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REVIEW ARTICLE

SUPRACRESTAL TISSUE ATTACHMENT: MORPHOLOGICAL BASIS AND CLINICAL SIGNIFICANCE IN MODERN DENTAL PRACTICE: NARRATIVE REVIEW

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Background: The concept of "biological width," now formally designated as supracrestal tissue attachment (STA) following the 2018 World Workshop on the Classification of Periodontal and Peri-Implant Diseases, defines a stable junctional complex of epithelial and connective tissue structures forming a physiological seal around natural teeth and dental implants. Despite its fundamental clinical importance, STA remains underappreciated in routine restorative and implant treatment planning.

Materials and Methods: A narrative literature search was conducted in PubMed/MEDLINE, Scopus, and the Cochrane Library (January 2009 – December 2024) using the following terms: "supracrestal tissue attachment," "biological width," "peri-implant soft tissue seal," "crestal bone remodeling," and related keywords. Histological studies, experimental and clinical investigations, systematic reviews, and meta-analyses were included, alongside seminal historical contributions. Eighteen publications were selected for final inclusion.

Conclusions: STA is a dynamic biological complex averaging 2.04 mm around natural teeth (range 1.77–2.43 mm) and 3–4 mm around two-piece implants. Its peri-implant architecture differs fundamentally from that of natural teeth due to the parallel orientation of supracrestal collagen fibers and the absence of cementum-mediated anchorage, rendering it inherently more susceptible to mechanical and microbial disruption. Implant macro-design, connection type, and soft tissue biotype are primary determinants of STA stability. Violation of STA dimensions initiates an irreversible cascade of junctional breakdown, marginal bone resorption, and soft tissue recession, underscoring the necessity of individualized STA assessment and preservation as a mandatory component of restorative and implant treatment planning.

Keywords: supracrestal tissue attachment; biological width; dentogingival junction; dental implantation; peri-implant tissues; marginal bone remodeling; soft tissue biotype.

INTRODUCTION

The maintenance of periodontal and peri-implant tissue integrity depends on a precise anatomical complex situated at the interface between the oral epithelium, connective tissue, and the underlying alveolar bone. This complex — historically referred to as the "biological width" — was first described by Gargiulo, Wentz, and Orban (1961), who established its average vertical dimension at approximately 2.04 mm, comprising the junctional epithelium (approximately 0.97mm) and the supracrestal connective tissue attachment (approximately 1.07 mm) [1]. The sulcular epithelium, with a mean depth of 0.69 mm, constitutes an additional but variable component of the dentogingival unit. The term "biological width" was further conceptualized in a clinical context by Ingber, Rose, and Coslet in 1977, who emphasized its relevance to restorative dentistry and the consequences of its violation[2].

However, following the 2018 World Workshop on the Classification of Periodontal and Peri-Implant Diseases, the terminology was formally updated: the preferred

designation is now supracrestal tissue attachment (STA), reflecting a more precise anatomical and functional characterization of this structure[3]. This terminological shift is not merely semantic — it underscores the complex's role as an active biological barrier rather than a passive dimensional parameter. Throughout this review, both terms are used where contextually appropriate, with preference given to the current nomenclature. Anatomically, the STA is localized between the apical margin of the restorative margin and the alveolar bone crest. Its dimensions are not uniform across the dentition: posterior teeth exhibit STA measurements averaging 0.33 mm greater than anterior teeth, and individual variation is considerable, ranging from as narrow as 0.75 mm to as wide as 4.3 mm [4]. This biological variability necessitates individualized clinical measurement under local anesthesia using a calibrated periodontal probe, rather than reliance on population averages.

The clinical relevance of STA extends beyond natural dentition. With the widespread adoption of osseointegrated implants, it has become evident that implant-supported restorations are also surrounded by a soft tissue attachment complex analogous — yet not identical — to that of natural teeth. Around titanium implants, the peri-implant STA is characterized by a parallel orientation of collagen fibers along the abutment surface, in contrast to the perpendicular fiber insertion seen around natural roots [7]. This structural difference renders peri-implant tissues inherently more vulnerable to mechanical disruption and microbial invasion, with direct implications for marginal bone stability.

Furthermore, implant macro-design plays a decisive role in STA formation and maintenance. Two-piece implants introduce a microgap at the implant-abutment interface, which serves as a reservoir for bacterial colonization and is associated with inflammatory bone resorption [8-10]. One-piece implants eliminate this microgap, thereby reducing the inflammatory stimulus at the crestal level [11,15]. The spatial position of the implant-abutment connection relative to the bone crest further modulates the extent of crestal bone remodeling and the dimensions of the peri-implant STA [12].

Despite the growing body of evidence, STA remains underutilized as a treatment-planning parameter in routine clinical practice. Violation of its dimensions initiates a predictable biological response: disruption of the junctional epithelium, activation of osteoclastic bone resorption, and ultimately irreversible soft tissue recession [13]. The present narrative review aims to consolidate current morphological, histological, and clinical evidence on STA around both natural teeth and dental implants, and to provide clinically applicable recommendations for its preservation across restorative, periodontal, and implantological treatment modalities.

MATERIALS AND METHODS

Study Design

This study was designed as a narrative review in accordance with the Scale for the Assessment of Narrative Review Articles (SANRA) guidelines. No ethical approval was required, as the review is based exclusively on previously published data.

Literature Search Strategy

A systematic literature search was conducted in PubMed/MEDLINE, Scopus, and the Cochrane Library. The search covered publications from January 2009 to December 2024, with inclusion of seminal historical studies published prior to this period where clinically or historically relevant. The following search terms were applied in various combinations using Boolean operators (AND, OR): "supracrestal tissue attachment", "biological width", "dentogingival junction", "peri-implant soft tissue seal", "peri-implant connective tissue", "crestal bone remodeling", "implant-abutment connection", "soft tissue biotype", "junctional epithelium", "marginal bone resorption".

Inclusion and Exclusion Criteria

Inclusion criteria: studies were considered eligible if they: (1) were published in peer-reviewed journals in English or Russian; (2) focused on the morphology, histology, or clinical significance of STA around natural teeth or dental implants; (3) were designed as histological, experimental, or clinical studies, case series, systematic reviews, or meta-analyses.

Exclusion criteria: studies were excluded if they were published as conference abstracts, editorials, or letters without original data, or did not include quantitative outcomes related to STA dimensions.

Data Extraction and Final Selection

Titles and abstracts were screened for relevance; full texts of eligible studies were reviewed in detail. Data were extracted regarding study design, sample characteristics, histological findings, implant parameters, and clinical outcomes. Given the heterogeneity of study designs, a formal meta-analysis was not performed; findings are presented descriptively. Following screening, 18 publications were included in the final review.

RESULTS

5.1 Anatomical and Histological Dimensions of STA Around Natural Teeth

The foundational morphological description of the dentogingival complex was established by Gargiulo, Wentz, and Orban (1961), who analyzed 287 teeth from 30 human autopsy specimens and identified three distinct components of STA[1]. The sulcular epithelium demonstrated a mean depth of 0.69 mm; the junctional

epithelium measured 0.97 mm (range: 0.71–1.35 mm); and the supracrestal connective tissue fiber attachment averaged 1.07 mm (range: 1.06–1.08 mm). The combined vertical dimension — excluding the sulcus — amounts to a mean of 2.04 mm (range: 1.77–2.43 mm), representing the minimum tissue volume required to maintain periodontal health [4,5].

These dimensions were corroborated by Vacek et al. (1994), who confirmed regional variation: posterior teeth exhibited STA dimensions averaging 0.33 mm greater than anterior teeth [4]. Individual biological variability is considerable — STA may range from 0.75 mm to 4.3 mm in healthy subjects — underscoring the inadequacy of applying population-based averages to individual treatment planning [6].

The connective tissue component of STA is histologically characterized by densely arranged collagen fiber bundles — the Sharpey fibers — that insert perpendicularly into the root cementum and extend coronally toward the alveolar bone crest. This perpendicular insertion confers significant mechanical resistance and establishes a robust fibrous seal against microbial penetration. The junctional epithelium adheres to the tooth surface via hemidesmosomes and a basal lamina, forming a semi-permeable biological barrier against pathogenic microorganisms and foreign particles [18].

Clinical measurement of STA is performed under local anesthesia using a calibrated periodontal probe. The distance from the base of the gingival sulcus to the alveolar bone crest is recorded; subtracting the probing depth yields the STA dimension. This procedure should be performed at a minimum of two sites per tooth in subjects with clinically healthy periodontium [6].

5.2 Structural Characteristics of Peri-Implant STA

The peri-implant soft tissue complex shares several morphological features with its periodontal counterpart, yet differs in fundamental histological respects. Following osseointegration and abutment connection, a soft tissue barrier forms around the transmucosal component that structurally resembles the dentogingival unit [14].

The most clinically significant distinction lies in collagen fiber orientation. Whereas periodontal collagen fibers insert perpendicularly into root cementum, peri-implant connective tissue fibers originate from the marginal bone and align parallel to the titanium abutment surface without inserting into it [7]. Kondo et al. (2022) demonstrated through polarized-light microscopy that fibers within 200 μm of the implant surface are organized in bundles of 1–5 μm diameter, oriented perpendicularly near the crestal bone, transitioning to a parallel orientation coronally[7]. This three-dimensional network provides mechanical stability and establishes a sealed barrier against microbial ingress.

Berglundh et al. (1991) documented a thin, avascular, collagen-rich layer of less than 100 μm at the implant-connective tissue interface[14]. The absence of vascularization renders this zone particularly susceptible to ischemic injury during prosthetic manipulation. The total vertical dimension of peri-implant STA consistently exceeds that of natural teeth: around two-piece implants, it ranges from 3 to 4 mm, compared to the 2.04 mm average around natural dentition, reflecting a compensatory tissue response to the absence of cementum-mediated fiber insertion [12].

5.3 Influence of Implant Macro-Design and Implant-Abutment Connection on STA Stability

The macro-configuration of the implant system is a primary determinant of peri-implant STA architecture. Two-piece implant systems incorporate an implant-abutment microgap typically positioned at or near the alveolar bone crest. Canullo et al. (2015) demonstrated that microbial composition within the implant-abutment interface was qualitatively similar to subgingival peri-implant plaque in a cross-sectional study of 5-year loaded implants, confirming that microgap contamination occurs regardless of connection geometry [8]. This persistent bacterial presence is mechanistically linked to crestal bone resorption of 1.5–2.0 mm observed during the first year of loading [9,10].

Platform-switching — connecting a smaller-diameter abutment to a wider implant platform — displaces the microgap away from the bone crest, reducing the inflammatory infiltrate volume and attenuating marginal bone resorption [12]. Rodriguez et al. (2016) confirmed histologically in human specimens that platform-switched implants with conical abutments demonstrated a more coronally positioned connective tissue attachment and reduced crestal bone remodeling [12]. One-piece implants eliminate the microgap entirely; Glauser et al. (2005) and Broggini et al. (2006) confirmed that crestal positioning of the implant-abutment interface is directly associated with significantly greater inflammatory cell accumulation [11,15].

5.4 Role of Soft Tissue Biotype in STA Stability and Clinical Outcomes

The soft tissue biotype — defined by the thickness and morphological characteristics of the gingival or peri-implant mucosa — exerts a significant modulatory influence on STA stability. The thin-scalloped biotype demonstrates substantially greater susceptibility to recession following surgical or prosthetic manipulation. Kawahara et al. (1998) confirmed that the epithelial adhesion mechanism around titanium implants is functionally comparable to that of natural teeth, but that tissue volume critically determines the resilience of this seal against invasive factors [17]. In the anterior esthetic

zone, recession of even 0.5–1.0 mm may produce unacceptable esthetic outcomes, warranting prophylactic soft tissue augmentation in patients with thin biotype [17].

5.5 Clinical Consequences of STA Violation and Preventive Strategies

Violation of STA dimensions initiates a well-characterized biological cascade [13]. Lindhe et al. (1992) demonstrated experimentally in a beagle dog model that deliberate disruption of the attachment apparatus resulted in progressive bone loss and soft tissue breakdown [13]. The sequence follows a predictable pattern: inflammatory disruption of the junctional epithelium → osteoclastic activation → marginal bone resorption → apical migration of the soft tissue and clinically visible recession. This cascade is largely irreversible without surgical intervention.

Crown margins should be placed at or coronal to the gingival margin whenever possible; where subgingival margins are indicated, they must not encroach within 2.0–2.5 mm of the alveolar bone crest. In implant dentistry, platform-switched connections, conical implant-abutment interfaces, and tissue-level implant designs are associated with reduced crestal bone remodeling. Soft tissue augmentation should be considered a standard protocol component rather than an optional adjunct in patients with thin biotype [12,17].

DISCUSSION

The findings synthesized in this review affirm that STA constitutes a dynamic, biologically active interface whose integrity is fundamental to the long-term success of both periodontal and implant-supported restorations. The transition from "biological width" to "supracrestal tissue attachment" reflects a deeper conceptual evolution: STA is now understood not merely as a dimensional parameter to be respected, but as a functional tissue complex to be actively preserved and, where necessary, surgically reconstructed.

Terminological Evolution and Its Clinical Significance

The formal reclassification by the 2018 World Workshop redirects clinical focus from passive dimensional compliance toward active maintenance of tissue integrity. Clinicians who apply population-based averages of 2.04 mm without individualized assessment risk systematically underestimating STA, given the documented range of 0.75 to 4.3 mm [6]. This review advocates for routine individualized STA measurement as a standard component of pre-restorative and pre-implant examination.

Structural Differences Between Periodontal and Peri-Implant STA

The perpendicular insertion of Sharpey fibers into root cementum provides the natural dentition with mechanically resilient attachment that has no true equivalent around titanium implants [7]. The wider STA dimensions around two-piece implants (3–4 mm vs. 2.04 mm) represent a compensatory tissue response rather than superior biological adaptation [12]. Clinicians must account for these expanded dimensions when planning implant depth and restoration margins.

The Microgap: From Biological Liability to Engineering Solution

Convergent evidence confirms that the microgap functions as a persistent bacterial reservoir sustaining low-grade crestal inflammation [8,9,10]. Platform-switching, conical connections, and subcrestal positioning can substantially attenuate crestal bone remodeling [11,12,15], reframing early marginal bone loss as a largely preventable complication rather than an inevitable biological phenomenon.

Soft Tissue Biotype: An Underutilized Diagnostic Parameter

Biotype assessment remains inconsistently applied in routine practice. Patients with thin biotype should be considered candidates for prophylactic soft tissue augmentation regardless of whether recession is clinically apparent — serving not merely an esthetic but a biological function by increasing peri-implant STA resilience and reducing long-term marginal bone loss risk [17].

Limitations of the Current Evidence Base

The majority of histological studies on peri-implant STA are based on animal models or small human autopsy series, with sample sizes frequently ranging from 3 to 30 specimens, limiting generalizability. Several key studies — including Gargiulo et al. (1961) and Berglundh et al. (1991) — were conducted on cadaveric or animal material, which may not accurately reflect the tissue dynamics in living patients under functional loading conditions. Significant heterogeneity exists across studies in measurement methodologies and follow-up durations. Histological measurements in some studies were performed using light microscopy while others employed polarized-light or scanning electron microscopy, producing non-comparable absolute values. Furthermore, variability in implant systems, abutment materials, loading protocols, and patient demographics across studies precludes direct cross-study comparison and limits the strength of pooled conclusions. The long-term behavior of peri-implant STA under occlusal overload, parafunctional habits, and systemic conditions such as diabetes mellitus remains incompletely characterized. The influence of host-related factors — including smoking, immunosuppression, and osteoporosis — on peri-implant STA dimensions has not been systematically investigated in the studies included in this review, representing a significant gap in the current evidence base. No universally accepted protocol currently exists for standardized STA measurement in routine practice — a

priority area for future research.

These methodological limitations collectively restrict the generalizability of findings regarding peri-implant STA dimensions and their clinical thresholds. Caution is warranted when extrapolating histological measurements derived from animal or autopsy specimens to clinical decision-making in living patients, particularly with regard to determining safe restoration margin positions and implant placement depths.

Future Directions

Emerging ceramic and zirconia abutment materials have demonstrated promising soft tissue biocompatibility and reduced bacterial adhesion. Prospective controlled trials comparing zirconia and titanium abutments with standardized STA measurement outcomes are needed to establish evidence-based material selection criteria. Platelet-rich fibrin and cell-based therapies for augmenting peri-implant soft tissue volume warrant evaluation in randomized controlled trials. Such trials should stratify patients by soft tissue biotype and report STA-specific outcomes using a uniform measurement protocol to enable cross-study comparison. Integration of cone beam CT with enhanced soft tissue protocols and intraoral scanning with automated tissue dimension analysis may facilitate more precise STA assessment, bridging the gap between research-level histological measurement and routine clinical applicability.

A priority area for future research is the development and validation of a universally accepted, clinician-friendly protocol for standardized peri-implant STA measurement. Such a protocol should define minimum probe force, number of measurement sites per implant, reference anatomical landmarks, and acceptable measurement error thresholds. Adoption of a consensus-based measurement standard would allow pooling of data across studies and facilitate the transition of STA assessment from a research parameter to a routine clinical benchmark — analogous to established periodontal probing protocols.

Finally, longitudinal studies with a minimum follow-up of five years are required to characterize the natural history of peri-implant STA under real-world clinical conditions, including the impact of occlusal loading, parafunctional habits, systemic disease, and aging on STA stability and marginal bone maintenance.

CONCLUSION

Supracrestal tissue attachment is a fundamental biological parameter governing long-term stability of both periodontal and peri-implant tissues. The present review affirms that STA is a dynamic complex modulated by biological, surgical, and prosthetic variables.

First, the mean STA of 2.04 mm constitutes a minimum threshold, not a universal standard. Individualized STA measurement under local anesthesia is an indispensable pre-treatment step given the range of 0.75–4.3 mm.

Second, the parallel collagen fiber orientation of peri-implant STA — versus perpendicular in periodontal tissue — renders it inherently more vulnerable. Greater clinical caution is required during all prosthetic and surgical manipulations around implants.

Third, the implant-abutment microgap is a modifiable biological liability. Platform-switched connections, internal conical interfaces, and strategic implant positioning can substantially prevent early crestal bone loss, which should no longer be accepted as inevitable.

Fourth, soft tissue biotype is a critical underutilized risk parameter. Thin-biotype patients require individualized planning including prophylactic soft tissue augmentation to ensure adequate STA volume and long-term esthetic stability.

Fifth, the terminological transition to "supracrestal tissue attachment" — adopted by the 2018 World Workshop — reflects a conceptually significant shift that warrants broader adoption in clinical education, specialist training, and interdisciplinary communication.

Violation of STA integrity initiates an irreversible cascade of marginal bone resorption and soft tissue recession. Prevention through meticulous treatment planning, biotype-informed protocols, and evidence-based implant system selection remains the most effective strategy for durable functional and esthetic outcomes. Future research should prioritize standardization of STA measurement methodologies, long-term evaluation of novel implant materials, and evidence-based guidelines for soft tissue augmentation in biotype-stratified populations.

DECLARATIONS

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Competing Interests

The authors declare no competing or conflicting interests related to this work.

Ethical Approval

Ethical approval was not required for this study, as it is a narrative review based exclusively on previously published, publicly available data. The review was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

Author Contribution

Kurakhmaeva Sayat Abdulazizovna contributed to the study conceptualization, conducted the investigation, and wrote the original draft of the manuscript.

Osmanova Hairulbariyat Osmanovna contributed to the investigation, curated the data, and participated in writing the original draft.

Rustamova Emilia Semedovna carried out the investigation, performed the formal analysis, and contributed to the original draft preparation.

Aidaeva Karina Ramazanovna was involved in the investigation, developed the visual materials, and contributed to writing the original draft.

Kalandarov Said Kalandarovich contributed to the investigation, provided study resources, and participated in drafting the manuscript.

Gadzhibutaev Alil Valerievich took part in the investigation, managed data curation, and contributed to writing the original draft.

Sharipova Madina Makhachevna contributed to the investigation, validated the findings, and participated in drafting the manuscript.

Gadzhiagaev Kamal Kemranovich was involved in the investigation, prepared the visual materials, and contributed to the original draft.

Ordashev Hasan Alievich conceived the study, developed the methodology, supervised the project, and critically reviewed and revised the manuscript.

All authors have read and approved the final version of the manuscript.

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