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REVIEW

Soft tissue augmentation around osseointegrated and uncovered dental implants: a systematic review

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Abstract
Objectives The aim was to compile the current knowledge about the efficacy of different soft tissue correction methods around osseointegrated, already uncovered and/or loaded (OU/L) implants with insufficient soft tissue conditions. Procedures to increase peri-implant keratinized mucosa (KM) width and/or soft tissue volume were considered.
Materials and methods Screening of two databases: MEDLINE (PubMed) and EMBASE (OVID), and manual search of articles were performed. Human studies reporting on soft tissue augmentation/correction methods around OU/L implants up to June 30, 2016, were considered. Quality assessment of selected full-text articles to weight risk of bias was performed using the Cochrane collaboration's tool.
Results Overall, four randomized controlled trials (risk of bias = high/low) and five prospective studies (risk of bias = high) were included. Depending on the surgical techniques and graft materials, the enlargement of keratinized tissue (KT) ranged between 1.15 ± 0.81 and 2.57 ± 0.50 mm. The apically positioned partial thickness flap (APPTF), in combination with a free gingival graft (FGG), a subepithelial connective tissue graft (SCTG), or a xenogeneic graft material (XCM) were most effective. A coronally advanced flap (CAF) combined with SCTG in three, combined with allogenic graft materials (AMDA) in one, and a split thickness flap (STF) combined with SCTG in another study showed mean soft tissue recession coverage rates from 28 to 96.3 %. STF combined with XCM failed to improve peri-implant soft tissue coverage.
Conclusions The three APPTF-techniques combined with FGG, SCTG, or XCM achieved comparable enlargements of peri-implant KT. Further, both STF and CAF, both in combination with SCTG, are equivalent regarding recession coverage rates. STF + XCM and CAF + AMDA did not reach significant coverage.
Clinical relevance In case of soft tissue deficiency around OU/L dental implants, the selection of both an appropriate surgical technique and a suitable soft tissue graft material is of utmost clinical relevance.

Keywords Peri-implant keratinized attached mucosa · Soft tissue recession · Soft tissue volume · Dental implant · Subepithelial connective tissue graft · Free gingival graft · Vestibuloplasty · Xenogeneic collagen matrix

Introduction

The need of a minimal width of keratinized tissue (KT) to maintain periodontal health is still controversially discussed in the literature [1]. Previous findings have indicated that a KT width of less than 2 mm exhibits more frequently clinical signs of inflammation, whereas 80 % of sites showing ≥2 mm of KT remained healthy. It was thus concluded that in order to maintain periodontal health, an adequate width of KT (≥2 mm) may be necessary [2]. These findings were later challenged by others demonstrating that clinical signs of inflammation may be detected irrespective of KT width [3]. Currently, it is accepted that, there is no need of a minimal width of attached gingiva for periodontal health around natural teeth [4–6].

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Nevertheless, the presence of an adequate width of KT might be important in specific situations, particularly in cases where the teeth are provided with fixed prosthetic restorations with subgingivally placed margins [7].

Soft tissue around teeth is subdivided into gingiva and mobile mucosa. However, in implant dentistry, the peri-implant soft tissues are inconsistently described [8]. Despite many similarities, the anatomy and soft tissue around teeth differ from that around implants [8] regarding the amount of blood supply [9], the direction of connective tissue fibers (implants = parallel, teeth = perpendicular) [10, 11], the amount of fibroblasts and collagen fibers [10, 12], the permeability of junctional epithelium [13], and the presence of a minimal width of attached keratinized soft tissue at teeth [14, 15].

The role of an adequate width of keratinized mucosa (KM) around dental implants on the long-term stability of peri-implant tissues is still a matter of debate [16–28]. Early animal [24] and human studies [16, 17, 21, 26] reported no correlation between implant success and the presence of KM. In contrast, three earlier studies have shown that implant sites without an adequate band of KM exhibit an increased susceptibility to inflammation and adverse peri-implant soft and hard tissue reactions [18, 25, 28]. While earlier reviews identified insufficient reliable evidence regarding the possible influence of the width of KM and peri-implant disease [19, 20, 23], recent publications suggest that an inadequate width and thickness of peri-implant KM may lead to more plaque deposition [29–33], increased mucosal inflammation [29, 31, 32, 34, 35], higher risk of peri-implant alveolar bone loss [34], as well as increased soft tissue recessions [29, 32, 33, 36] and clinical attachment loss [36]. Additionally, there is evidence that the width of peri-implant KM has an influence on immunological parameters [35, 37]. Thus, recent systematic reviews concluded that an inadequate width of peri-implant KM is associated with more plaque accumulation, signs of inflammation, soft tissue recession, and attachment loss [27, 38–40]. Furthermore, the peri-implant mucosa appears to possess less potential for an immune response against external irritations (plaque accumulation) [41].

Basically, two different methods can be applied to augment peri-implant soft tissue:

1. KM width enlargement using an apically positioned flap/vestibuloplasty (in combination with a free gingival graft (FGG) or an allogeneic or xengenic graft material).
2. Soft tissue volume gain by means of a subepithelial connective tissue graft (SCTG) or soft tissue replacement grafts.

In order to increase the width of KM or the mucosal thickness around dental implants, four different time points are distinguishable [42]: (a) before the implant placement, (b) during the implant placement, (c) during the second-stage surgery (re-entry), or (d) after the implant is osseointegrated, uncovered, and eventually, already loaded. The first three protocols seem to result in more predictable clinical outcomes, whereas the forth protocol might be challenged by esthetic problems or complications such as mucositis or peri-implantitis [8, 43, 44].

According to a recent systematic review, the implant localization in the jaw and the clinical situation have to be considered for the choice of a second-stage procedure [45]. Currently, there is scarce evidence on the outcomes of soft tissue augmentation/correction methods after uncovering or loading (time point *d*) around implants with insufficient peri-implant soft tissue conditions (soft tissue recession (Fig. 1a–c), inadequate width of peri-implant KM (Fig. 2a–c), or irritations caused by buccal frena (Fig. 3a–c)).

Thus, the aim of this systematic review was to compare different soft tissue augmentation/correction methods focusing on their effect on peri-implant KM width and/or soft tissue volume at osseointegrated, already uncovered and/or loaded (OU/L) dental implants with insufficient soft tissue conditions.

Materials and methods

Focused question

Applying the PICO criteria, the following focused question was formulated for the specific literature search [46]: *P* patients with insufficient soft tissue conditions around OU/L dental implants (soft tissue recession, inadequate width of peri-implant keratinized mucosa (KM), movements caused by buccal frenula); *I* soft tissue surgery to improve the peri-implant soft tissue conditions; *C* different soft tissue augmentation/correction methods, peri-implant soft tissue conditions before and after surgical soft tissue augmentation/correction procedures; and *O* efficacy of different soft tissue augmentation/correction methods in terms of increasing the peri-implant width of KM and/or gain of soft tissue volume.

Definitions

The following two peri-implant soft tissue conditions are considered insufficient:

1. The absence or an inadequate amount of peri-implant KM (peri-implant KM width of <2 mm)
2. The presence of a thin peri-implant mucosal tissue (peri-implant mucosal thickness of ≤2 mm)

Fig. 1 **a** Soft tissue recession at the implant crown 21. The implant neck is visible. **b** SCTG harvested from the palate to perform a recession coverage at implant 21 using the tunneling technique. **c** Clinical situation 4 weeks after the surgical intervention (tunneling technique + SCTG). The implant crown was not removed

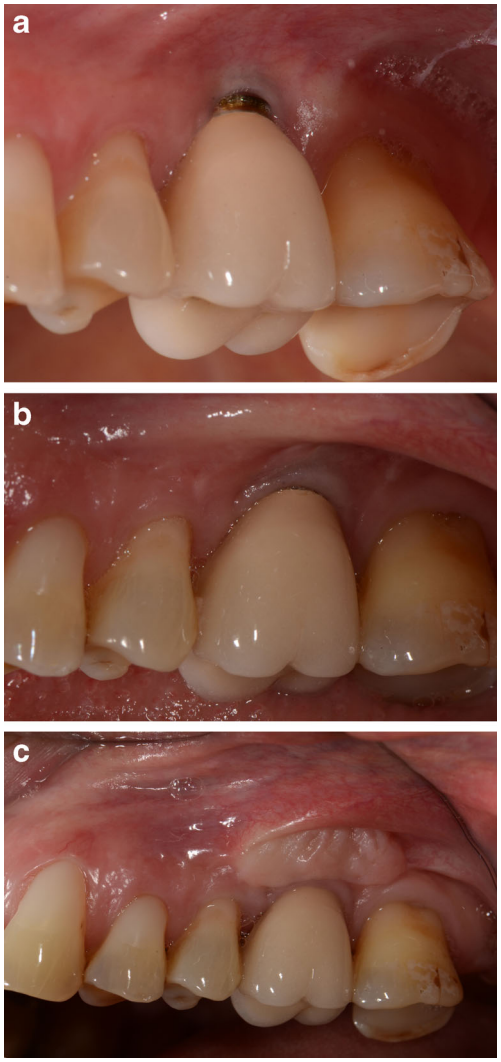

Fig. 2 **a** Implant crown reconstruction of tooth 16 with a buccal soft tissue recession due to an inadequate soft tissue volume and lack of KM. **b** Situation 6 months after the first surgical intervention (Recession coverage applying the tunneling technique in combination with an SCTG). **c** In order to gain an adequate band of KM at the buccal implant aspect, an APPTF in combination with an FST was performed in a second surgical intervention (situation 6 months after APPTF + FST)

Search strategy

An electronic search of two databases—MEDLINE (via PubMed) and EMBASE (via OVID)—was performed to identify systematically the available relevant literature. Articles published up to June 30, 2016 were considered. The search string comprised a combination of key words (medical subjects headings, MeSH) and free-text terms. Linkage was achieved using Boolean operators (OR, AND). The following search strategy was used:

- ((((acellular dermal matrix[Title/Abstract]) OR (dermal matrix allograft[Title/Abstract]) OR (alloderm[Title/Abstract]) OR (keratinized gingiva[Title/Abstract]) OR (keratinized mucosa[Title/Abstract]) OR (soft tissue graft[Title/Abstract]) OR (subepithelial connective tissue graft[Title/Abstract]) OR (connective tissue[Title/Abstract]) OR (FGG[Title/Abstract]) OR (human fibroblast-derived dermal substitute[Title/Abstract]) OR (dermagraft[Title/Abstract])

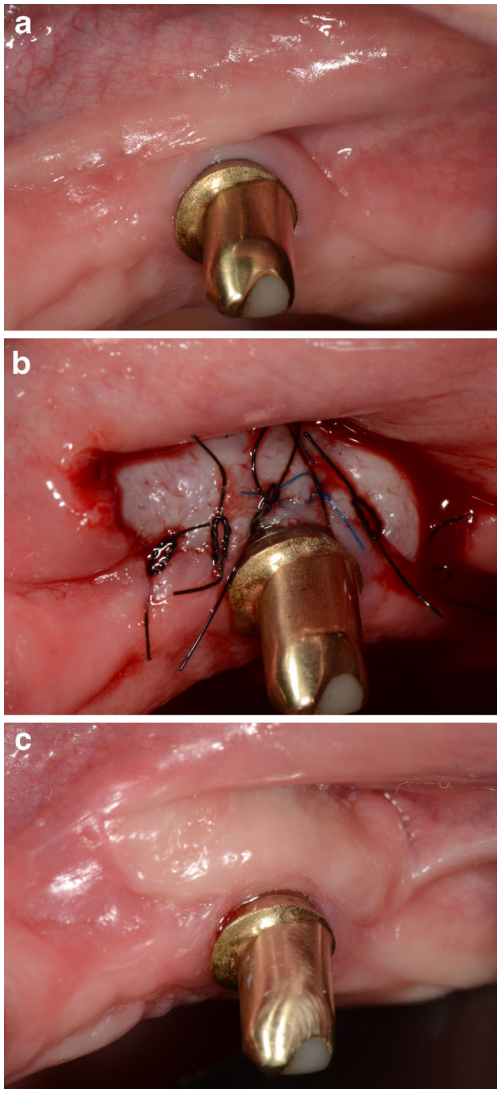

Fig. 3 **a** Situation of a buccal frenum inserting in close vicinity to the mucosal margin of the implant 23 provided with a conical abutment connection for an overdenture. **b** In order to detach the frenum from the peri-implant mucosal margin an APPTF in combination with an FST was performed. **c** Situation 10 months after the surgical intervention. An adequate band of KM is present and the buccal frenum is displaced in a cranial direction

OR apligraf[Title/Abstract]) OR (collagen matrix[Title/Abstract]) OR (extracellular membrane[Title/Abstract]) OR (gingival autograft[Title/Abstract]) OR (attached gingiva[Title/Abstract]) OR (buccal soft tissue thickness[Title/Abstract]) OR (soft tissue margin[Title/Abstract]) OR (attached mucosa[Title/Abstract]) OR (soft tissue augmentation[Title/Abstract]) OR (soft tissue transplantation[Title/Abstract]) OR (soft tissue defect*[Title/Abstract]) OR (ridge augmentation[Title/Abstract]) OR (soft tissue correction[Title/Abstract]) OR (apically positioned flap[Title/Abstract]) OR (coronally advanced flap[Title/Abstract]) OR (bilaminar technique[Title/Abstract]) OR (tunneling technique[Title/Abstact]) OR (vestibuloplasty[MeSH Terms])) AND (dental implant*[MeSH Terms])).

In addition, the search was complemented by a manual search of relevant articles published between January 1, 1900 and June 30, 2016 in the following journals: *Journal of Oral Rehabilitation*, *Clinical Oral Implants Research*, *International Journal of Oral & Maxillofacial Implants*, *Implant Dentistry*, *Clinical Implant Dentistry and Related Research*, *International Journal of Periodontics and Restorative Dentistry*, *International Journal of Prosthodontics*, *Journal of Oral and Maxillofacial Surgery*, *Quintessence International*, *Journal of Periodontology*, *International Journal of Oral and Maxillofacial Surgery*, and *Journal of Oral Implantology.* Finally, the references of all selected full-text articles were searched for relevant articles.

Inclusion criteria

The following inclusion criteria were applied:

1. Publication in the peer-reviewed literature.
2. Any case series, prospective pilot study (PPS), prospective cohort study (PCS), controlled clinical trial (CCT), or randomized clinical trial (RCT) (five or more patients included).
3. Full text in English, German, French, Spanish, or Italian.
4. Studies in which an insufficient soft tissue condition around dental implants (soft tissue recession, inadequate width of peri-implant KM, movements caused by buccal frena) resulted in biological (e.g., mucositis, peri-implantitis) or esthetical complications.
5. All dental implants are osseointegrated, already uncovered, and eventually already loaded (OU/L).
6. The biological and esthetical complications were treated applying a surgical soft tissue augmentation/correction method to improve the peri-implant soft tissue condition.
7. An observation period after surgery of at least 6 months.

Exclusion criteria

The following exclusion criteria were applied:

1. Studies not meeting all inclusion criteria
2. In vitro studies
3. Animal studies
4. Studies where the effect of soft tissue surgery could not be extracted from the data (e.g., combination of guided bone regeneration and soft tissue surgery)

Validity assessment

Two review authors (R.G.B. and A.S.) screened the publication records and abstracts identified by the electronic and manual searches independently using data extraction tables. Only reports with available full-text were evaluated and determined for inclusion. Any discrepancies and disagreements were resolved by discussion aiming for consensus.

Quality assessment

Quality and risk of bias assessments were performed independently by two authors (R.G.B. and A.S.) as part of the data extraction process. Discrepancies were discussed between the two authors until mutual agreement was obtained. The quality assessment of included randomized controlled trials (RCTs) and controlled clinical studies (CCS) was performed applying the Cochrane collaboration's tool for assessing risk of bias [47]. The quality assessment of included studies not conducted as RCTs or CCSs focused on the study design (prospective or retrospective), inclusion of a control group, predefined indication criteria for treatment, record of peri-implant clinical parameters (width of peri-implant KM and/or extent of peri-implant soft tissue dehiscence), and record of peri-implant clinical periodontal parameters (plaque index (PI), gingival index (GI), probing pocket depth (PPD), and/or clinical attachment level (CAL)) at both baseline and at least at one postoperative follow-up time point, completeness of outcome data for each main outcome, including attrition and exclusion from the analysis (according to the quality criteria "incomplete outcome data" of the Cochrane collaboration's tool for assessing risk of bias [47]), and radiographic follow-up. The studies were then rated as having a low risk of bias (all criteria met), an unclear risk of bias (one criteria did not meet), or a high risk of bias (two or more criteria not met).

Data synthesis

With a view to assess all possible data and examining for variations in terms of study characteristics and outcomes, data were summarized into evidence tables, and furthermore, a descriptive summary was created. This allowed the detection of similarities and differences between studies and determination of the suitability of further synthesis or comparison methods.

Results

Study selection

During the electronic (MEDLINE and EMBASE databases) and manual search, overall, 1595 (1322 (MEDLINE) + 271 (EMBASE) + 2 (manual search)) potentially relevant titles and abstracts were identified. After removal of duplicates and the first stage of study selection, based on title and abstract screening, in total, 31 studies were included (inter-reviewer agreement $k = 0.97$). For the second phase, the 31 full-text articles were screened and evaluated thoroughly. In total, 22 publications were excluded at this stage, because they did not fulfill the inclusion criteria (inter-reviewer agreement $k = 1.0$). Reasons for exclusion are presented in Table 1. Finally, nine publications met the inclusion criteria of this systematic review (Fig. 4).

Quality assessment and risk of bias assessment of selected publications

The quality and risk of bias assessments of included studies are presented in Tables 2 and 3. Four studies were conducted as RCT [69–72] so the quality assessment according the

Table 1 Studies excluded at the second stage of selection and the reason for exclusion

Publication	Reason for exclusion
Urban et al. [48]	Time point of mucogingival surgery in combination with second-stage surgery
Happe et al. [49]	Case report
Issarayangkul et al. [50]	Case report
Zucchelli et al. [51]	Case report
Ponzoni et al. [52]	Case report
Froum et al. [53]	The effect of soft tissue surgery could not be extracted from the data, because of the simultaneous application of guided bone regeneration
Mareque-Bueno [54]	Case report
Lai et al. [55]	Case report
Sanz et al. [56]	Tooth and implant sites included and not distinguishable
Karl et al. [57]	Case report
Shibli and Avila [58]	Case report
Yan et al. [44]	Case report
Deppe et al. [59]	Time point of mucogingival surgery in relation to implant placement not clear
Maksoud [60]	Technical note
El-Askary [61]	Case series with fewer than 5 subjects included
Mathews [62]	Case series with fewer than 5 subjects included
Deeb et al. [63]	Case series with fewer than 5 subjects included
Silverstein and Lefkove [64]	Case report
Yilmaz et al. [65]	Not the same surgical procedure in all subjects included. A respective distinction of the measurements was not taken in account
Campbell et al. [66]	Case report
Simons et al. [67]	Case report
Buser [68]	Mucogingival surgery was performed before implant placement

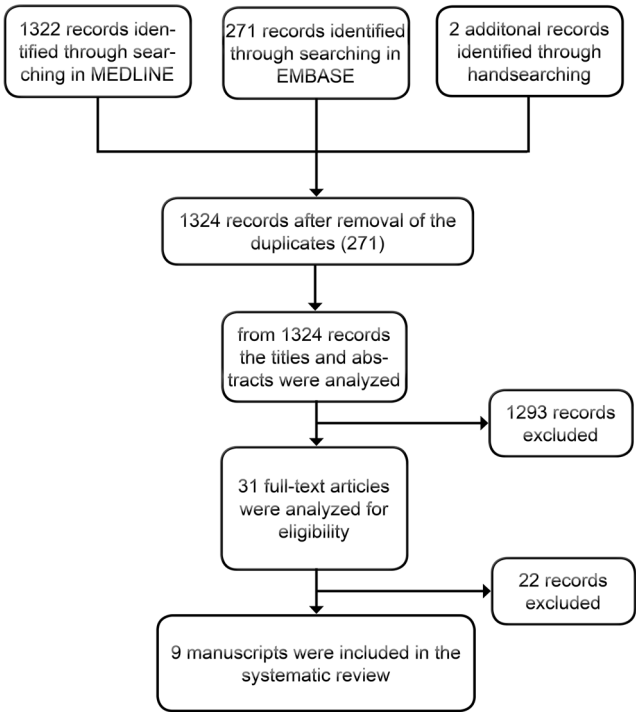

Fig. 4. Flow chart of search strategy

Cochrane collaboration's tool for assessing risk of bias [47] could be applied. In three trials, the estimated risk of bias was considered high, in one publication it was low (Table 2).

Five studies were not conducted as an RCT [73–77]. Thus, the quality assessment according the Cochrane collaboration's tool for assessing risk of bias [47] could not be applied. All five studies were conducted using a prospective study design, but none included a control group. All studies reported on predefined inclusion criteria. Two studies lacked complete records of peri-implant clinical parameters and were also incomplete in terms of outcome data. However, peri-implant clinical periodontal parameters had been documented in all studies. No study had radiographs taken. According to the given definition, in all five publications evaluated, the estimated risk of bias was considered high (Table 3).

Subdivision of included publications

Four of the nine selected publications examined several methods to enlarge the width of KM around OU/L dental implants [70–72, 77] (Table 4). The remaining five publications examined surgical approaches to cover soft tissue recessions or to increase soft tissue volume around OU/L dental implants [69, 73–76] (Table 5).

Enlargement of KM width around OU/L dental implants

Four studies dealing with treatment outcomes of KM augmentation around OU/L dental implants are presented in Table 4. Three studies were performed as RCT [70–72] and one as prospective cohort study (PCS) [77]. In total, 134 patients and 170 implant sites were treated for peri-implant KM gain. The methods and techniques to enlarge KT included vestibuloplasty (VP), apically positioned partial thickness flap (APPTF) in combination with autogenous tissues FGG, SCTG, and APPTF in combination with allogeneic graft materials (AMDA) or xenogeneic collagen matrices (XCM). The observation time periods ranged from 6 to 12 months. In all four studies, the main indication for treatment was an inadequate width of KM around OU/L dental implants (≤1 to ≤2 mm). Due to the heterogeneity of study designs, observation times, surgical procedures, and the use of different augmentation materials, no meta-analysis was performed.

Treatment outcomes

Width of keratinized tissue

Overall, four studies (three RCTs, one PCS) reported on the width of augmented KT. Depending on the surgical technique applied and graft material used, the enlargement of KT ranged between 1.15 ± 0.81 and 2.57 ± 0.50 mm. One study compared the application of AMDA (Alloderm, LifeCell Corporation, The Woodlands, TX, USA) (gain = 1.58 ± 0.37 mm) to that of FGG (gain = 2.57 ± 0.50 mm), both used in conjunction with

Table 2 Presentation of risk of bias assessment for included RCTs [47]

Anderson et al. [69]	+	?	?	−	?	?	+	High
Basegmez et al. [70]	+	+	+	+	+	+	+	Low
Basegmez et al. [71]	+	?	?	−	+	+	+	High
Lorenzo et al. [72]	?	+	?	−	?	+	−	High
	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias	Summary assessment

Table 3 Risk of bias assessment for included studies not conducted as randomized controlled trials, as judged by the authors. Key: + low risk of bias, ? unclear risk of bias, − high risk of bias

Schallhorn et al. [73]	+	−	+	+	+	+	−	High
Roccuzzo et al. [74]	+	−	+	−	+	−	−	High
Zucchelli et al. [75]	+	−	+	+	+	+	−	High
Burkhardt et al. [76]	+	−	+	−	+	−	−	High
Park [77]	+	−	+	+	+	+	−	High
	Prospective (+)/retrospective (−) design	Inclusion of a control group	Predefined indication criteria for treatment	Record of peri-implant clinical parameters (width of peri-implant keratinized mucosa (KM) and/or extent of peri-implant soft tissue dehiscence	Record of peri-implant clinical periodontal parameters (plaque index (PI), gingival index (GI), probing pocket depth (PPD) and/or clinical attachment level (CAL))	Completeness of outcome data for each main outcome, including attrition and exclusion from the analysis	Radiographic follow-up	Summary assessment

an APPTF. This difference was statistically significant ($p < 0.0001$), and in both groups, a statistically significant increase in KT was achieved [70]. A second study evaluated the change in width of KT after VP (gain = 1.15 ± 0.81 mm) and APPTF in combination with FGG (gain = 2.36 ± 0.49 mm). The difference between the groups was statistically significant in favor of the group using FGG ($p < 0.0001$). However, compared to baseline, a statistically significant increase in KT was found in both groups [71]. The third study performed an RCT, examining the enlargement in KT width after APPTF in combination with SCTG or with XCM (Mucograft, Geistlich, Wolhusen, Switzerland). The mean gain in width of KT after APPTF + SCTG was 2.30 mm and after APPTF + XCM was 2.33 mm. The inter-group comparison after 6 months did not reach statistical significance, but compared with baseline, a statistically significant improvement of KT width was obtained in both groups [72]. The fourth and last publication (PCS) has evaluated the efficacy of APPTF in combination with AMDA. Compared to baseline, the increase of KT width was statistically significant (e.g., 0.80 ± 0.60 versus 2.20 ± 0.60 mm) [77].

Postoperative shrinkage or relapse of KM

All four included publications (three RCTs and one PCS) reported on post operative shrinkage or relapse of augmented KT. The three RCTs measured the shrinkage in millimeter [70–72] and the PCS in percentage [77]. The mean shrinkage in the RCTs ranged between 0.20 and 3.06 mm dependent on the surgical technique and the graft material used. The PCS reported on a mean graft relapse of 50.7 %.

Depth of vestibule in the buccal aspect of implants

Only one study reported on the change in depth of vestibule following the application of two different graft materials (APPTF + SCTG or APPTF + XCM) [72]. In both groups, compared to baseline, a statistically significant increase of vestibular depth could be achieved ($p < 0.05$). At both time points, the differences between groups were not statistically significant.

Extent of soft tissue recession

In one study, the extent of soft tissue recession before and 6 months after surgery was evaluated [72]. In both groups, a mean increase of about 0.5 mm of mucosal recession resulted following augmentation of KT. However, the differences between baseline and follow-up did not reach a statistically significant level.

Peri-implant probing depth

All four included studies collected peri-implant probing depth (PPD) data at baseline and follow-up examination. Compared to baseline, two studies, applying the APPTF + FGG in group 1 and APPTF + AMDA in group 2 [70] as well as APPTF + AMDA [77], reported a statistically significant reduction of PPD values at 6 months after surgery. In the two other studies, the reduction of PPD did not reach statistical significance [71, 72]. Statistically significant inter-group differences were reported at baseline examination in one RCT [70] and at follow-up examination in another RCT [71].

Table 4 Included studies: augmentation of keratinized mucosa (KM)

Publication	Study design	Number of implants (*I*) and patients (*P*)	Indication for treatment	Surgical soft tissue intervention	Use of synthetic material	Observation time (months)	Outcome measurements	Baseline (before surgical intervention)	Last follow-up	Final gain of KM	Postoperative relapse of KM	Comments
Basegmez et al. [70]	RCT	Group 1: *I* = 36 *P* = 18 Group 2: *I* = 36 *P* = 18	Inadequate width of peri-implant KM (<1.5 mm) Second-stage surgery is performed	Group 1: APPTF + FGG Group 2: APPTF + AMDA	Group 1: nihil Group 2: AMDA	6	Peri-implant width of KM (mm)	Group 1: 1.01 ± 0.34 mm Group 2: 0.89 ± 0.31 mm (NSSD)	Group 1: 3.58 ± 0.40 mm† Group 2: 2.47 ± 0.32 mm† (SSD)	Group 1: 2.57 ± 0.50 mm Group 2: 1.58 ± 0.37 mm (SSD)	Group 1: −1.73 ± 0.38 mm Group 2: −2.68 ± 0.39 mm (SSD)	AMDA are capable of increasing the peri-implant width of KM, but FGG seems to be more effective
							Plaque index	Group 1: 1.38 ± 0.45 Group 2: 1.12 ± 0.15 (NSSD)	Group 1: 0.12 ±0.16† Group 2: 0.35 ±0.29† (SSD)			
							Gingival index	Group 1: 1.57 ± 0.32 Group 2: 0.19 ± 0.17 (NSSD)	Group 1: 0.19 ± 0.17† Group 2: 0.29 ± 0.33† (NSSD)			
							Probing depth (mm)	Group 1: 4.80 ± 0.58 mm Group 2: 4.06 ± 0.30 mm (SSD)	Group 1: 3.33 ± 0.27 mm† Group 2: 3.22 ± 0.15 mm† (NSSD)			
Basegmez et al. [71]	RCT	Group 1: *I* = 32 *P* = 32 Group 2 *I* = 32 *P* = 32	Inadequate width of peri-implant KM (< 1.5 mm) Mucosal movability No mucosal recession Signs of peri-implant mucositis No signs of radiographic bone resorption	Group 1: APPTF + FGG Group 2: VP	Group 1: nihil Group 2: nihil	12	Peri-implant width of KM (mm)	Group 1: 0.75 ± 0.36 mm Group 2: 0.67 ± 0.32 mm (NSSD)	Group 1: 3.11 ± 0.58 mm† Group 2: 1.83 ± 0.73 mm† (SSD)	Group 1: 2.36 ± 0.49 mm Group 2: 1.15 ± 0.81 mm (SSD)	Group 1: −2.00 ± 0.59 mm Group 2: −3.06 ± 0.88 mm (SSD)	FGG is more effective for enhancing the width of peri-implant KM compared to VP
							Plaque index	Group 1: 1.56 ± 0.67 Group 2: 1.25 ± 0.62 (NSSD)	Group 1: 0.18 ± 0.39† Group 2: 0.28 ± 0.52† (NSSD)			
							Gingival index	Group 1: 0.34 ± 0.78 Group 2: 1.43 ± 0.62 (NSSD)	Group 1: 0.28 ± 0.52† Group 2: 0.37 ± 0.55† (NSSD)			
							Probing depth (mm)	Group 1: 3.09 ± 0.81 mm Group 2: 3.25 ± 0.91 mm (NSSD)	Group 1: 3.18 ± 0.39 mm Group 2: 3.62 ± 0.49 mm (SSD)			
Lorenzo et al. [72]	RCT	Group 1: *I* = 12 *P* = 12 Group 2: *I* = 12 *P* = 12	Inadequate width of peri-implant KM (≤1 mm)	Group 1: APPTF + SCTG Group 2: APPTF + XCM	Group 1: nihil Group 2: XCM	6	Peri-implant width of KM (mm)	Group 1: 0.42 ± 0.51 mm Group 2: 0.50 ± 0.52 mm (NSSD)	Group 1: 2.75 ± 1.55 mm† Group 2: 2.8 ± 0.42 mm† (NSSD)	Group 1: 2.30 mm Group 2: 2.33 mm (NSSD)	Group 1: −0.33 mm Group 2: −0.20 mm (NSSD)	The treatment approach with XCM was as effective and predictable as with SCTG for attaining a band of KM Total surgery time: Group 1: 46.25 min Group 2: 32.50 min Similar results in esthetics and color blending with the adjacent tissues in both groups.
							Gingival index	Group 1: 0.50 ± 0.67 Group 2: 0.73 ± 0.90 (NSSD)	Group 1: 0.33 ± 0.65 mm Group 2: 0.20 ± 0.63 mm (NSSD)			
							Probing depth (mm)	Group 1: 2.08 ± 0.99 mm Group 2:2.00 ± 0.73 mm (NSSD)	Group 1: 2.08 ± 1.08 mm Group 2: 1.60 ± 0.52 mm (NSSD)			
							Extent of soft tissue recession (mm)	Group 1: 0.67 ± 1.07 mm Group 2: 1.08 ± 1.44 mm (NSSD)	Group 1: 1.17 ± 1.55 mm Group 2: 1.50 ± 1.08 mm (NSSD)			
							Depth of vestibule at implant location	Group 1: 4.17 ± 3.27 mm	Group 1: 6.00 ± 2.89 mm†			

Table 4 (continued)

Publication	Study design	Number of implants (*I*) and patients (*P*)	Indication for treatment	Surgical soft tissue intervention	Use of synthetic material	Observation time (months)	Outcome measurements	Baseline (before surgical intervention)	Last follow-up	Final gain of KM	Postoperative relapse of KM	Comments
								Group 2: 1.17 ± 2.20 mm (NSSD)	Group 2: 5.10 ± 2.47 mm† (NSSD)			
Park [77]	PCS	*I* = 10 *P* = 10	Inadequate width of peri-implant KM buccally (≤2 mm)	APPTF + AMDA	AMDA	6	Peri-implant width of KM (mm)	0.80 ± 0.60 mm	2.20 ± 0.6 mm†	NA	50.7 ± 9.2 %	AMDA could be applied as a grafting material to increase the width of peri-implant KM The surgical procedure described seems to have benefits for oral hygiene methods
							Modified gingival index	0.80 ± 0.40	0.40 ± 0.50			
							Modified plaque index	1.60 ± 0.50	0.40 ± 0.50†			
							Probing depth (mm)	1.90 ± 0.7 mm	1.4 ± 0.6 mm†			

AMDA acellular dermal matrix allograft (AlloDerm®, LifeCell Corporation, The Woodlands, TX, USA); *FGG* free gingival graft; *KM* keratinized mucosa; *NA* not available; *NSSD* no statistically significant difference; *PCS* prospective cohort study; *APPTF* apically positioned partial thickness flap; *RCT* randomized controlled trial; *SCTG* subepithelial connective tissue graft; *SSD* statistically significant difference; *VP* vestibuloplasty; *XCM* xenogeneic collagen matrix (Mucograft®, Geistlich Pharma AG, Switzerland)

† Statistically significant difference compared to baseline

Not statistically significant difference compared to baseline

Plaque index and gingival index

Three studies reported on peri-implant hygiene level as well as on mucosal inflammation at baseline and follow-up examination [70, 71, 77]. In two RCTs, plaque and gingival index examinations in both groups showed statistically significant reductions compared to the baseline examination [70, 71]. In the PCS, only the modified plaque index was statistically significantly reduced, whereas the modified gingival index improved also, but not at statistically significant level [77]. One study presented only data using the gingival index at baseline and follow-up, albeit not significant in both groups [72].

Total surgery time

One RCT reported on total surgery time of two different surgical procedures. The mean surgical time measured 46.25 min for APPTF + SCTG and 32.50 min for APPTF + XCM, respectively. The difference was statistically significant ($p = 0.0096$).

Esthetic outcomes

One publication described similar results in esthetics and color with adjacent tissues in both groups (group 1: APPTF + SCTG, group 2: APPTF + XCM) [72].

Augmentation of soft tissue volume in order to cover soft tissue dehiscences around OU/L dental implants

Treatment outcomes for the augmentation of soft tissue volume to cover soft tissue recessions around OU/L dental implants from five studies are presented in Table 5. One study was conducted as randomized controlled clinical (pilot) trial (RCT) with an observation period of 6 months [69]. Three studies were performed as prospective pilot studies (PPS) with a follow-up period of 20 [75], 12 [74], and 6 months [73], and another as prospective cohort study (PCS) with an observation period of 6 months [76]. Overall, a total of 89 patients and 94 implant sites were treated. In two studies, a coronally advanced flap (CAF) in combination with an SCTG, harvested from the palate was applied [75, 76]. In another study, CAF in combination with an SCTG (group 1) was compared with CAF combined with an AMDA (group 2) [69]. In a fourth study, the effectiveness of a split thickness flap (STF) in combination with an SCTG, harvested from the maxillary tuberosity area, was evaluated, whereas in the fifth publication, the outcome of STF in combination with a xenogeneic collagen matrix (XCM) was studied. The main indication for treatment in three studies was a buccal soft tissue dehiscence [74–76], in the fourth study, an inadequate soft tissue thickness [73], and in the fifth publication, a buccal soft tissue dehiscence (≥2 mm) or a buccal soft tissue concavity (≥2 mm) around

Table 5 Included studies: augmentation of soft tissue volume in order to cover soft tissue recessions around OU/L dental implant

Publication	Study design	Number of implants (*I*) and patients (*P*)	Indication for treatment	Surgical soft tissue intervention	Use of synthetic material:	Observation time (months)	Outcome measurements
Schallhorn et al. [73]	PPS	*I* = 35 *P* = 30	Implant sites with: 1. Gray show-through 2. Facial soft tissue contour deficiency or concavity 3. KM width <2 mm	STF + XCM	XCM	3/6	Soft tissue thickness KM width (mm) Extent of soft tissue recession (mm) Probing depth (mm)
Anderson et al. [69]	RCT	*I* = 13 *P* = 13	Maxillary nonmolar implants with failing pink esthetic profile: ≥2 mm soft tissue concavity or ≥2 mm recession	Group 1 (*n* = 7): CAF + SCTG Group 2 (*n* = 6): CAF + AMDA	Group 2: AMDA	6	Soft tissue thickness Extent of soft tissue recession Concavity depth Patient-evaluated esthetic outcomes (modified CEI) Clinician-evaluated esthetic outcomes (CEI)
Roccuzzo et al. [74]	PPS	*I* = 16 *P* = 16	Implant-supported tooth in the maxillary area displaying an apical displacement of the soft tissue margin with no significant interproximal bone loss and/or adjacent papillae recession	STF + SCTG	Nihil	12	Extent of soft tissue recession (mm) Peri-implant probing depth (mm) Esthetic outcome (VAS)
Zucchelli et al. [75]	PPS	*I* = 20 *P* = 20	Buccal soft tissue dehiscence around single implant in the esthetic area (unfavorable esthetic appearances because of exposure of implant surface)	CAF + SCTG	Nihil	20	Extent of soft tissue recession (mm) Width of KM (mm) Soft tissue thickness (mm) Peri-implant probing depth (mm) Esthetic outcome (VAS)
Burkhardt et al. [76]	PCS	*I* = 10 *P* = 10	Peri-implant soft tissue dehiscence at a single implant in the maxillary front area (implant loading >12 months ago)	CAF + SCTG	Nihil	6	Extent of soft tissue recession (mm) Extent recession coverage (%) Peri-implant width of KM (mm) Peri-implant probing depth (mm)

Publication	Baseline (before surgical intervention)	Last follow-up	Final recession coverage (%) Final soft tissue reduction (mm)	Postoperative relapse of recession coverage	Comments
Schallhorn et al. [73]	1.5 ± 0.5 mm	Follow-up 3 months: 2.2 ± 0.8 mm† Follow-up 6 months: 2.2 ± 0.9 mm†	0.1 ± 0.7 mm	NA	No significant changes in color and soft tissue contour. ΔSoft tissue thickness: 0.7 ± 0.8 mm ΔKM: 0.7 ± 1.2 mm Δ Probing depth: −0.5 ± 1.0 mm
	1.7 ± 1.8 mm	Follow-up 3 months: 2.6 ± 2.0 mm† Follow-up 6 months: 2.1 ± 1.0 mm†			
	1.5 ± 1.5 mm	Follow-up 3 months: 1.5 ± 1.5 mm Follow-up 6 months: 1.5 ± 1.4 mm			
	3.5 ± 1.7 mm	Follow-up 3 months:			

Table 5 (continued)

Publication	Baseline (before surgical intervention)	Last follow-up	Final recession coverage (%) Final soft tissue reduction (mm)	Postoperative relapse of recession coverage	Comments
		3.1 ± 1.4 mm† Follow-up 6 months: 3.0 ± 1.6 mm†			
Anderson et al. [69]	Group 1: 1.6 mm Group 2: 1.5 mm (NSSD)	Group 1: 2.7 mm Group 2: 3.1 mm	Group 1: 0.3 mm (40 %) Group 2: 0.3 mm (28 %)	NA	Significant difference between groups in favor of group 1 regarding wound healing (p = 0.021), soft tissue contour (p = 0.030), and soft tissue color and texture (p = 0.006)
	Group 1: 0.7 mm Group 2: 1.1 mm (NSSD)	Group 1: 0.4 mm Group 2: 0.8 mm			
	Group 1: 2.2 mm Group 2: 2.2 mm (NSSD)	Group 1: 0.4 mm† Group 2: 0.1 mm†			
	Group 1: 4.00 Group 2: 2.57	Group 1: 3.95 Group 2: 3.39 (NSSD)			
	Group 1: 2.29 Group 2: 2.52 (NSSD)	Group 1: 1.20† Group 2: 1.69† (NSSD)			
Roccuzzo et al. [74]	2.0 ± 0.7 mm 2.7 ± 0.4 mm	0.3 ± 0.3 mm† 3.1 ± 0.5 mm†	89.6 ± 13.1 %	NA	By means of the surgical technique presented, buccal soft tissue dehiscences around dental implants can be successfully treated
	3.60 ± 0.20	8.50 ± 0.30†			
Zucchelli et al. [75]	2.72 ± 0.68 mm 1.72 ± 0.61 mm	0.10 ± 0.44 mm† 2.30 ± 0.52 mm†	96.3 % 2.62 ± 0.81 mm	3.7 %	Applying CAF + SCTG is effective in the coverage of buccal soft tissue dehiscences around single dental implants
	0.92 ± 0.27 mm	2.50 ± 0.21 mm†			
	1.87 ± 0.51 mm	2.27 ± 0.69 mm†			
	3.8	8.0†			
Burkhardt et al. [76]	3.0 ± 0.8 mm 0 %	NA 66 %	66 %	44 %	Applying CAF + SCTG, a clinically significant improvement, but in none of the implant sited a complete soft tissue dehiscence coverage could be achieved
	1.3 ± 1.0 mm	1.1 ± 0.5 mm			
	2.8 ± 1.0 mm	3.0 ± 0.8 mm			

AMDA =acellular dermal matrix allograft; *CAF* coronally advanced flap; *CEI* complex esthetic index; *KM* keratinized mucosa; *NA* not available; *NSSD* no statistically significant difference; *PCS* prospective cohort study; *PPS* prospective pilot study; *RCT* randomized controlled trial; *SCTG* subepithelial connective tissue graft; *STF* split thickness flap; *VAS* visual analog scale; *XCM* xenogeneic collagen matrix (Mucograft®, Geistlich Pharma AG, Switzerland)

Not statistically significant difference compared to baseline

† Statistically significant difference compared to baseline

Δ Difference between baseline measurement and last follow-up

single loaded implants [69]. Due to the heterogeneity of study designs, observation times, and implant sites, no meta-analysis was performed.

Treatment outcomes

Coverage of peri-implant soft tissue recession

In the most recent publication, no significant change in mean soft tissue recession over the course of the study was reported [73]. A second study evaluated the reduction of buccal soft tissue recession after CAF in combination with SCTG (mean reduction = 0.3 mm, 40 %) compared with CAF combined with AMDA (mean reduction = 0.3 mm, 28 %) 6 months after surgery [69]. In another publication, the mean soft tissue recession decreased significantly from 2.0 ± 0.7 mm (baseline) to 0.3 ± 0.3 mm (12 months after surgery). A mean final recession coverage of 89.6 % was reported. Complete coverage was achieved in nine of 16 cases (56.3 %) [74]. In the fourth study, the mean extent of soft tissue recession was 2.72 ± 0.68 mm at baseline and 0.10 ± 0.44 mm at follow-up examination, 20 months after the intervention. The difference (2.62 ± 0.81 mm) was statistically significant and corresponded to a mean soft tissue recession coverage of 96.3 %. Complete coverage was observed in 75 % of treated sites [75]. In the fifth study, a mean soft tissue recession coverage of 66 % was reported after a healing period of 6 months [76].

Postoperative shrinkage

In three publications, no outcome data regarding postoperative shrinkage were available [69, 73, 74]. In the fourth study, the mean postoperative relapse of recession coverage was 3.7 % [75], whereas in the fifth study, a mean shrinkage of 44 % was observed [76].

Width of keratinized tissue

Three studies reported on the width of KT at baseline and at follow-up examinations. In the most recent study, the width of KT measured 1.7 ± 1.8 mm at baseline and 2.1 ± 1.0 mm at the 6-month follow-up, respectively. This increase was statistically significant ($p < 0.0016$) [73]. In the second publication, the baseline width of KT amounted to 1.72 ± 0.61 mm and increased to 2.30 ± 0.52 mm at 20 months after surgery. This increase was statistically significant ($p < 0.01$) [75]. In the third study, the width of KT was 1.3 ± 1.0 mm at baseline and measured 1.1 ± 0.5 mm at 6 months after surgery without reaching statistical significance [76]. However, none of these two studies reported any data on the width of KT [69, 74].

Soft tissue volume/thickness

Three out of the five included studies reported on horizontal changes in soft tissue volume following soft tissue grafting procedures [69, 73, 75]. In two studies, soft tissue thickness was determined 1.5 mm apical to the soft tissue margin using a short needle for anesthesia and a 3-mm diameter silicon disk stop [75] or an endodontic probe in combination with a 1-mm diameter silicon stop [73]. In the third study, soft tissue thickness was measured 1 mm apical to the soft tissue margin applying a #25 endodontic file in combination with a silicon stop [69].

In the recent study, the mean soft tissue thickness at baseline was 1.5 ± 0.5 mm. Six months after surgery, a statistically significant increase in volume ($p < 0.0001$) up to 2.2 ± 0.9 mm was reported [73]. In the second publication, the mean soft tissue thickness measured at baseline was 0.92 ± 0.27 mm. The volume of the SCTG was 1.64 ± 0.18 mm. Twenty months after surgery, the soft tissue volume amounted to 2.50 ± 0.39 mm. The mean increase in soft tissue thickness (1.58 ± 0.21 mm) was statistically significant ($p < 0.01$) [75]. In the third study, a soft tissue thickness improvement as well as buccal concavity reduction of 63 and 82 %, respectively (group 1 (CAF + SCTG)) and of 105 and 96 %, respectively (group 2 (CAF + AMDA)) was observed 6 months after surgery. Compared to baseline, the reduction in buccal concavity in both groups was statistically significant ($p < 0.002$) [69].

Peri-implant probing depth

Four studies reported on PPD values [73–76]. In the first publication, a statistically significant ($p < 0.0042$) PPD reduction was achieved (e.g., baseline PPD = 3.5 ± 1.7 mm versus 3.0 ± 1.6 mm at 6 months) [73]. In the second study, baseline PPD measured 2.7 ± 0.4 mm and increased statistically significantly (e.g., to 3.1 ± 0.5 mm) at 12 months ($p = 0.0004$) [74]. In the third study, mean PPD measured 1.87 ± 0.51 mm at baseline and increased to 2.27 ± 0.69 mm at 20 months after soft tissue grafting. This increase was statistically significant ($p < 0.05$ mm) [75]. In the fourth study, mean PPD measured 2.8 ± 1.0 mm before recession coverage and increased to 3.0 ± 0.8 mm 6 months, postoperatively. However, the PPD increase did not reach statistical significance [76].

Esthetic outcome

Four studies collected esthetic outcome data at baseline and at follow-up examination [69, 73–75]. In the first study, an improvement of the color was found in only two patients, while overall, no statistically significant improvements in gray show-through and facial soft tissue contour were observed [73]. In the second study, the clinician-evaluated complex esthetic index (CEI) showed a statistically significant improvement ($p = 0.001$) in both treatment groups (SCTG group = from 2.29 to 1.20; AMDA-

group = from 2.52 to 1.69) but no significant inter-group difference was detected. However, significant differences between the two groups in terms of soft tissue contour ($p = 0.030$) and soft tissue color and texture ($p = 0.006$) were found favoring SCTG grafting. In contrast, treatment with SCTG nor with AMDA resulted in any statistically significant changes over time in terms of the total patient-evaluated modified CEI ($p = 0.204$) [69]. The average score in the third study increased from 3.6 ± 0.3 to 8.5 ± 0.3 [74], while in the fourth publication, the median score changed from 3.8 to 8.0 [75]. In the last two studies [74, 75], the visual analog scale analysis revealed statistically significant differences between baseline and final examination (Zucchelli et al., $p < 0.01$ [75]; Roccuzzo et al., $p < 0.0001$ [74]).

Discussion

Dental implants are either covered by keratinized mucosa (KM) and/or by mobile alveolar mucosa. The specificity of epithelium (keratinized or non-keratinized) seems to be determined by the type of underlying connective tissue. This is, at least partly, the reason why connective tissue, harvested from subepithelial palatal area and transplanted into a region covered by non-keratinized epithelium, may induce keratinization [78, 79]. However, even though keratinization is present, the peri-implant KM is not always attached to the underlying bone or implant surface [15].

Recently, it has been demonstrated that both adequate peri-implant width of KM and soft tissue thickness appear to have an impact on the long-term stability of peri-implant tissues, which may consequently increase the predictability of an implant therapy over time [80–85]:

1. Compared to implant sites with a band of ≥2-mm KM, sites with <2 mm seem to be more prone to brushing discomfort, plaque accumulation, peri-implant soft tissue inflammation [80], impaired immunological reaction [83], and to peri-implantitis [84].
2. Thin peri-implant mucosal tissue is associated with a higher prevalence of crestal bone loss compared to naturally thick or augmented soft tissue [81, 82]. Two studies have demonstrated that compared to sites presenting a soft tissue thickness of >2 mm, sites with ≤2 mm are associated with significantly more distinct peri-implant marginal bone loss [82, 85].

Consequently, the aim of this systematic review was to evaluate the efficacy of several soft tissue augmentation/correction methods in terms of increasing the peri-implant KM width and/or gain of soft tissue volume around OU/L dental implants in cases of a soft tissue deficiency to improve the long-term stability of peri-implant tissues.

Most studies to this topic were conducted in a highly inhomogeneous way, making comparisons difficult. Therefore, no meta-analysis could be performed. The risk of bias of the four trials conducted as RCTs was assessed according to the Cochrane collaboration's tool for assessing risk of bias [47]. Accordingly, a low risk of bias was revealed in one study [70] and a high one was identified in three others [69, 71, 72]. The remaining five studies did not include a control group and were not designed as RCTs, which precluded the quality assessment according to the Cochrane collaboration's guidelines [47]. Hence, a high risk of bias needs to be assumed for these five prospective studies [73, 75–77]. This should be considered when interpreting the results of this systematic review.

Enlargement of KM width around OU/L dental implants

Gain of width of keratinized tissue

Overall, four studies reported on techniques and augmentation materials to enlarge KT around OU/L dental implants. In all four studies, a significant and successful augmentation of KT around dental implants was obtained. Regarding the amount of KT gain, the application of an APPTF in combination with an FGG, from the palate, with mean enlargement values of 2.57 ± 0.50 and 2.36 ± 0.49 mm seems to be the treatment of choice [70, 71]. The application of an APPTF in combination with AMDA or XCM was also effective to augment KT around OU/L implants. However, the amount of KT enlargement using AMDA was less pronounced as compared to APPTF + FGG or APPTF + XCM [70, 72, 77]. In one RCT, more KT was gained after APPTF + FGG than APPTF + AMDA [70]. Compared to the use of allogeneic or xenogeneic material, FGGs are associated with both increased patient' morbidity [72, 86] and a longer surgical time [72]. In one study, an SCTG was used in place of an FGG, and resulted in a significant enlargement of KT (2.30 mm) comparable to the application of XCM (2.33 mm) [72]. These results are in line with a former RCT performed in teeth and implants comparing the efficacy of SCTG and XCM [56]. The VP alone, i.e., without the application of an augmentation material seems to yield significantly less favorable results in terms of final KT gain (1.15 ± 0.81 mm) [71].

Postoperative shrinkage or relapse of KM

The postoperative shrinkage extent of augmented KT can be utilized to assess the predictability of different surgical soft tissue augmentation procedures. All four included studies reported some postoperative shrinkage of augmented KT. Evaluating the included studies, a shrinkage of 0.20 to 3.06 mm [70–72] or a shrinkage rate right up to 50.7 % [77] has to be expected. The variability observed may, at least in part, be explained by the surgical technique and materials used

(e.g., APPTF + FGG, APPTF + SCTG, or APPTF + XCM seem to be accompanied by less postoperative relapse compared to other techniques such as APPTF + AMDA or a VP alone). However, it has to be considered that different time points taken as baseline and variable follow-up periods may have influenced the results. Indeed, it is known that the shrinkage rate is much more pronounced within the first month after surgery [56, 87] and seems to continue on a lower level up to 6 months [87]. A recent comparative study indicates that after 6 months, the shrinkage rate slows down and only a minimal relapse has to be expected, whereby the changes are more pronounced in the XCM-group compared to the FGG group [87].

Depth of vestibule in the buccal aspect of implants

Only one RCT reported on the change of vestibule depth following the augmentation of KT [72]. Compared to baseline, in both groups (group 1: APPTF + SCTG, group 2: APPTF + XCM) a significant increase of vestibular depth has been reported, albeit statistically insignificant. Furthermore, there was no difference of KT width between the different treatment groups. Thus, an enlargement of KT increases the dimension of vestibule in a proportional extent, irrespective of the procedure. Accordingly, a low inserting frenulum can be repositioned apically.

Extent of soft tissue recession

In one study, the extent of soft tissue dehiscence before and 6 months after surgical KT enlargement was reported [72]. In both groups (group 1 = APPTF + SCTG, group 2 = APPTF + XCM), a mean increase of about 0.5 mm of mucosal recession was observed following surgery, implying that, to a certain extent, an apical displacement of the mucosal margin has to be accepted.

Peri-implant probing depth

In all four studies, a reduction of PPD following surgical intervention occurred. However, only in two studies, this reduction in PPD reached statistical significance [70, 77]. This reduction of PPD may be attributed to an increased tissue tonus which in turn enhances the resistance to probe penetration [77, 88]; furthermore, a PPD reduction is associated with an apical displacement of the mucosal margin which seems to be a side effect of a surgical KT augmentation around OU/L dental implants [72]. An inadequate width of KM around dental implants has also been correlated with plaque accumulation and soft tissue inflammation [29, 31, 32], which per se causes higher peri-implant PPD values compared to a non-inflamed peri-implant soft tissue situation.

Plaque index and gingival index

In two publications, plaque and gingival index examinations were significantly reduced at follow-up as compared to baseline [70, 71]. Additionally, another study reported significant reduction of the modified plaque index [77]. Adequate KM around implants might lead to less plaque accumulation and soft tissue inflammation [29, 31, 32]. However, surgical procedures are usually accompanied by meticulous oral hygiene instructions before and after treatment, which may bias the result.

Total surgery time

One publication demonstrated that the surgery time can be significantly reduced when no autogenous soft tissue graft is harvested [72]: On average, a time reduction of 30 % (14 min) could be achieved using a soft tissue substitute graft material. Similar outcomes have been reported in other studies using the same graft material [56, 87, 89].

Esthetic outcomes

One study reporting on esthetic outcomes by comparing two different soft tissue grafts (e.g., SCTG or XCM) in combination with APPTF found no esthetic differences neither between the two procedures nor between grafted areas and adjacent regions [72]. However, differences could be detected after the application of an FGG + APPTF, which were still apparent at the 60-month follow-up. [87, 89]. Therefore, in esthetically important areas, the use of XCM or SCTG may be recommended.

Augmentation of soft tissue volume in order to cover soft tissue recessions around OU/L dental implants

Coverage of peri-implant soft tissue recession

Five studies reporting on soft tissue recession coverage around OU/L dental implants were included in this review. In two studies, recession coverage was performed applying a CAF in combination with an SCTG from the palate [75, 76]. In a comparative study, a CAF combined with SCTG or AMDA was applied to cover soft tissue recessions [69]. In the last two publications, the recession coverage was performed using an STF in combination with am SCTG, harvested from the maxillary tuberosity [74], or in combination with an XCM [73].

Zucchelli et al. 2014 reported a soft tissue recession coverage of 96.3 % at 20 months [75] compared to a mean coverage of 66 % after 6 months observed by Burkhardt et al. [76]. It was speculated that the reason of this difference [75]: First, the removal of the implant crown and the change of implant abutment provided larger interdental connective tissue beds for the graft and for the surgical papillae of the covering flap. Second, the use

of different harvesting techniques for SCTG may have led to different qualities of soft tissue grafts (e.g., in one study [76], the SCTG was harvested using a single incision harvesting technique [90] which may yield a graft containing more fatty and glandular tissue, in the other study, an FGG was harvested and subsequently deepithelialized, thus resulting in a more collagen rich graft [75]). The amount of KT at baseline may have also affected the outcomes in terms of recession coverage. In the study by Zucchelli et al. [75], the mean KT width at baseline measured 1.72 ± 0.61 mm, whereas in the study by Burkhardt et al. [76], the mean KT width amounted to 1.3 ± 1.0 mm. In the third study, mean soft tissue recession coverage measured 89.6 % at 12 months following surgery [74] and compared well to the findings reported by Zucchelli et al. [75]. However, compared to the other two studies [75, 76], no vertical releasing incisions in combination with a split-flap design (STF) were applied which may have the advantage of intact blood supply, thus minimizing the risk of graft necrosis and scar tissue formation. However, without releasing incision, a coronally advanced flap is more limited in its expansion. Consequently, it appears that this technique may be indicated for less pronounced soft tissue recession [74].

In a recent publication, the same study design was applied, but instead of an SCTG, an XCM was used in combination with an STF [73]. In contrast to Ruccuzzo et al. [74], no significant recession coverage could be achieved [73]. An RCT comparing the treatment of multiple adjacent Miller class 1 and 2 gingival recessions has shown that the modified coronally advanced tunnel in combination with an SCTG led to better clinical outcomes (more KT and greater recession coverage) when compared to XCM [91]. When comparing CAF with either SCTG or AMDA, the percentage of recession coverage was higher in the SCTG group (40 %) than in the AMDA group (28 %) [69]. Thus, autogenous soft tissue grafts may still be preferred to other types of soft tissue replacement grafts (e.g., allogeneic or xenogeneic materials).

Postoperative shrinkage

Two included studies reported on mean postoperative shrinkage [75, 76]. The overall postoperative relapse rate was inversely correlated to the soft tissue recession coverage rate. To explain the differences between the two studies, the same aspects than those in the section "Coverage of peri-implant soft tissue recession" can be discussed.

Width of keratinized tissue

The surgical techniques (CAF + SCTG/CAF + AMDA/STF + SCTG/STF + XCM) used in the five included studies represent not the gold standard in order to augment KT. However, in two studies, a statistically significant increase of KT was obtained compared to baseline examination [73, 75]. Thus, it seems that a statistically significant gain of KT may be achieved using both XCM and SCTG in combination with CAF or STF, respectively. In the third publication, no statistically significant alteration of KT was detected at 6 months after surgery [76]. In the last two studies, no data regarding KT were presented [69, 74]. Among other factors, the presence of residual height of KT before augmentation surgery might have also influenced the outcomes of recession coverage [75].

Soft tissue volume/thickness

Only three out of five included publications reported on horizontal changes in soft tissue volume using SCTG [75], XCM [73], or AMDA [69]. Following the soft tissue augmentation procedure, a statistically significant increase of soft tissue thickness was measured in two studies [73, 75]. In the third study [69], in both groups, the soft tissue thickness as well as the buccal concavity depth were improved. No statistically significant inter-group differences (group 1 = CAF + SCTG; group 2 = CAF + AMDA) were reported. A buccal soft tissue thickness of 2 mm at dental implants seems to be the threshold thickness for better esthetic outcomes [92, 93].

Peri-implant probing depth

Three studies reported an increase of PPD following surgical intervention [74–76]. The results indicate that in using soft tissue augmentation techniques, no peri-implant bone regeneration can be achieved. Instead, only soft tissue volume is increased, which is accompanied by an increase in PPD. However, the increase in PPD with a range of 0.3–0.4 mm in all three studies [74–76], does not appear to have any clinical consequences. Only one study reported on a reduction of PPD following surgical intervention [73]. This might be due to the treatment approach using STF in combination with XCM that failed to cover the peri-implant soft tissue recessions.

Esthetic outcomes

Two studies reported on a significant improvement in the subjective patients' esthetic evaluation over time [74, 75]. An esthetic improvement was achieved when the soft tissue recession coverage is effective and when a minimal buccal soft tissue thickness of 2 mm is present [92, 94]. In a third study, only the total clinician-evaluated esthetic index improved significantly in both groups, whereas the total patient-evaluated esthetic index did not improve neither in groups 1 nor in 2. However, regarding soft tissue contour, soft tissue color, and texture, the use of an SCTG seems to have significant advantages over the application of an AMDA [69]. In the fourth study, no significant improvement in soft tissue contour and color, despite a significant increase in soft tissue thickness was

reported [73]. An explanation might be that no [73] or only minor [69] changes in soft tissue recession were achieved.

Conclusions

Within their limits, the results of the present systematic review suggest that: (a) the three APPTF-techniques combined with FGG, SCTG, or XCM achieved comparable enlargements of peri-implant KT, (b) both STF and CAF, in combination with SCTG, are equivalent regarding recession coverage rates around OU/L implants, and (c) STF + XCM and CAF + AMDA did not reach significant coverage. Thus, in case of soft tissue deficiency around OU/L dental implants, the selection of the appropriate surgical technique and soft tissue graft material is of utmost clinical relevance.

Compliance with ethical standards

Conflict of interest Renzo Bassetti declares that he has no conflict of interest. Alexandra Stähli declares that she has no conflict of interest. Mario Bassetti declares that he has no conflict of interest. Anton Sculean declares that he has no conflict of interest.

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Informed consent For this type of study, formal consent is not required.

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