corporation, Somers, N.Y.).

RESULTS

A total of 1739 citations from PubMed, Medline, and Cochrane Library were initially identified. After a title and abstract review, analyzed by 2 different reviewers, 41 records were considered relevant. Full text examination excluded further 29 articles. Only 12 articles of the initial research, published between 2004 and 2019, fulfilled inclusion criteria and were included in the systematic review (Fig. 1). Among the 12 selected studies,[18,23–33] 6 were retrospective studies[23,25,26,29,32] (1 case control study[27]) and 6 were prospective studies[18,24,28,30,31,33] (1 randomized control study[33]; Tables 1–3). A total of 337 patients were included and the sample size of each study ranged from 8 to 78 patients. Among the 337 patients, 225 had undergone a partial breast reconstruction using a local TDAP flap, 21 patients had undergone a partial breast reconstruction using a local LD flap (control group), and 13 patients had undergone BCS without any type of oncoplastic breast procedure (control group). Moreover, in 78 cases, an intraoperative conversion from a TDAP flap to an MS-LD flap was necessary. The mean age of patients was 44.86. Concerning the timing of breast reconstruction, in 94.22% of the cases (212 patients), the TDAP flap

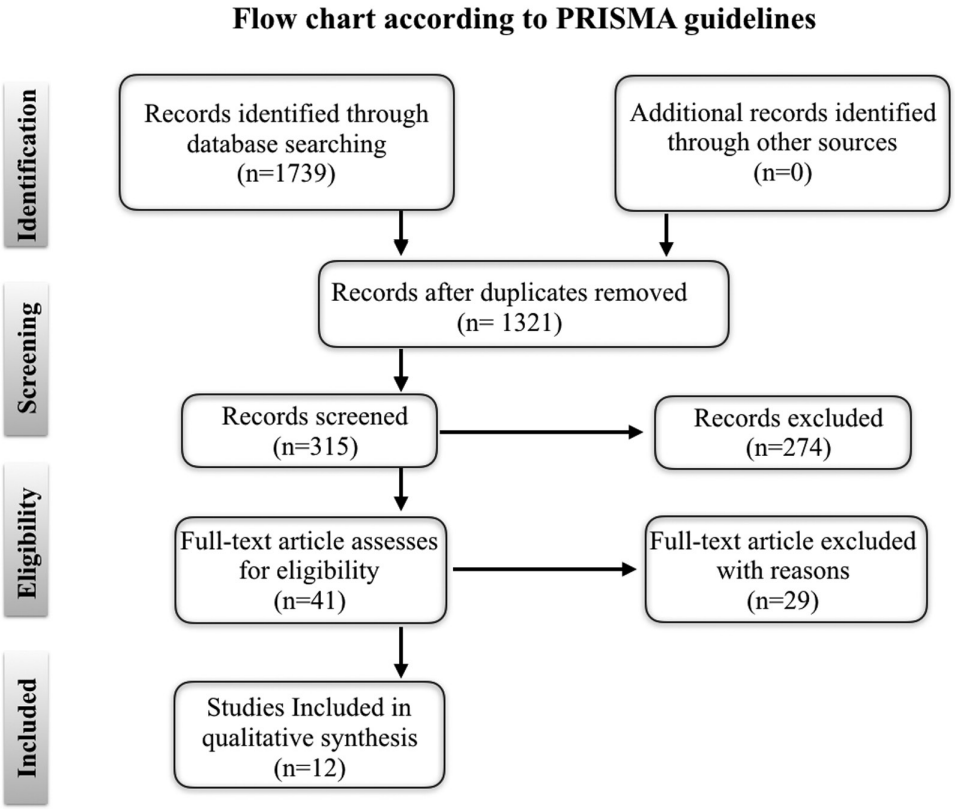

Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines.

was harvested at the time of the tumor resection, while in 5.78% of cases (13 patients) the oncoplastic breast procedure was delayed to a second operation.

Tumor Location

Seven out of 12 studies reported tumor location. The most common tumor location was in the upper outer quadrant (36 cases) followed by the lower outer quadrant (15 cases), the upper inner quadrant (13 cases), and the lower inner quadrant (5 cases). Two studies reported 24 cases of columnar-shaped partial mastectomy (upper and lower outer quadrants). One study considered partial breast defects of the upper inner quadrant as an exclusion criterion for TDAP breast reconstruction. The mean weight of the resected breast tissue was 97.28 g (range, 50–150 g). Three studies did not report the weight of resected breast tissue, instead reporting the ratio between resected breast and total breast volume. In detail, patients with over 20% of volume deficiency were considered eligible for oncoplastic procedures with TDAP flap volume replacement. Skin deficiency and nipple areola complex distortion in the lateral quadrants or in the lower pole of the breast represented other indications in lieu of TDAP flap reconstruction.

Preoperative Planning and Flap Design

Most authors performed a preoperative identification of perforator vessels using either a Doppler probe[18,25,29,31–33] (6 studies), a color Doppler ultrasonography[23] (1 study), or a 3-dimensional chest computed tomography angiography[30] (1 study). Hamdi et al[18,24,25] suggested positioning the patients in the same position that they would be placed in during flap harvesting (lateral decubitus with 90 degree of shoulder abduction and 90 degree of elbow flexion) so that the perforators enter the skin with a more perpendicular orientation making their Doppler signal more distinct.[25] A pinch test was often used to identify the widest portion of the skin paddle to allow for donor site primary closure.

Regarding flap design, some authors[18,24,25,29,32,33] suggested extending the ellipse-shaped skin paddle over the anterior border of the LD muscle to include possible septocutaneous perforator vessels (located anteriorly to the LD muscle) and/or to reach the lateral border of the inframammary fold. In 4 studies,[28,31–33] the skin paddle was oriented transversally (Fig. 2); in 4 studies,[24,26,29] the skin paddle was oriented in an oblique downward (Fig. 3); and Hamdi et al[18,24,25] reported that in their series, flaps were mostly oriented in an oblique upward, parallel to skin lines with the tip toward the angle of the scapula (Fig. 4). In 1 study, the flap was oriented either horizontally or vertically in consultation with the patient to ensure that the scar was not visible.[30] Lastly, Kijima et al[27] harvested 15 thoracodorsal C-shaped adipofascial cutaneous flaps with a crescent-shaped dermis for outer quadrant defects (Fig. 5).

The anatomical landmark to identify the emergence of the proximal perforator corresponded to an area located 8 cm below the posterior axillary fold and 2 cm

Table 1. Preoperative Characteristics

Authors	Type	Sample	Age	Rec Time	Defect	Specimen Weight
Hamdi et al,[18] 2004	P	18+10 MS-LD	—	Immediate	All quadrants	—
Ortiz et al,[23] 2007	R	9	46.7	Immediate	UOQ	—
Hamdi et al,[24] 2008	P	22	52.5	Immediate	—	—
Hamdi et al,[25] 2008	R	78 (10 MS-LD 6 → I 4 → II)	44 (17–69)	Immediate 73 Secondary 5	All quadrants	—
Yang et al,[26] 2012	R	12	46.1 (27–65)	Immediate	UOQ 7 UIQ 3 LOQ 2	<150 g Mean: 112.6 g
Kijima et al,[27] 2013	R	28 (15 TDAP control + 13 control group)	—	Immediate	Columnar-shaped partial mastectomy (outer quadrants) Control group: 10 → UO or LO quadrantectomy 3 → columnar-shaped partial mastectomy (outer quadrants)	—
Lee et al,[28] 2014	P	20	45.7 (23–65)	Immediate	UOQ 11 LOQ 3 UIQ 5	>50<150 g Mean: 99.2
Jacobs et al,[29] 2015	R	8	53 (32–73)	Immediate → 6 Secondary → 2	Postlumpectomy	—
Kim et al,[30] 2017	P	14 (+19 LICAP)	47.2 ± 7.76	Immediate	LOQ → 8 UOQ+LOQ → 6	81.42 ± 24.73 g
Amin et al,[31] 2017	P	40 TDAP → 2 MS-LD I → 38	41 (34–52)	Immediate	ie, patients who needed volume replacement	20% or more of breast volume
Youssif et al,[32] 2019	R	6+20 MS-LD	45 (23–61)	Secondary	UOQ, LOQ, LIQ, central NO UIQ	20%–40% of breast volume (mean 27%)
Abdelrahman et al,[33] 2019	Pr	42 (21 → 21 LD control group)	40.33 ± 5.25	Immediate	UOQ 9 LOQ 2 UIQ 5 LIQ 5	—

KNUH, Kyungpook National University Hospital; LD, latissimus dorsi; LICAP, lateral intercostal artery perforator; LIQ, lower inner quadrant; LO, lower outer; LOQ, lower outer quadrant; P, prospective; Pr, prospective randomized; R, retrospective; UIQ, upper inner quadrant; UO, upper outer; UOQ, upper outer quadrant.

behind the anterior border of LD muscle, as previously described.[18,24,33] Additionally, Amin et al[31] reported that at least 1 perforator vessel could be found in 80% of the cases in a quadrant created through the intersection of 4 lines: 2 horizontal lines 9 cm and 11 cm downward from the posterior axillary fold and 2 vertical lines 1 cm and 4 cm medial to the anterior border of LD muscle.

Harvesting Technique

In all cases, patient positioning was in lateral decubitus, leaving the upper limb in neutral abduction (90 degree of shoulder abduction and 90 degree of elbow flexion).

Most authors began the dissection from the anterior and caudal border of the flap, progressing in a distal to proximal and medial to lateral direction. This type of dissection allowed operators to check for the septocutaneous perforator possibly located anteriorly to the LD muscle and to keep open the option of converting the TDAP flap to a musculocutaneous flap. Both suprafascial and subfascial dissections were described. Some authors described an extended version of the TDAP flap by incising the skin paddle to the deep plane in a beveled angle to include the maximum available fat and increase the flap's volume.

Perforators pulsating and showing a caliber greater than 0.5 cm were considered suitable by most authors; perforators originating in the descending branch of the thoracodorsal artery over those originating in the transverse branch were generally preferred because of their more simplified dissection. Hamdi et al described that when tiny but pulsating perforators were found, the TDAP flap was converted to an MS-LD flap including 2–4 cm of muscle around the vessels (MS-LD type I).[18] In the same articles, when tiny and no pulsating perforators were found, the TDAP flap was converted to an MS-LD flap type II, including 5 cm of muscle (MS-LD type II). Conversely, Jacobs et al[29] considered the MS-LD flap (including a muscle strip of 4 cm) the first choice, taking into account that it is more robust, reliable, and easier in harvesting when compared with the TDAP flap. In their series, the TDAP flap was reserved for small outer half partial breast defects.

In some articles, thoracodorsal vessels were dissected until their origin to provide a long pedicle. Other authors retained that the dissection should progress until enough length was achieved to allow for insetting of the flap in the breast defect without tension. Nerve branches were carefully preserved in every case of TDAP flap. One author described intraoperative assessment of flap's perfusion using an indocyanine green angiography.[27]

The flap was rotated by different degrees (from 90 degree to 180 degree as a propeller flap) depending on the orientation of the skin paddle and the topography of the breast defect and it was passed through a tunnel created under the lateral breast. In cases of propeller flap harvesting, Jacobs et al[29] reported that the perforator was not

Table 2. Intraoperative Characteristics

Authors	Preoperative Assessment	Patient Positioning	Flap Design	Dissection	Flap Size	Perforators	Operative Time
Hamdi et al,[18] 2004	Doppler Pinch test	Lateral decubitus position with 90 degree of shoulder abduction and 90 degree of elbow flexion	Extended over the anterior border of the LD muscle Oblique upward or transversal	Dissection bevelled to include a maximum of fat Flap elevation starts from anterior and caudal border Nerve branches preserved Dissection above the fascia The TD vessels are dissected proximally until their origin Only when the dissection of the vessels is complete, the skin paddle can be raised from the LD muscle When tiny perforators are found, an MS technique is used	20 × 8 cm (length 16–25/ width 6–10 cm)	Pulsating and >0.5 cm Originating from the descending branch preferentially 13 → 1 perforator 5 → 2 perforators	2.5 h (1.5–3 h)
Ortiz et al,[23] 2007	Echo Doppler	Lateral position, leaving the upper limb in neutral abduction	Central point located 8 cm below the posterior axillary fold and 2 cm behind the anterior border of the LD muscle	Desepidermization of the skin area before the raising of the flap Flap elevation starts from anterior border Subfascial dissection (after dissection, limit the amount of fascia up to 1 cm around perforator) Nerve branches preserved Flap is tunneled in every case toward the defect Vessel dissection until enough length is achieved to allow insetting of the flap in the breast defect without tension	21 × 8 cm	7 → 1 perforator 1 → 2 perforators	—
Hamdi et al,[24] 2008	—	—	—	—	—	—	—
Hamdi et al,[25] 2008	Unidirectional Doppler probe (8 Hz) simulate operative positioning	Lateral decubitus position with 90 degree of shoulder abduction and 90 degree of elbow flexion	Extended over the anterior border of the LD muscle Oblique upward or transversal	Flap elevation starts from anterior and caudal border Nerve branches preserved Dissection above the fascia The TD vessels are dissected proximally until their origin Only when the dissection of the vessels is complete, the skin paddle can be raised from the LD muscle Flap is pulled through the muscle and transposed into the defect Partial or total deepithelization (flap can be folded to increase projection) When tiny perforators are found, an MS technique is used	20 × 8 cm 16–25/6–10	Pulsating and >0.5 cm Originating from the descending branch preferentially 89 → 1 perforator 7 → 2 perforators 90 → from the descending branch 6 → from the transverse branch 2 → direct septal perforator	Harvesting time = 80′ (25′–120′)
Yang et al,[26] 2012	—	Lateral decubitus position	Oblique downward	—	—	—	—

(*Continued*)

Table 2. (*Continued*)

Authors	Preoperative Assessment	Patient Positioning	Flap Design	Dissection	Flap Size	Perforators	Operative Time
Kijima et al,[27] 2013	—	—	TDAP cutaneous flap with a crescent-shaped dermis	Tumor resection via an incision at the anterior axillary line (lazys-shaped, s-shaped ellipse, or leaf-shaped incision if skin was included in the resection) Crescent-shaped dermis TDAP flap involved 5 steps: 1. Formation of a de-epithelialized crescent of skin along the incision line 2. Raising a C-shaped cutaneous flap of fat attached to the fascia of the LD 3. Rotation of the flap into the defect 4. Trimming or gathering the flap to adjust it to the shape of the contralateral breast 5. Fixing the flap to the edge of the remaining breast Indocyanine green angiography	—	—	Total = 127′ Reconstruction = 62′ Control group: Total = 169′ Reconstruction = 51′
Lee et al,[28] 2014	Pinch test	—	Transversally oriented	—	—	—	—
Jacobs et al,[29] 2015	Doppler	Lateral decubitus position	Extended over the anterior border of the LD muscle Oblique downward oblique	Flap raised in an extended version incising the skin paddle to the deep fascia in a beveled angle to harvest more subcutaneous tissue and fascia than skin Perforator was not skeletonized, and the muscle fibers surrounding were left undissected At times, a limited back-cut into the anterior border of the LD inferior to the perforator was helpful to facilitate the rotation. The flap was either rotated 140 degree to 160 degree as a propeller to the anterior thorax or completely deepithelialized and turned over to be buried (flipover design)	From 7 × 21 to 11 × 37 cm	Originating from the descending branch preferentially 1, 2, or 3	200′ (60′–485′)
Kim et al,[30] 2017	3D Chest computed tomography angiography Pinch test	Lateral decubitus position	Transversally or vertically oriented (in consultation with the patient)	Dissection until enough length is achieved to allow insetting of the flap in the breast defect without tension	6 × 14.2 Range: 4 × 12 to 8 × 18	—	267.3′ ± 35.3′
Amin et al,[31] 2017	Doppler	Lateral decubitus position	Transversally oriented	At least 1 perforator or 2 are present, in 80% of cases, in a quadrant formed through the intersection of four lines: Two horizontal lines 9 and 11 cm downward from the level of the posterior axillary fold with the arm abducted 90 degrees and Two vertical lines 1 and 4 cm medial to the anterior border of LD	18 × 9 cm Length range: 14–23 cm Width range: 7–12 cm	2 → TDAP 38 → MS-LD I	227′ (310′–180′)

(*Continued*)

Table 2. (*Continued*)

Authors	Preoperative Assessment	Patient Positioning	Flap Design	Dissection	Flap Size	Perforators	Operative Time
Youssif et al,[32] 2019	Doppler Pinch test	Lateral decubitus position	Extended over the anterior border of the LD muscle Transversally oriented	6 → TDAP 20 → MS-LD II Tunnel from the donor site to the breast approximately at 4 o'clock position to inset the flap (allows preservation of the natural lateral breast borders with no disruption of the axillary silhouette)	Max: 9 × 21 cm	—	—
Abdelrahman et al,[33] 2019	Doppler Pinch test	Lateral decubitus position	Extended over the anterior border of the LD muscle Transversally oriented	Dissection was beveled outward to include the maximum fat, beginning from the anterior side along the suprafascial plane When the anterior border of the muscle was reached, a tunnel was created under the lateral breast mound and lateral thoracic wall Vascular pedicle was dissected until enough length was achieved to allow insetting of the flap in the breast defect without tension	—	—	155.7′ ± 9.26′

3D, 3 dimensional; TD, thoracodorsal.

completely skeletonized, leaving some undissected muscle fibers surrounding the vessel and that it was sufficient in the majority of cases to enable tension-free rotation of the flap. However, the author specified that additional perforator and muscle dissection were needed in some cases. In a series of delayed partial breast defect reconstructions, Youssif et al[32] described the creation of a tunnel from the donor site to the breast at approximately 4 o'clock position to inset the flap to preserve the natural lateral breast border with no disruption of the axillary silhouette. Jacobs et al[29] reported that, at times, a limited back-cut into the anterior border of the LD inferior to the perforator was helpful to facilitate the rotation.

Partial or total deepithelization of the skin paddle was performed depending on the defect, and the flap was folded to increase breast projection when necessary.

Flap Characteristics

Eight studies reported the average flap size as ranging from 4 × 12 to 21 × 9 cm. Range of flap length varied from 12 to 37 cm and range of flap width varied from 4 to 12 cm. The number of perforators included in the flap ranged from 1 to 3. In most of the cases, the perforator vessel originated in the descending branch. Hamdi et al reported 6 TDAP flaps that were harvested on a perforator vessel originated in the transverse branch and 2 TDAP flaps were harvested on a septocutaneous perforator vessel.[24–25]

The mean procedure time (breast surgery and plastic surgery) was 192.21 minutes (range, 60–485 minutes). The mean operative time of flap harvesting was only reported by 2 studies and was recorded as 77 minutes (range, 25–120 minutes).

Mean follow-up was 17.42 months (range, 1–52 months).

Cosmetic Results

Eight out of 12 studies reported aesthetic results. Aesthetic outcomes were evaluated in 4 of the studies[26,28,31,33] using the 5-point Likert scale considering symmetry, color match, consistency of the flap, appearance of scars, and overall satisfaction. Two studies[26,28] reported a mean value of 4.08 and 4.13. The other 2 studies reported that cosmetic results were considered as excellent or good in 62.5% and in 76.2% of cases, respectively.[33] The latter consisted of a prospective randomized study that compared 2 groups of patients who had undergone LD flap (group A) reconstruction and TDAP flap (group B) reconstruction. Although the percentage of satisfactory outcomes was higher in group A (80.9% versus 76.2%), no statistically significant difference was seen between the 2 groups in terms of aesthetic outcomes and patient satisfaction. Subjective assessment of the aesthetic results was described in 3 studies.[23,29,32] In detail, the achievement of satisfactory outcome in 100% of cases was reported in 2 articles, and 92.85% satisfaction was reported in the third study. Yang et al[26] analyzed the use of different types of local flaps in partial breast defects, reporting similar results in terms of aesthetic satisfaction with LD flap and the TDAP flap showing higher scores than the others (lateral thoracodorsal flap, thoracoepigastric flap, and intercostal artery perforator flap). Kijima

Table 3. Outcomes

Authors	Follow-up	RT	Aesthetic Outcomes	Functional Outcomes (Shoulder Morbidity)	Patient Satisfaction	Complications	Donor Site Morbidity
Hamdi et al,[18] 2004	—	—	—	—	—	1 partial necrosis	1 wound dehiscence
Ortiz et al,[23] 2007	—	—	Satisfactory in all cases	—	—	1 hematoma	Any complication
Hamdi et al,[24] 2008	19.4 (6–45)	All pts	—	LD strength and thickness of the anterior border of the LD: statistically comparable values between operated and unoperated sides Shoulder mobility: statistically comparable range of motion between operated and unoperated sides in most of the different movements Significant decreases in active and passive forward elevation and passive abduction of the operated shoulder compared with the unoperated side	—	—	—
Hamdi et al,[25] 2008	—	All pts	—	—	—	1 major flap necrosis (immediate) debridement + second flap surgery 2 partial flap loss	1 wound dehiscence Seroma formation in all cases of MS type II flaps but in none of the TDAP or MS type I flaps
Yang et al,[26] 2012	10.3 (4–21)	93.3% postoperative 3.8% preoperative	5-point Likert scale Mean aesthetic score (3 plastic surgeons) = 4.08 LD flap and TDAP flap had higher scores than the others local flaps	—	Michigan Breast Reconstruction Outcomes Survey General satisfaction: 85% Aesthetic satisfaction: 75%	0	0
Kijima et al,[27] 2013	11 (1–23)	26.6% (4 pts)	Cosmetic scale (Japanese Breast Cancer Society) Excellent: 4/11 Good: 7/11 Control group Excellent or Good: 5/13 Poor: 8/13	—	—	1 wound healing delay due to a partial flow disorder	Any complication
Lee et al,[28] 2014	11.3 (4–23)	—	KNUH breast reconstruction satisfaction questionnaire (5-point Likert scale) Mean score (3 plastic surgeons): 4.13	—	KNUH breast reconstruction satisfaction questionnaire 81.3% satisfactory results	0	0

(*Continued*)

Table 3. (*Continued*)

Authors	Follow-up	RT	Aesthetic Outcomes	Functional Outcomes (Shoulder Morbidity)	Patient Satisfaction	Complications	Donor Site Morbidity
Jacobs et al,[29] 2015	15.2 (0.3–38.2)	(16 pts previous RT)	Satisfactory results 100% of cases	Very low morbidity	—	—	0
Kim et al,[30] 2017	25.2 ± 8.69	All pts	Physician satisfaction: Excellent: 7 cases Good: 5 cases	—	Patient satisfaction Excellent: 7 cases Good: 4 cases	7 patients 2 wound disruptions that required major revision 4 linear necrosis healed secondarily 1 fat necrosis required additional treatment	0
Amin et al,[31] 2017	—	All pts	5-point Likert scale Excellent: 2 Good: 23 Fair poor: 12 Very poor: 3	Subjective assessment: average time patients needed to regain full range of motion of their shoulder joints after operation → 10 days (range 7–16)	5-point Likert scale Excellent: 4 Good: 28 Fair poor: 6 Very por: 2	8 patients 1 hematoma 2 minor wound infection (dressings) 4 flap congestion: reversible in 3 patients within 48 h; progressed to superficial sloughing in 1 patient	Any complication
Youssif et al,[32] 2019	24.8 (9–52)	All pts	Satisfactory	No reported cases of shoulder muscle power deficit	Patient questionnaire survey: overall satisfaction reached 94%	1 fat necrosis	Any complication 1 scar revision for excess skin at the axillary fold in 1 patient
Abdelrahman et al,[33] 2019	12	All pts	Satisfactory results including "excellent" and "good" outcomes group A: 80.9%; group B: 76.2%; No significantly difference	Shoulder Pain And Disability Index Group B: significantly less shoulder disability compared with group A ($P < 0.001$).	Excellent: 6 Good: 10 Fair: 3 Poor: 2 Bad: 0	1 hematoma 1 infection 2 wound dehiscence, partial flap loss	1 seroma

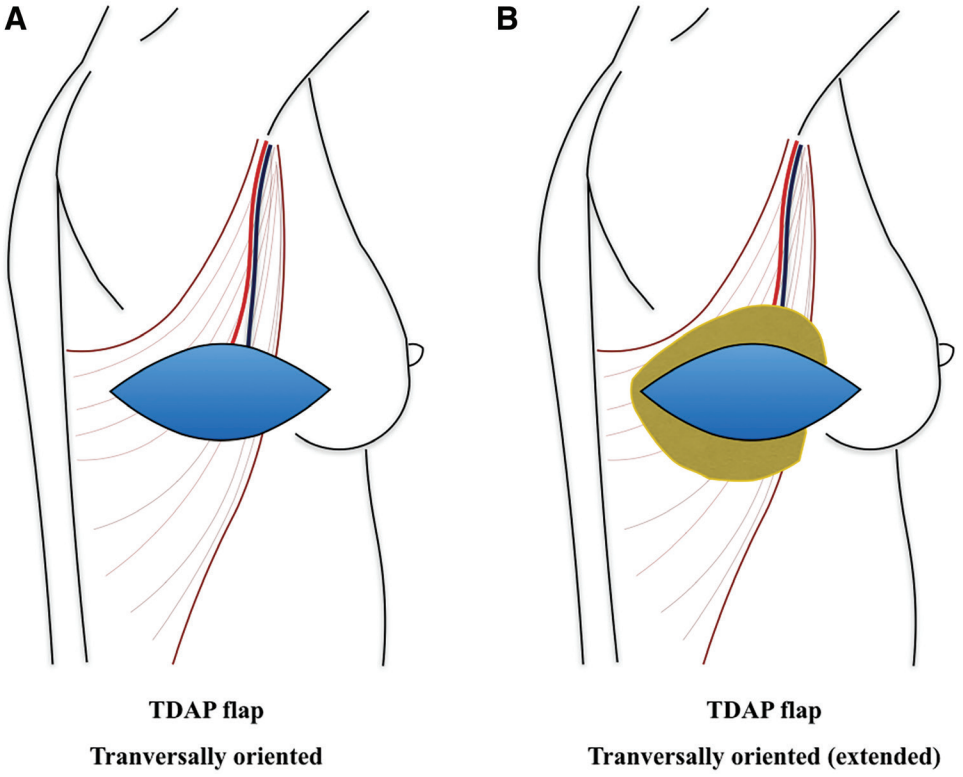

Fig. 2. A, TDAP flap with a transversally oriented skin paddle (blue). B, Extended TDAP, including subcutaneous tissue (yellow) on both sides, to increase flap volume.

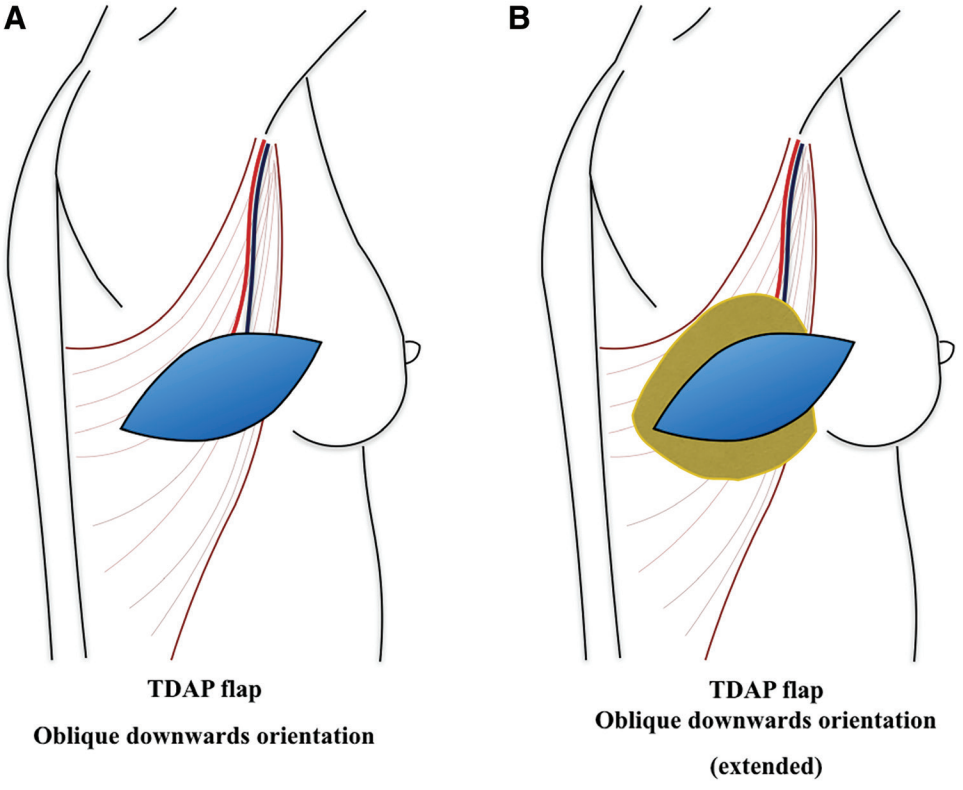

Fig. 3. A, TDAP flap with an oblique downward skin paddle (blue). B, Extended TDAP, including subcutaneous tissue (yellow) on both sides, to increase flap volume.

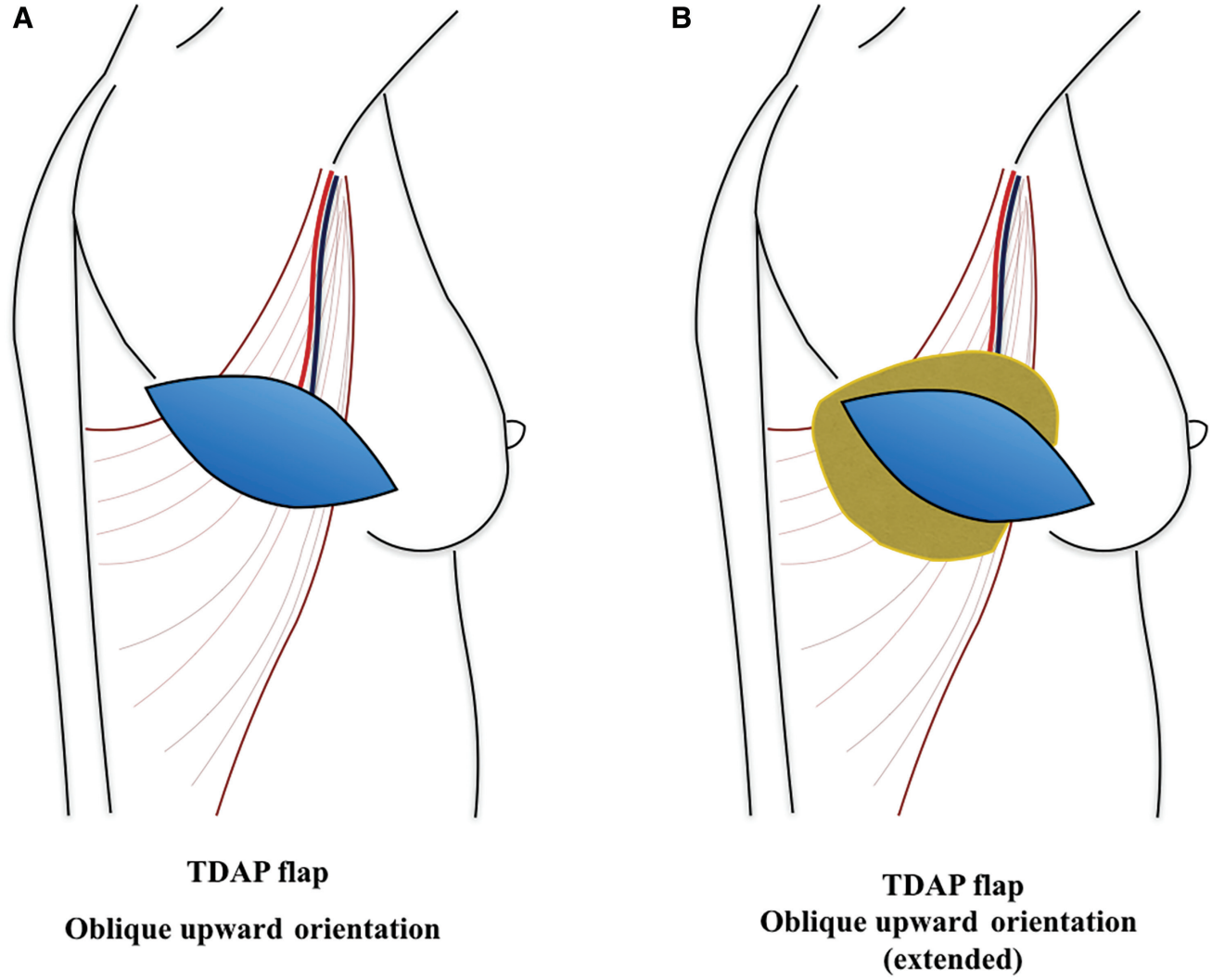

Fig. 4. A, TDAP flap with an oblique upward skin paddle (blue). B, Extended TDAP, including subcutaneous tissue (yellow) on both sides, to increase flap volume.

et al[27] reported that the number of patients cosmetically evaluated as good to excellent was higher (11/11) among patients with immediate volume replacement using a TDAP flap compared with the control group (5/13) of those who had undergone BCS without plastic surgery procedures. In this study, patients were evaluated using the cosmetic scale of the Japanese Breast Cancer Society.[27]

An estimated 9 of 12 studies reported details regarding postoperative RT. In 7 studies, all of the patients underwent postoperative RT. In 1 study where 26.6% of the patients underwent postoperative RT, aesthetic outcomes in irradiated versus nonirradiated patients were compared 12 months postsurgery or after the end of the adjuvant treatment. In detail, among the 4 patients treated with postoperative RT, 1 was evaluated as having an excellent aesthetic outcome and 3 were considered to have an excellent aesthetic outcome; among the 7 patients without postoperative RT, 3 were evaluated to have an excellent aesthetic outcome, and 4 were evaluated to have a good cosmetic outcome. In this study, RT did not affected aesthetic outcomes.

Figure 6 shows a patient who underwent delayed partial breast reconstruction using a TDAP flap.

Functional Results (Shoulder Morbidity)

Shoulder morbidity was evaluated in 5 of 12 studies. Postoperative physiotherapy was reported by 2 studies. One study[24] selectively investigated the shoulder function after harvesting a TDAP flap on 16 patients, comparing the operated side with the unoperated side. This study analyzed LD muscle strength and thickness describing comparable values between operated and unoperated sides. Shoulder mobility showed a comparable range of motion in all movements except active and passive forward elevation and passive abduction. Abdelrahman et al[33] compared a group of patients who had undergone LD flap (group A) and a group of patients who had undergone TDAP flap (group B) by use of the Shoulder Pain And

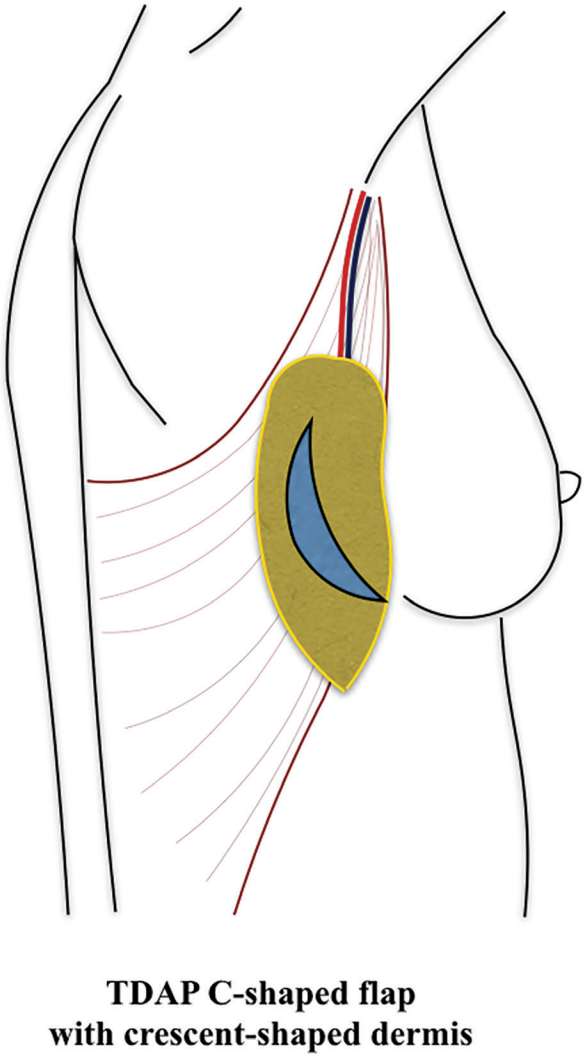

Fig. 5. Thoracodorsal C-shaped adipofascial (yellow) flaps with a crescent-shaped dermis (blue) for outer quadrants defects.

Disability Index and described significantly less shoulder disability in group B ($P < 0.001$).

Amin et al[31] reported that the average time needed to regain the full range of motion of shoulder joints after MS-LD type-I or TDAP operation was 10 days with a range of 7–16 days. Although a formal evaluation of shoulder morbidity was not performed, Youssif et al[32] reported that no patient described shoulder muscle power deficit.

Patient Satisfaction

Six of 12 studies reported data about patient satisfaction using 5-point Likert Scale[28,30,31,33] (4 studies), the Michigan Breast Reconstruction Outcomes Survey[26] (1 study) or an unspecified patient questionnaire. Patient satisfaction was expressed as a percentage by 3 studies ranging from 80% to 94% of cases. In the other 3 studies, 32 of 40, 16 of 21, and 11 of 14 patients evaluated their reconstructive results as good or excellent.

Complications

The overall complication rate was 7.92. A partial flap necrosis was described in 17 patients (5.610%). In detail, in 3 cases, the partial flow disorder was reversible within 48 hours; in 11 cases, the partial flow disorder caused a wound healing delay; and in 3 cases, a major surgical revision was needed. In most cases, the partial flap necrosis was described as being on the edge opposite to the perforator vessel.

Major flap necrosis was reported in only one case (0.330%), which required a secondary flap surgery. Hematoma formation and wound infection were both described in 3 cases (0.990%).

Donor Site

Among all patients, only 3 cases of wound dehiscence were reported. One study described the onset of seroma at the donor site after the TDAP flap, which, in 1 case, was resolved by aspiration. Hamdi et al[18] reported that seroma formation was encountered in all cases of muscle-sparing TDAP type II flaps (4 patients) but in none of the TDAP flaps or muscle-sparing TDAPs type I.

Scar revision for excess skin at the axillary fold was necessary in 1 patient.

DISCUSSION

Oncoplastic intervention after BCS represents one of the most common procedures reconstructive surgeons

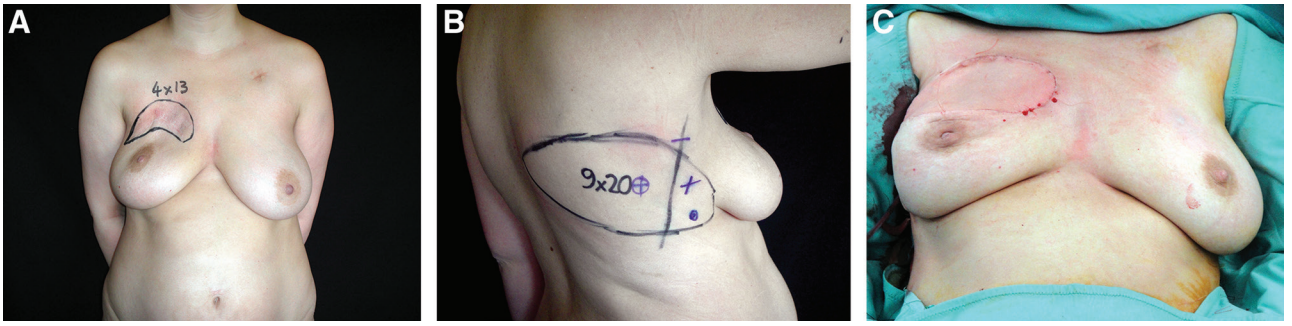

Fig. 6. Photographs of a patient who underwent a delayed partial breast reconstruction (upper quadrants) using a TDAP flap. A, Preoperative. B, Flap design (oblique upward skin paddle). C, Surgical result.

face daily, including both volume replacement and volume displacement techniques. Differently from volume displacement techniques, symmetrization of the contralateral breast is usually not required in cases of volume replacement techniques.[6,12,13] Standardized algorithms are not available, but many articles have been published in the attempt to provide a guide to help oncoplastic breast surgeons decide the best surgical procedure to apply to each single case. In a recent review,[9] the indication for either volume displacement or volume replacement techniques was essentially based on the expected percentage of breast volume excised: up to 10%, the result is considered satisfactory using simple wide local excisions, in cases between 10% and 20% of breast volume loss the use of volume displacement techniques should be favored, finally, for resections above 20% more complex approaches using tissue transfer and volume replacement are indicated. Volume replacement procedures have evolved over time allowing for several reconstructive options mainly represented by local perforator flaps. The TDAP flap constitutes the minimally invasive evolution of the LD flap, offering the possibility to preserve the LD muscle and thus reducing donor site morbidity. The current article includes 337 patients and provides a comprehensive review regarding the use of the TDAP flap after BCS. The articles included presented at least a level of evidence IV and 2 randomized control trials, as well as one prospective. Our analysis confirmed that this flap has great versatility and is useful for reconstructing breast defects of different topographies. In fact, except for one article that excluded a patient with tumor location in the upper inner quadrant, all authors agreed that the TDAP flap can safely reach every breast quadrant. Angrigiani et al[34,35] compared the differences in the "reaching distances" between propeller and island TDAP flaps. This study reported that the propeller TDAP flap is easier to harvest, which reduces operating time by approximately 30 minutes, but has about an 8.4 cm shorter reach in comparison with the island TDAP flap.[35] This limit is crucial when the breast defect is located in the inner quadrants. Converting the propeller flap into a conventional island TDAP flap and dissecting the pedicle until its origin allows for the maximization of the flap-reaching distance, making volume replacement possible in upper and lower inner quadrants. In our review, some authors described that thoracodorsal vessels were dissected until their origin in all cases to provide the longest possible pedicle. Other authors retained that the dissection should progress until enough length has been achieved to allow for insetting of the flap in the breast defect without tension.

While the TDAP flap reduces the morbidity of the donor site, it presents one main disadvantage: its lack of volume.[36,37] In 2015, Gunnarsson et al[38] and Angrigiani et al[39] described the extended version of the TDAP flap, which included additional fat tissue on each side of the skin paddle to allow for a more voluminous flap. Dast et al,[36] in a recent anatomical study, reported that the TDAP flap via the deep muscular fascial network allows for a harvest flap with a mean surface of 441 cm^2 and a mean volume of 193 g. In select cases, the TDAP flap can also achieve total breast reconstruction alone or in combination with fat grafting.[19] In our review, partial breast defects varied from lumpectomy to outer columnar mastectomy. However, the average weight of resected breast tissue was relatively moderate (about 100 g; <150 g). Different authors have harvested extended versions of the TDAP flap, incising the skin paddle to the deep plane in a beveled angle to include the maximum of fat and increase flap volume.

One of the main advantages of the TDAP flap compared with others perforator flaps available in the thoracic region is that, depending on the perforator caliber, it can be converted in an MS-LD flap by including a part of LD muscle to protect the perforators, sparing the nerves that innervate the rest of the LD muscle. In our review, 78 patients underwent an MS-LD flap. In detail, in 58 cases, an intraoperative conversion from a TDAP flap to an MS-LD flap was necessary due to inadequate perforator vessels. Hamdi et al[24] distinguished 2 types of MS-LD based on the amount of muscle included in the flap. The MS-LD type I increased flap safety by preserving a 2 cm cuff of LD muscle around the perforator vessel posteriorly; the MS-LD type II allows for the incorporation of the maximum number of perforator vessels, including 5 cm of muscle longitudinally where the perforators are identified. When the perforators are <0.5 mm but pulsatile, the TDAP flap should be converted to an MS-LD type I. When the perforators are <0.5 mm and nonpulsatile, the TDAP flap should be converted to an MS-LD type II. Contrariwise, Youssif et al[32] considered the MS-LD flap as the first choice and included 4 cm of muscle around the perforator vessels, while reserving the TDAP flap for small outer half partial breast defects.

Most of the authors began the dissection from the anterior and caudal border of the flap to preserve the possibility to convert the TDAP to a musculocutaneous flap and to check for septocutaneous perforators. Septocutaneous perforators are located anteriorly to the LD muscle having a circummuscular course.[40–42] These were present in about 60% of cases[40,42] and allow for the avoidance of intramuscular dissection and thus shorten operative time. In our review, Hamdi et al reported septocutaneous TDAP flaps in 2 cases.[24–25] However, most of the authors suggested extending the skin paddle over the anterior border of the LD muscle to include possible septocutaneous perforators vessels and/or to reach the lateral border of the inframammary fold when indicated. Regarding flap orientation oblique downward, transversal and oblique upward designs were all described. Hamdi et al considered that the oblique upward design best matched with the related TDAP angiosome area, which is parallel to the ribs as described by Taylor.[43] Other authors took into consideration patient preference, orienting the skin paddle either horizontally or vertically. Another option was the C-shaped TDAP flap, which was also proposed when reconstructing lateral columnar-shaped partial mastectomy through an anterior axillary incision. This included forming a crescent-shaped patch of excised skin along the incision line and

raising a C-shaped cutaneous flap of fat attached to the fascia of the LD muscle, rotating horizontally into the defect and its trimming or gathering to adjust it to the shape of the contralateral breast.

Despite the heterogeneity of the rating scales, our systematic review suggested that the use of the TDAP flap in oncoplastic surgery allows for satisfactory aesthetic outcomes and quite high levels of patient satisfaction.

RT can lead to many unfavorable aesthetic outcomes including significant volume and skin deficiency, as well as nipple areola complex distortion. According to our analysis, even in cases of postoperative RT, aesthetic results and patient satisfaction were satisfactory in most of cases. However, the relatively significant variability of follow-up time and the heterogeneity of outcome evaluation methods represented considerable limitations on the outcome analysis.

The LD muscle plays a crucial role in providing stability to the glenohumeral joint, as well as in extension, adduction, and medial rotation. Previous studies strongly suggested a substantial difference in terms of "shoulder-related" donor site morbidity between LD and TDAP flaps.[44] In our review, only one study noted shoulder morbidity in active and passive forward elevation and passive abduction.[24] All the extracted data confirmed significantly less shoulder disability in patients who had undergone TDAP flap versus LD flap.

The overall complication rate was 7.92, and the most common complication was partial flap necrosis, often described at the edge opposite to the perforator vessel. Donor site morbidity was very low. Our review confirmed that the incidence of seroma formation after TDAP flap was significantly lower when compared with LD flap, where seroma was described in more than 60% of cases.[45]

CONCLUSIONS

According to our research, this is the first systematic review on the use of the TDAP flap in partial breast defects. Our analysis highlights the great versatility of this flap for volume replacement in cases of moderate partial breast defects of varying topographies. In fact, most of the authors described partial breast reconstruction of every breast quadrant by harvesting the TDAP flap as propeller or island flap. Moreover, the intraoperative adjustability of the TDAP flap (starting the dissection from the anterior and caudal border) allows it to be converted into an MS-LD in cases of a tiny perforator vessel, maintaining low morbidity on the donor site.

Despite the heterogeneity of the evaluation methods, our review suggested that the use of the TDAP flap in oncoplastic surgery allows for overall satisfactory aesthetic outcomes and quite high levels of patient satisfaction. The incidences of seroma formation and "shoulder-related" donor site morbidity were very low.

In conclusion, the TDAP flap represents an effective and versatile tool that amplifies the arsenal of oncoplastic surgeons, associating the benefits of perforator flaps (minimal donor site morbidity) with the advantages of pedicled flaps (safety) and allowing for satisfactory cosmetic outcomes.

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