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# Soft Tissue Sculpting in Implantology: Bridging Biology, Biomaterials, and Aesthetics

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## Abstract

This review article analyses the evolution of soft tissue sculpting in implantology, emphasizing the synergy of biological knowledge, biomaterials, and aesthetics to enhance peri-implant health and appearance. Assessing modern methods such as connective tissue grafts, creative flap designs, soft tissue augmentation using autogenous and alternative biomaterials, and digital planning for accurate tissue replication were among the goals. The review shows that immediate implantation with less invasive tissue handling produces the best stability and aesthetics, outlining the impact of surgical timing, digital processes, and emergence profile management. The multidisciplinary nature of contemporary soft tissue sculpting in implant dentistry is ultimately confirmed by the conclusion that tailored, evidence-based approaches incorporating biological principles and material selection are crucial for predictable, aesthetically pleasing, and long-lasting results.

**Keywords:** Peri-implant mucosa**,** Emergence Profile, Immediate provisionalization, soft tissue augmentation, aesthetics.



## INTRODUCTION

The evolution of implant dentistry offers a biologically integrated and aesthetically driven treatment option, highlighting the optimal role of peri-implant soft tissues. The success rate of implant–supported restorations depends significantly on the quality, quantity, and architecture of the surrounding soft tissue. [1] The peri-implant mucosa, composed of an epithelial barrier and a connective tissue component, establishes a protective transmucosal seal analogous to the junctional epithelium around natural teeth. This seal safeguards the underlying bone from microbial invasion and mechanical insults, thereby preserving crestal bone stability and peri-implant health. [2,3]

Soft tissue sculpting is not merely a cosmetic adjunct but a biological imperative. Properly contoured soft tissues resist recession, support interdental papilla formation, and create self-cleansing environments that minimise plaque accumulation. The biologic width of the peri-implant mucosa, typically comprising a 2 mm epithelial layer and a 1.5 mm connective tissue layer, must be maintained for tissue homeostasis. A reduction in mucosal thickness can trigger compensatory bone resorption to re-establish this dimension, demonstrating the intrinsic link between soft tissue profile and underlying hard tissue stability. [4-6]

Keratinised tissue (KT) plays a pivotal role in peri-implant soft tissue health. A band of KT ≥2 mm, with at least 1 mm of attached gingiva, has been associated with reduced mucosal recession, better plaque control, and decreased inflammation. In contrast, inadequate KT increases susceptibility to peri-implant mucositis and recession, particularly in patients with suboptimal oral hygiene. Moreover, mucosal thickness influences marginal bone stability; tissues thinner than 2.5 mm are prone to increased crestal bone loss.

Consequently, soft tissue sculpting through augmentation, flap manipulation, or biomaterial integration is often essential to achieve stable peri-implant conditions and ensure the long-term integrity of the biological seal. [4-6]

Advancements in biomaterials and surgical techniques have expanded the armamentarium for soft tissue sculpting. Approaches such as apically positioned flaps, free gingival grafts, subepithelial connective tissue grafts, and collagen matrices enhance keratinised tissue width and mucosal volume. These interventions not only fortify biological stability but also lay the groundwork for predictable aesthetic outcomes, highlighting the synergy between biology and biomaterials in modern implantology.

**Importance of Peri-Implant Pink Esthetics and Patient Satisfaction [7]**

As implant therapy shifts toward a patient-centred, aesthetics-driven paradigm, peri-implant pink esthetics have emerged as a critical determinant of clinical success and patient satisfaction. The harmonious integration of peri-implant soft tissue with adjacent dentition and facial structures significantly contributes to the visual success of implant restorations, just as to their functional performance. Discrepancies in mucosal contour, colour, or texture, as well as papilla loss and gingival recession, can result in compromised aesthetics — manifesting as visible metal margins, “black triangles,” and disharmony with the gingival architecture.

The Pink Esthetic Score (PES) and Pink Esthetic Score/White Esthetic Score (PES/WES) have been developed to objectively evaluate peri-implant soft tissue outcomes. These scoring systems assess factors such as mesial and distal papilla presence, soft tissue contour, level, colour, and texture. Clinical studies show that connective tissue grafting and other augmentation procedures can significantly improve PES values, particularly in immediate implant placement scenarios, where the preservation of tissue architecture is critical. [7]

Patient perception of implant therapy extends beyond mechanical function and osseointegration. Aesthetic satisfaction, particularly in the anterior maxilla, is deeply influenced by the seamless blending of peri-implant soft tissues with natural gingiva. Loss of papillae, even as little as 1 mm, can be perceived as a major aesthetic failure, affecting phonetics, food impaction, and psychological comfort. Furthermore, soft tissue thickness and keratinised mucosa width influence not only aesthetic outcomes but also patient-reported satisfaction levels, underscoring the biopsychosocial dimensions of implant therapy. [8]

Modern soft tissue sculpting strategies aim to achieve this delicate balance between biological stability and aesthetic excellence. Techniques such as papilla-preserving flaps, customised healing abutments, soft tissue grafts, and biomaterial substitutes are tailored to recreate natural gingival contours and optimise pink esthetics. Ultimately, the convergence of surgical precision, material science, and biological understanding in soft tissue management is pivotal in transforming implant therapy into a truly restorative and patient-centred discipline. [8]

**Biological Basis of Soft Tissue Sculpting**

**Peri-implant Mucosa vs. Natural Gingiva [4-6]**

A deep understanding of peri-implant soft tissue biology is essential for predictable and aesthetic implant therapy. Although peri-implant mucosa shares several structural and functional similarities with the gingiva surrounding natural teeth, there are significant histological and biomechanical differences that directly influence soft tissue sculpting outcomes.

The peri-implant mucosa, like natural gingiva, consists of a junctional epithelial barrier and a connective tissue zone that together form the protective transmucosal seal. However, the peri-implant soft tissue is not anchored to cementum but to the titanium or ceramic surface of the implant, resulting in differences in fibre orientation and vascular supply. Around natural teeth, supracrestal connective tissue fibres insert perpendicularly into cementum, providing robust mechanical resistance. In contrast, peri-implant connective tissue fibres run parallel or circumferentially to the implant surface without inserting into it, which reduces tissue resistance to mechanical insult and makes the peri-implant mucosa more susceptible to inflammation and recession.

Additionally, the absence of dento-gingivo-alveolar fibre groups such as circular, semicircular, transeptal, and inter-gingival fibres around implants compromises the formation and maintenance of papillae. This is a key reason why peri-implant sites are more prone to the appearance of “black triangles” and soft tissue deficiencies. The peri-implant mucosal height closely follows the alveolar bone crest, but inter-implant papilla formation is influenced by numerous factors, including bone level, tooth morphology, interdental contact points, and soft tissue quality.

The vascularity of peri-implant soft tissues is also reduced compared to that around natural tooth. The absence of a periodontal ligament and its vascular contribution results in a less robust blood supply, which may impair healing and limit the capacity for tissue remodelling. As a result, peri-implant soft tissues require meticulous surgical handling, adequate thickness, and optimal implant positioning to achieve outcomes comparable to those around natural teeth. (9-11)

**Biological Width, Mucosal Thickness, and Keratinised Tissue Requirements [12]**

The concept of biological width, originally described around natural teeth, extends to peri-implant tissues and plays a pivotal role in maintaining peri-implant health and stability. Peri-implant biological width consists of a junctional epithelium (~2 mm) and a supracrestal connective tissue zone (~1.5 mm), totalling approximately 3–4 mm. This dimension is essential for the establishment of a stable soft tissue seal and the protection of underlying bone from microbial invasion and mechanical stress.

Peri-implant mucosal thickness is another critical determinant of long-term stability. Clinical and experimental studies indicate that mucosal thicknesses less than 2.5 mm are associated with increased crestal bone remodelling as the tissue attempts to re-establish the biological width. In contrast, a thick mucosal phenotype (>2.5 mm) offers improved resistance to recession, better aesthetic outcomes, and enhanced tissue stability. The facial alveolar bone morphology and implant angulation significantly influence mucosal thickness: lingual angulation tends to support thicker facial bone and more coronal soft tissue, while buccal angulation often correlates with a thinner bone plate and a higher risk of recession. [12]

The presence of an adequate band of keratinised mucosa (≥2 mm), including at least 1 mm of attached mucosa, is widely regarded as beneficial for peri-implant health. Keratinised tissue provides resistance to mechanical trauma, reduces plaque accumulation, and facilitates effective oral hygiene maintenance. Sites lacking sufficient keratinised tissue show higher rates of mucosal inflammation, recession, and patient discomfort, particularly when plaque control is inadequate. [12]

The quality of peri-implant mucosa also varies depending on its type. Masticatory mucosa, firm, keratinised, and tightly attached to the periosteum, is far more resistant to thermal, chemical, and mechanical insults compared to the alveolar mucosa, which is thin, nonkeratinized, and loosely attached. The strategic use of grafting procedures such as free gingival grafts, subepithelial connective tissue grafts, and soft tissue substitutes can increase the volume and keratinisation of peri-implant mucosa, thereby improving both biological protection and aesthetic integration.

Periodontal biotype is another influential factor. Thin, scalloped biotypes are more prone to mucosal recession and aesthetic complications, whereas thick, flat biotypes offer greater stability and more predictable outcomes. Proper case selection, soft tissue augmentation, and implant positioning should be guided by the patient's periodontal phenotype to optimise biological width, mucosal thickness, and keratinised tissue dimensions.

**Factors Influencing Soft Tissue Outcomes**

**Implant Position and Angulation [13]**

The three-dimensional placement of an implant plays a decisive role in determining soft tissue stability and esthetic outcomes. When an implant is positioned too deeply, excessive crestal bone remodelling occurs, which in turn compromises soft tissue support and makes maintenance more difficult. Conversely, a shallow placement often results in recession and the need for bone resorption to re-establish biologic width.

Correct angulation is equally vital. Implants placed outside the bony housing—such as too far buccally or lingually- can lead to soft-tissue dehiscence, inflammation, and peri-implant pocket formation. A minimum of 2 mm of intact buccal bone and proper inter-implant distances (≥1.5 mm from adjacent teeth and ≥3 mm between implants) are critical for preserving soft tissue contours.

Clinically, the implant position should be planned with both restorative needs and long-term tissue stability in mind. Digital planning tools, guided surgery, and CBCT imaging now allow clinicians to predict the influence of implant angulation on both bone and soft tissue outcomes, minimising esthetic failures and biological complications.

**Emergence Profile Considerations**

The emergence profile, particularly the design of the critical and subcritical contours, directly influences how soft tissue adapts around the implant restoration. The critical contour (from tissue margin to ~1.5 mm subgingivally) must mimic the natural tooth morphology to support papillae and maintain gingival architecture. The subcritical contour provides the transition space between the implant platform and the critical contour, ensuring tissue is not compressed or inflamed. [14]

Over-contoured restorations often result in soft-tissue impingement, inflammation, or papillary loss, while under-contoured profiles may leave inadequate support for the gingiva, causing esthetic deficiencies. Modern CAD/CAM prosthetics allow precise emergence profile design, which can be customised to the patient's phenotype. Furthermore, immediate provisionalization with a well-shaped provisional crown can "train" soft tissues, achieving more predictable esthetic outcomes.

**Biotype and Tissue Phenotype**

Soft tissue phenotype, either thin or thick, has a major influence on peri-implant stability. Studies show that a thick phenotype is associated with a thicker buccal plate, offering greater resistance to recession, while thin biotypes are prone to mucosal recession and black triangle formation.

Adequate keratinised mucosa also contributes to improved plaque control, reduced inflammation, and greater long-term stability. Patients with insufficient keratinised tissue often present higher plaque indices, bleeding scores, and attachment loss. Phenotype assessment should be integrated early in treatment planning. In thin biotype patients, adjunctive procedures such as soft tissue grafting (connective tissue grafts, acellular dermal matrix, or xenogeneic collagen matrices) can improve mucosal thickness and resilience. Importantly, digital and intraoral scanning technologies can help quantify soft tissue volume changes over time, supporting personalised care and proactive management of at-risk patients. [14]

**Techniques for Soft Tissue Sculpting [5, 15-17]**
**Prosthetically Driven Approaches**
**Immediate vs. Delayed Provisionalization**

The timing of implant provisionalization significantly influences soft tissue sculpting and esthetic outcomes. Immediate provisionalization, (Fig. 1 to 3) where a temporary crown is placed at the time of implant insertion, helps preserve papillary architecture, minimises soft tissue collapse, and "trains" the peri-implant mucosa to adapt to the desired emergence profile. This reduces mid-buccal recession and maintains contour, especially in the esthetic zone (Fig. 4). However, it requires high primary stability and is contraindicated in cases of poor bone quality or infection.

**Fig. 1: Implant Placement**

**Fig. 2: Immediate Loading of Abutment**

**Fig. 3: Immediate Temporary Acrylic Crown**

**Fig. 4: Soft Tissue Profile After 2 Months**

Delayed provisionalization allows for healing and osseointegration before soft tissue manipulation. While it provides a safer biological environment, it often results in more soft tissue flattening and resorption, necessitating additional sculpting procedures later. Immediate provisionalization can optimise esthetics, but a risk–benefit assessment based on stability, phenotype, and defect severity is essential. Digital workflows and chairside CAD/CAM provisionals now enhance precision in both immediate and delayed strategies.

**Customised Healing Abutments and Provisional Crowns**

Customised healing abutments and provisional crowns are critical in shaping peri-implant soft tissues. Unlike stock abutments, they mimic natural tooth contours, directing tissue healing into a stable, esthetic architecture. By modifying the critical contour (1–1.5 mm below the gingival margin) and subcritical contour (area coronal to the implant platform), clinicians can sculpt gingival margins and papillae predictably. With advancements in digital dentistry, 3D-printed or CAD/CAM-milled customised abutments have become routine, offering superior control over emergence profile and esthetic outcomes compared to chairside manual modifications.

**Surgical Approaches**
**Connective Tissue Grafts**

Connective tissue grafts (CTGs) are the gold standard for augmenting peri-implant soft tissue thickness and keratinised mucosa. They enhance ridge contour, resist recession, and improve long-term pink esthetic scores. CTGs can be harvested from the palate or tuberosity and placed via tunnelling, pouch, or flap designs. They are particularly effective in patients with thin tissue phenotypes or high esthetic demands. Despite donor site morbidity, CTGs provide predictable volumetric stability compared to collagen matrices. Their use remains highly recommended when recession risk is high.

**Pedicle Flaps and Pouch Techniques**

Pedicle flaps, such as the roll flap, utilise adjacent tissue while maintaining vascular supply, making them suitable for small ridge defects (<3 mm). Pouch graft techniques involve inserting a free graft into a subepithelial pocket, ideal for class I defects with minimal resorption. Pedicle-based techniques reduce healing complications and donor morbidity, while pouch techniques allow correction of contour deficiencies with less tension. Proper case selection is crucial for predictable outcomes.

**Socket Shield and Partial Extraction Therapies**

The socket shield technique (SST) and partial extraction therapies (PET) are minimally invasive approaches designed to preserve the buccal plate and its periodontal ligament, thereby maintaining natural gingival contours. By retaining part of the root (especially buccal root fragments), these techniques prevent post-extraction ridge collapse and recession. Although technically sensitive, SST and PET reduce the need for extensive grafting procedures. Long-term studies are still emerging, but short- to medium-term data show promising stability in both soft tissue contours and bone volume. [18]

**Materials and Adjuncts in Soft Tissue Shaping [19-20]**

**Role of Biomaterials (Collagen Matrices, Allografts, Xenografts)**

Biomaterials have emerged as reliable alternatives to autogenous grafts, minimising patient morbidity and surgical time.

- Collagen matrices (such as Mucograft® and Mucoderm®) are xenogeneic scaffolds derived primarily from porcine or bovine dermis. They provide a three-dimensional framework that allows cellular infiltration, angiogenesis, and revascularisation. Clinical trials demonstrate their effectiveness in increasing keratinised tissue width and supporting root coverage, with improved esthetic outcomes. However, their limitations include lower mechanical strength and rapid biodegradation compared to connective tissue grafts.
- Allografts, especially acellular dermal matrices like AlloDerm®, Puros Dermis®, and Epiflex®, have been used to restore gingival thickness and keratinised tissue. These offer the benefit of eliminating donor site morbidity while demonstrating good biocompatibility, vascularisation, and integration with host tissues. Some studies even suggest results comparable to autografts.
- Xenografts provide widely available substitutes for autografts, most often porcine-derived. Their natural extracellular matrix structure supports fibroblast migration and long-term stability. For example, Mucograft has shown predictable increases in attached gingiva and improved wound healing in recession coverage.

Biomaterials are not only substitutes but adjuncts that expand surgical possibilities, particularly in patients with limited donor tissue or high esthetic demands. Hybrid strategies—combining autografts with collagen matrices are gaining favour for enhanced stability and volumetric maintenance.

Advances in Digital Workflows (CAD/CAM Customised Abutments) [21]

Digital dentistry has revolutionised soft tissue sculpting by enabling the design of prosthetic components that actively shape peri-implant mucosa.

- CAD/CAM customised abutments replicate natural tooth contours, allowing precise control of the emergence profile. This facilitates papillary preservation, stable gingival margins, and improved esthetics. Compared with stock abutments, they offer superior biological integration by minimising soft tissue impingement and inflammation.
- Digital workflows also allow virtual planning of abutment design before surgery, ensuring harmony with soft tissue phenotype and prosthetic needs. Combined with intraoral scanning, they support chairside fabrication of customised healing abutments or provisional crowns.

The integration of CAD/CAM not only standardises abutment design but also shortens treatment time, increases predictability, and reduces chairside modifications. Future developments, such as AI-assisted emergence profile modelling, may further individualise soft tissue sculpting.

**Laser-Assisted and Piezo-Assisted Sculpting**

Adjunctive use of minimally invasive surgical tools enhances soft tissue manipulation with reduced morbidity.

- **Laser-assisted sculpting** allows precise gingival recontouring, improved hemostasis, and decreased postoperative discomfort. Diode and erbium lasers are commonly employed to shape peri-implant mucosa, with reported benefits of reduced bacterial load and accelerated wound healing.
- **Piezo-assisted techniques**, although more widely known for bone surgery, are increasingly applied in delicate mucosal modifications. Their micrometric vibrations allow controlled tissue sculpting while preserving vascularity and minimising trauma.

These energy-based adjuncts complement traditional scalpel or electrocautery approaches by offering enhanced precision, improved healing environments, and patient comfort. Their use is especially valuable in esthetic zones where tissue preservation is paramount.

## Evaluation of Soft Tissue Sculpting Success

### Pink Esthetic Score (PES)

The Pink Esthetic Score (PES) is the most widely used clinician-reported index for objective assessment of peri-implant soft-tissue esthetics. Originally described by Fürhauser *et al.,* (2005), PES evaluates seven soft-tissue parameters (mesial & distal papilla, soft-tissue level, contour, alveolar process deficiency, colour and texture) using a 0–1–2 scale (maximum 14), allowing reproducible comparison to the contralateral natural tooth. The PES has been incorporated into many clinical outcome studies and is often paired with the White Esthetic Score (WES) to capture both soft- and hard-tissue/restorative esthetic components (PES/WES). PES's strengths are simplicity, reproducibility across observers, and broad acceptance; its limitations include reliance on 2-D photographs, potential observer bias, and reduced sensitivity to subtle three-dimensional contour changes that are important after soft-tissue sculpting procedures. [7]

### Digital assessment methods

Digital technologies are rapidly transforming how peri-implant soft-tissue outcomes are measured. Intraoral scanners and extraoral 3-D imaging allow capture of volumetric soft-tissue contours, enabling objective measurement of buccal contour changes, emergence profile, and soft-tissue volume gain/loss with sub-millimetre resolution. Recent narrative and empirical studies have documented applications for digital planning, monitoring of healing, and objective quantification of soft-tissue augmentation outcomes. Advantages of digital assessment include high reproducibility, the ability to perform superimposition analyses (baseline vs follow-up), and improved sensitivity to small dimensional changes that PES/photographs may miss. Technical challenges remain: scanning mobile or translucent soft tissues, standardising reference planes for superimposition, and integrating colour/texture metrics. For these reasons, many recent papers recommend combining PES (clinician-rated) with 3-D digital metrics for a comprehensive evaluation of soft-tissue sculpting success. [21]

Suggested metrics to extract/compare in studies: linear gingival margin change, buccal soft-tissue thickness/volume ($mm^3$), emergence profile area, and 3-D superimposition RMS deviation values, alongside PES to provide both objective geometry and clinical esthetic context.

### Patient-reported esthetic outcomes

Clinician-rated indices do not always align perfectly with patient perception. Patient-reported outcome measures (PROMs) and Visual Analogue Scales (VAS) for esthetic satisfaction provide the patient perspective and are essential when assessing the success of soft-tissue sculpting aimed at improving appearance. Systematic reviews and recent large cohorts report generally high patient satisfaction after single-tooth implant therapy, even when clinician scores vary, but they also show that PREs/PROs capture domains (self-image, social comfort, smile satisfaction) that PES/WES cannot. The field has several validated instruments (e.g., Orofacial Esthetic Scale, domain-specific questionnaires, VAS for overall esthetics), and consensus statements recommend routine inclusion of PROMs in esthetic outcome studies to ensure treatments meet patients' expectations. Combining PES/WES, quantitative digital measures, and PROMs gives the most complete picture of success after soft-tissue sculpting.

Practical recommendation: report PROMs as both absolute scores and the proportion of patients reaching a predefined "acceptable" threshold (for example, VAS ≥8/10), and include a brief description of the instrument used (validated vs ad-hoc) so results can be pooled in future meta-analyses.

## Clinical Challenges and Complications [22-32]

Despite significant advances in biomaterials, digital workflows, and surgical techniques, soft tissue sculpting around dental implants is not without complications. Clinical challenges such as mucosal recession, peri-implant mucositis, and errors in contouring can compromise both functional and esthetic outcomes. Recognising their aetiology, clinical impact, and prevention strategies is crucial to achieving predictable results.

### Soft Tissue Recession

Soft tissue recession, defined as the apical migration of the peri-implant mucosal margin, remains one of the most common complications affecting esthetic success. Even minor recession (≥1 mm) can expose implant components or abutments, disrupt mucosal symmetry with adjacent teeth, and reduce pink esthetic scores (PES) (Cosyn *et al.,* 2012). Multiple factors contribute, including thin peri-implant biotype, inadequate buccal bone thickness (<2 mm), poor flap handling, traumatic provisionalization, and over-compression during soft tissue sculpting (Buser *et al.,* 2017). Recession is particularly prevalent in the anterior maxilla, where soft tissue thickness and buccal bone plate morphology play pivotal roles.

Longitudinal studies demonstrate that mucosal recession typically manifests within the first year after prosthesis placement, but may progress over time, especially in patients with poor oral hygiene or thin soft tissues (Kan *et al.,* 2011). Soft tissue augmentation with connective tissue grafts or collagen matrices at the time of implant placement has been shown to reduce the risk of recession and improve long-term mucosal stability (Zeltner *et al.,* 2017). Meticulous management of emergence profile development and the use of platform-switching abutments further minimise soft tissue displacement.

**Peri-implant Mucositis and Its Impact on Esthetics**

Peri-implant mucositis, characterised by reversible inflammation of the peri-implant mucosa without bone loss, affects up to 43–47% of implants and significantly impacts soft tissue health and esthetics (Berglundh *et al.,* 2018). Inflammation leads to swelling, redness, bleeding on probing, and volumetric changes that distort the gingival contour and symmetry. Chronic mucositis may alter the emergence profile and negatively affect PES/WES scores due to loss of papillary fill or irregular mucosal margins (Roccuzzo *et al.,* 2018).

The inflammatory state also compromises the stability of sculpted soft tissue contours by disrupting collagen organisation and angiogenesis critical to mucosal architecture. If untreated, mucositis can progress to peri-implantitis, with associated bone loss leading to irreversible soft tissue collapse and esthetic failure (Sanz & Chapple, 2012). Early detection through bleeding indices, patient education on plaque control, and supportive maintenance therapy are therefore crucial. Adjunctive use of laser therapy, photodynamic disinfection, and locally delivered antimicrobials has shown promise in reducing mucositis-associated soft tissue complications (Renvert *et al.,* 2019).

**Over- or Under-Contouring of Soft Tissue**

Accurate contouring of peri-implant soft tissue is central to achieving a harmonious emergence profile and natural esthetics. Over-contouring occurs when excessive soft tissue bulk or improperly shaped provisional restorations lead to convex mucosal architecture, creating unnatural shadowing, plaque accumulation niches, and pseudopocket formation (Wittneben *et al.,* 2013). Conversely, under-contouring results from insufficient volume or inadequate sculpting, producing flat or concave mucosal surfaces that fail to mimic natural gingival scallop and compromise papillary fill (De Bruyckere *et al.,* 2018).

Both errors negatively influence PES by altering soft tissue level, contour, and papillary presence. They may also predispose to biological complications — over-contoured profiles impede effective oral hygiene, while under-contoured sites are more prone to soft tissue recession. The use of CAD/CAM-customised healing abutments and provisional restorations, along with digital emergence profile planning, has significantly improved contour predictability (Suárez-López Del Amo *et al.,* 2020). Stepwise soft tissue conditioning, using progressive provisional modifications, is recommended to fine-tune mucosal shape and prevent abrupt or excessive remodelling.

**Clinical Recommendations**

- **Soft tissue recession**: Ensure ≥2 mm buccal bone thickness, use soft tissue augmentation in thin biotypes, and minimise flap trauma.
- **Peri-implant mucositis**: Implement strict maintenance protocols and patient education; treat early to prevent irreversible breakdown.
- **Contour errors**: Use digital planning and customised Provisionals to achieve ideal emergence profile geometry.

**Recent Advances and Future Directions: [33-40]**

**3D-printed scaffolds and bioprinting for peri-implant soft tissue**

Three-dimensional printing and extrusion-based bioprinting have evolved from proof-of-concept studies into translational platforms capable of fabricating patient-matched soft-tissue constructs and porous scaffolds that support cell ingrowth, vascularisation and controlled biodegradation. Recent reviews and experimental studies demonstrate that biomimetic bioinks (gelatin-methacryloyl, collagen, decellularised extracellular matrix blends) and multi-material printing enable constructs with graded stiffness and microarchitecture closely matching the gingival mucosa. These scaffolds can be seeded with fibroblasts, keratinocytes and endothelial cells to recreate mucosal layers and vascular networks — a key step toward off-the-shelf soft-tissue grafts tailored to peri-implant defects. Early animal and in-vitro data also show promising integration with titanium surfaces and improved soft-tissue thickness compared with acellular matrices. Major barriers remain: long-term in vivo durability, immunogenicity of cell-laden grafts, sterile manufacturing at scale, and regulatory pathways for clinical use. Continued work on bioink optimisation, vascularisation strategies, and combined hard/soft tissue bioprinting (for simultaneous bone and mucosa regeneration) will determine clinical feasibility.

**Growth factors and biologics (PRF, EMD, rhPDGF)**

Biologic adjuncts aimed at modulating wound healing and stimulating soft-tissue gain have gained traction in peri-implant therapy. Platelet-rich fibrin (PRF) is widely used as a simple, autologous scaffold providing concentrated growth factors and has shown encouraging results in improving soft-tissue healing, biotype thickness, and patient-reported esthetic outcomes in recent clinical series and systematic reviews — though heterogeneity in PRF preparation protocols limits pooled conclusions. Enamel matrix derivatives (EMD) appear to enhance early mucosal healing and keratinised tissue formation when used adjunctively at implant sites, with several clinical reports supporting reduced inflammation and better early esthetic perception. Recombinant human PDGF (rhPDGF-BB), delivered in collagen matrices, has the strongest clinical evidence for predictable soft-tissue volume gain and sustained thickness improvement in comparative trials and longer-term follow-ups. Collectively, biologics can accelerate and improve the quality of soft-tissue augmentation, but cost, standardisation, and clear indication guidelines remain unresolved.

**Artificial intelligence in predicting peri-implant esthetics**

Artificial intelligence (AI) and machine learning (ML) are rapidly entering implantology for diagnostic support, outcome prediction and treatment planning. Recent reviews show AI can accurately detect peri-implant bone loss on radiographs and stratify risk factors for complications. Early studies are now focusing on predicting esthetic outcomes (e.g., PES/WES, likelihood of recession) by combining clinical, radiographic and digital-scan data. Promising applications include automated landmarking on CBCT/intraoral scans, virtual soft-tissue simulations, and decision-support tools that suggest when augmentation is likely to be necessary to achieve target esthetic thresholds. Key limitations are dataset size and diversity, lack of external validation, and ethical/interpretability concerns (clinicians need explainable models). Integration of AI with digital workflows (scan → simulation → 3D print/biomaterial selection) could greatly improve individualised soft-tissue planning and reduce operator variability.

**Clinical Guidelines and Recommendations**

**Evidence-based strategies for predictable outcomes**

Predictable peri-implant soft-tissue esthetics requires a layered, evidence-based approach that integrates biology, biomechanics, and prosthetic planning.

- **Pre-operative risk assessment and planning.** Evaluate soft-tissue biotype, buccal bone thickness, keratinised mucosa width, mucosal phenotype and patient risk factors (smoking, periodontal history). Sites with thin biotype or buccal bone <2 mm should be flagged for prophylactic soft-tissue and/or bone augmentation to reduce post-restorative recession.
- **Timing of augmentation.** Soft-tissue augmentation can be performed simultaneously with implant placement, at second-stage surgery, or as a staged procedure; the choice depends on defect morphology and the clinician's ability to achieve tension-free closure. Consensus reviews indicate improved mucosal thickness and plaque control with augmentation, but limited impact on marginal bone levels — thus, timing should target mucosal stability and esthetic demands rather than bone preservation alone.
- **Choice of grafting material.** Autogenous subepithelial connective tissue grafts (SCTG) remain the gold standard for increasing soft-tissue thickness and achieving stable long-term volume; xenogeneic or volume-stable collagen matrices offer reasonable alternatives when donor-site morbidity is a concern, but generally deliver smaller gains. Document the graft choice, preparation protocol and expected gain (mm) in the surgical plan.
- **Prosthetic management and emergence profile control.** Use provisional restorations to progressively condition tissues and shape the emergence profile; avoid over- or under-contouring. Platform switching and careful abutment selection reduce microgap-related inflammation and help preserve soft-tissue contours. Digital design and CAD/CAM provisionals increase reproducibility.
- **Maintenance and monitoring.** Implement structured maintenance with plaque control reinforcement and recall intervals tailored by risk (e.g., 3- to 6-monthly). Early detection and treatment of mucositis prevent progression to defects that compromise esthetics. Objective outcome measures should include PES/WES, digital volumetric scans and PROMs to assess both clinician and patient perspectives.

## CONCLUSION

**Summary of techniques and outcomes**

Soft-tissue sculpting around implants blends surgical skill, biomaterial choice and prosthetic finesse. Evidence supports the following practical hierarchy: accurate pre-op assessment → preservation or augmentation of buccal bone and mucosal thickness (SCTG preferred for maximal stability) → progressive prosthetic conditioning using provisional restorations → rigorous maintenance. Clinical indices (PES/WES), digital volumetric metrics and PROMs together provide the most complete appraisal of success. While biologics and xenogeneic matrices reduce donor morbidity, autogenous grafts still offer the most consistent volumetric gains. Overall, coordinated multidisciplinary workflows yield the most reproducible esthetic outcomes.

**Future scope in enhancing peri-implant soft tissue sculpting**

Future improvements will come from integrating technologies and evidence: validated AI models to predict esthetic risk and guide augmentation need; patient-matched 3-D printed/bioprinted scaffolds combined with growth factors for off-the-shelf volumetric grafts; standardised outcome reporting (PES + digital volumetrics + PROMs) to enable robust meta-analyses; and multicenter randomised trials directly comparing biologics, scaffolds, and graft types. Emphasis on external validation, cost-effectiveness and regulatory pathways will be essential to translate promising lab advances into routine clinical care.

 

# REFERENCES


1. Kalra, M., IN, A., & B, D. (2013). Evolution of surgical guidance in implant dentistry. *Dental update*, *40*(7), 577-582.
2. Ivanovski, S., & Lee, R. (2018). Comparison of peri-implant and periodontal marginal soft tissues in health and disease. *Periodontology 2000*, *76*(1), 116-130.
3. Araújo, M. G., & Lindhe, J. (2018). Peri-implant health. *Journal of Clinical Periodontology*, *45*(S20), S230–S236.
4. Somanathan RV. Soft tissue esthetics in implant dentistry.
5. Agarwal, S., Sachdev, S. S., Mistry, L. N., Agrawal, S., Deshpande, S., Sharma, V., ... & Sharma Sr, V. (2025). Soft Tissue Management in Implant Dentistry: A Comprehensive Review. *Cureus*, *17*(2).
6. Fürhauser, R., Florescu, D., Benesch, T., Haas, R., Mailath, G., & Watzek, G. (2005). Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. *Clinical oral implants research*, *16*(6), 639-644.
7. Berglundh, T., Armitage, G., Araujo, M. G., Avila-Ortiz, G., Blanco, J., Camargo, P. M., ... & Zitzmann, N. (2018). Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *Journal of clinical periodontology*, *45*, S286-S291.
8. Wolff, J., Farré-Guasch, E., Sándor, G. K., Gibbs, S., Jager, D. J., & Forouzanfar, T. (2016). Soft tissue augmentation techniques and materials used in the oral cavity: An overview. *Implant Dentistry*, *25*(3), 427-434.
9. Nevins, M., Nevins, M. L., Schupbach, P., & Kim, D. M. (2011). The use of mucograft collagen matrix to augment the zone of keratinized tissue around teeth: a pilot study. *International Journal of Periodontics & Restorative Dentistry*, *31*(4).
10. Chambrone, L., Chambrone, D., Pustiglioni, F. E., Chambrone, L. A., & Lima, L. A. (2008). Can subepithelial connective tissue grafts be considered the gold standard procedure in the treatment of Miller Class I and II recession-type defects? *Journal of dentistry*, *36*(9), 659-671.
11. Paolantonio M, D'Archivio D, Mauro D, *et al.*,Increasing the width of keratinised mucosa around endosseous implants by means of an acellular dermal matrix: a randomised controlled trial. Clin Oral Implants Res. 2006;17(3):310–318.
12. Noelken, R., Geier, J., Kunkel, M., Jepsen, S., & Wagner, W. (2018). Influence of soft tissue grafting, orofacial implant position, and angulation on facial hard and soft tissue thickness at immediately inserted and provisionalized implants in the anterior maxilla. *Clinical implant dentistry and related research*, *20*(5), 674-682.
13. Lee, A., Fu, J. H., & Wang, H. L. (2011). Soft tissue biotype affects implant success. *Implant dentistry*, *20*(3), e38-e47.
14. Saadoun AP. Esthetic soft tissue management of teeth and implants.
15. Castellon, P., Casadaban, M., & Block, M. S. (2005). Techniques to facilitate provisionalization of implant restorations. *Journal of oral and maxillofacial surgery*, *63*(9), 72-79.
16. Lemongello Jr, G. J. (2007). Immediate custom implant provisionalization: A prosthetic technique. *Pract Proced Aesthet Dent*, *19*(5), 273-279.
17. Saez-Alcaide, L. M., Fernandez-Tresguerres, F. G., Brinkmann, J. C. B., Segura-Mori, L., Iglesias-Velazquez, O., Perez-Gonzalez, F., ... & Garcia-Denche, J. T. (2021). Socket shield technique: A systematic review of human studies. *Annals of Anatomy-Anatomischer Anzeiger*, *238*, 151779.
18. Khoury F, Hoppe A. Soft tissue management in oral implantology: a review of surgical techniques for shaping an esthetic and functional peri-implant soft tissue structure. Quintessence International. 2000 Jul 1;31(7).
19. Nevins M, Camelo M, De Paoli S, *et al.*,Use of xenogeneic collagen matrices for soft tissue augmentation: a review and clinical considerations. Int J Periodontics Restorative Dent. 2015;35(3):301–309.
20. Suárez-López del Amo F, Lin GH, Monje A, Galindo-Moreno P, Wang HL. Digital tools for soft tissue contour management in implant dentistry. J Prosthet Dent. 2020;124(2):197–205.
21. Cosyn J, *et al.*, The influence of the gingival biotype on peri-implant tissue stability. *Clin Oral Implants Res*. 2012;23(11):1316–21.
22. Buser D, *et al.*,10-year implant survival and success rates with early and late implant placement. *Clin Oral Implants Res*. 2017;28(2):211–20.
23. Kan, J. Y., Rungcharassaeng, K., Lozada, J. L., & Zimmerman, G. (2011). Facial gingival tissue stability following immediate placement and provisionalization of maxillary anterior single implants: a 2-to 8-year follow-up. *International Journal of Oral & Maxillofacial Implants*, *26*(1).
24. Zeltner M, *et al.*, Soft tissue volume changes after connective tissue grafting and collagen matrix application. *Clin Oral Implants Res*. 2017;28(4):496–503.
25. Berglundh, T., Armitage, G., Araujo, M. G., Avila-Ortiz, G., Blanco, J., Camargo, P. M., ... & Zitzmann, N. (2018). Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *Journal of clinical periodontology*, *45*, S286-S291.
26. Roccuzzo M, *et al.*, Peri-implant mucositis and peri-implantitis: A systematic review. *Clin Oral Implants Res*. 2018;29(S16):84–99.
27. Sanz, M., Chapple, I. L., & Working Group 4 of the VIII European Workshop on Periodontology*.

(2012). Clinical research on peri-implant diseases: consensus report of W orking G roup 4. *Journal of clinical periodontology*, *39*, 202-206.

28. Renvert S, *et al.*, Treatment of peri-implant mucositis and peri-implantitis. *Periodontol 2000*. 2019;79(1):190–212.
29. Wittneben, J. G., Joda, T., Weber, H.-P., & Brägger, U. (2013). Overcontouring of implant restorations: A systematic review. *Clinical Oral Implants Research, 24*(2), 104–110.
30. De Bruyckere, T., Eeckhout, C., Eghbali, A., Younes, F., Cosyn, J., & De Bruyn, H. (2018). The impact of undercontoured emergence profiles on peri-implant health. *Clinical Implant Dentistry and Related Research*, *20*(5), 785–792
31. Suárez-López del Amo, F., Lin, G.-H., Monje, A., Galindo-Moreno, P., & Wang, H.-L. (2020). Digital tools for soft tissue contour management. *The Journal of Prosthetic Dentistry, 124*(2), 197–205.
32. Ostrovidov, S., Ramalingam, M., Bae, H., Orive, G., Fujie, T., Shi, X., & Kaji, H. (2023). Bioprinting and biomaterials for dental alveolar tissue regeneration. *Frontiers in Bioengineering and Biotechnology*, *11*, 991821.
33. Subbiah, U., Rajaram, V., Mahendra, J., Kannan, L. P., Chellathurai, B. N., & Namasivayam, A. (2024). Biomimetic scaffold and 3D bioprinting in dental application: A review. *Bioinformation*, *20*(7), 789.
34. Vickram, A. S., Infant, S. S., Manikandan, S., Sowndharya, B. B., Gulothungan, G., & Chopra, H. (2025). 3D bio-printed scaffolds and smart implants: evaluating functional performance in animal surgery models. *Annals of Medicine and Surgery*, *87*(6), 3618-3634.
35. Giammarinaro, E., Baldini, N., Covani, U., Menini, M., Pesce, P., & Marconcini, S. (2025). Does platelet-rich fibrin enhance the outcomes of peri-implant soft tissues? A systematic review. *BMC Oral Health*, *25*(1), 615.
36. Alberti, A., Francetti, L., Taschieri, S., & Corbella, S. (2021). The applications of enamel matrix derivative in implant dentistry: a narrative review. *Materials*, *14*(11), 3045.
37. Tavelli, L., Barootchi, S., & Giannobile, W. V. (2020). Recombinant human platelet-derived growth factor: A systematic review of clinical findings in oral regenerative procedures. *JDR Clinical & Translational Research*, *6*(2), 161–173.
38. Nazari, Y., Lngeroodi, P. F., Maddahi, M., Kobravi, S., Amin, M. R., Bargrizaneh, A. A., & Fouladi, S. (2025). Artificial intelligence models and predicting implant success. *Biomedical Research and Therapy*, *12*(1), 7029-7038.
39. Mugri, M. H. (2025). Accuracy of Artificial Intelligence Models in Detecting Peri-Implant Bone Loss: A Systematic Review. *Diagnostics*, *15*(6), 655.