THE USE OF AUTOGENOUS TOOTH BONE GRAFT FOR RECONSTRUCTIVE PERIODONTAL SURGERIES

PhD thesis

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"It is difficult to believe that almost 100 years after the birth of periodontal surgery, we still think we can do better than nature."

-Pat Allen DDS, 1997-

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1. List of abbreviations

ANGLE	Defect Angle
ATB	Autogenous Tooth Bone graft
BMP	Bone Morphogenetic Protein
CAL	Clinical Attachment Level
CBCT	Cone Beam Computed Tomography
CI	Confidence Interval
DDM	Demineralized Dentin Matrix
EDTA	Ethylenediaminetetraacetic Acid
EDS	Extraction Defect Sounding
EMD	Enamel Matrix Derivative
FMBS	Full-Mouth Bleeding Score
FMPS	Full-Mouth Plaque Score
GRADE	Grading of Recommendations Assessment, Development and Evaluation
GR	Gingival Recession
HCl	Hydrochloric Acid
INTRA	Vertical Defect Depth
MD	Mean Difference
NaOH	Sodium Hydroxide
PDDM	Partially Demineralized Dentin Matrix
PICO	Population, Intervention, Comparison, Outcome
PPD	Probing Pocket Depth

PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	International Prospective Register of Systematic Reviews
ROB-2	Risk of Bias 2 tool
ROBINS-I	Risk Of Bias In Non-randomized Studies of Interventions
SE RKEB	Semmelweis University Regional and Institutional Committee of Science and Research Ethics
TGF-β	Transforming Growth Factor beta
UDDM	Undemineralized Dentin Matrix
WIDTH	Horizontal Defect Width

2. Student profile

2.1. Vision and mission statement, specific goals

My vision is that none of the extraction sites should be left unpreserved.

My mission to change the mindset of the tooth extractions and the overall handling of the extraction site managements.

My specific goals include the investigation of the use of ATB for ARP and also its use for reconstructive periodontal surgeries.

2.2. Scientometrics

Number of all publications: 13

Cumulative IF: 41.671

Av IF/publication: 3.25

Ranking (Sci Mago): D1: 2; Q1:10; Q2: 1

Number of publications related to the subject of the thesis: 2

Cumulative IF: 6.5

Av IF/publication: 3.25

Ranking (Sci Mago): Q1: 2

Number of citations on Google Scholar: 290

Number of citations on MTMT (independent): 175

H-index: 7

The detailed bibliography of the student can be found on page 71.

2.3. Future plans

Looking ahead, my main objectives are to further pursue my research activities while simultaneously gaining experience in clinical practice. I am convinced that a deep and practical understanding of healthcare goes far beyond theoretical knowledge.

A key element of my professional vision is to engage in international research collaborations. I believe that cross-border cooperation fosters innovation and allows for the exchange of diverse approaches, which can significantly enrich both scientific and clinical work. I am particularly motivated to bring back the experience and knowledge acquired abroad and tailor it to the Hungarian healthcare context, contributing to its progress and modernization.

Through the integration of research, global partnerships, and patient-centered practice, I strive to build a career that not only contributes to international scientific advancement but also has a direct, positive impact on healthcare outcomes in Hungary.

3. Summary of the thesis

Bone regeneration following tooth extraction and periodontal tissue loss remains a central challenge in contemporary periodontal and implant-related therapy. Conventional graft materials, particularly xenogeneic substitutes, are widely used due to their space-maintaining properties; however, their limited remodeling capacity and long-term persistence may compromise physiological bone regeneration, especially in biologically unfavorable environments. Autogenous tooth-derived bone grafts have emerged as a promising alternative, offering a patient-specific, biocompatible, and potentially more physiologically integrated grafting option.

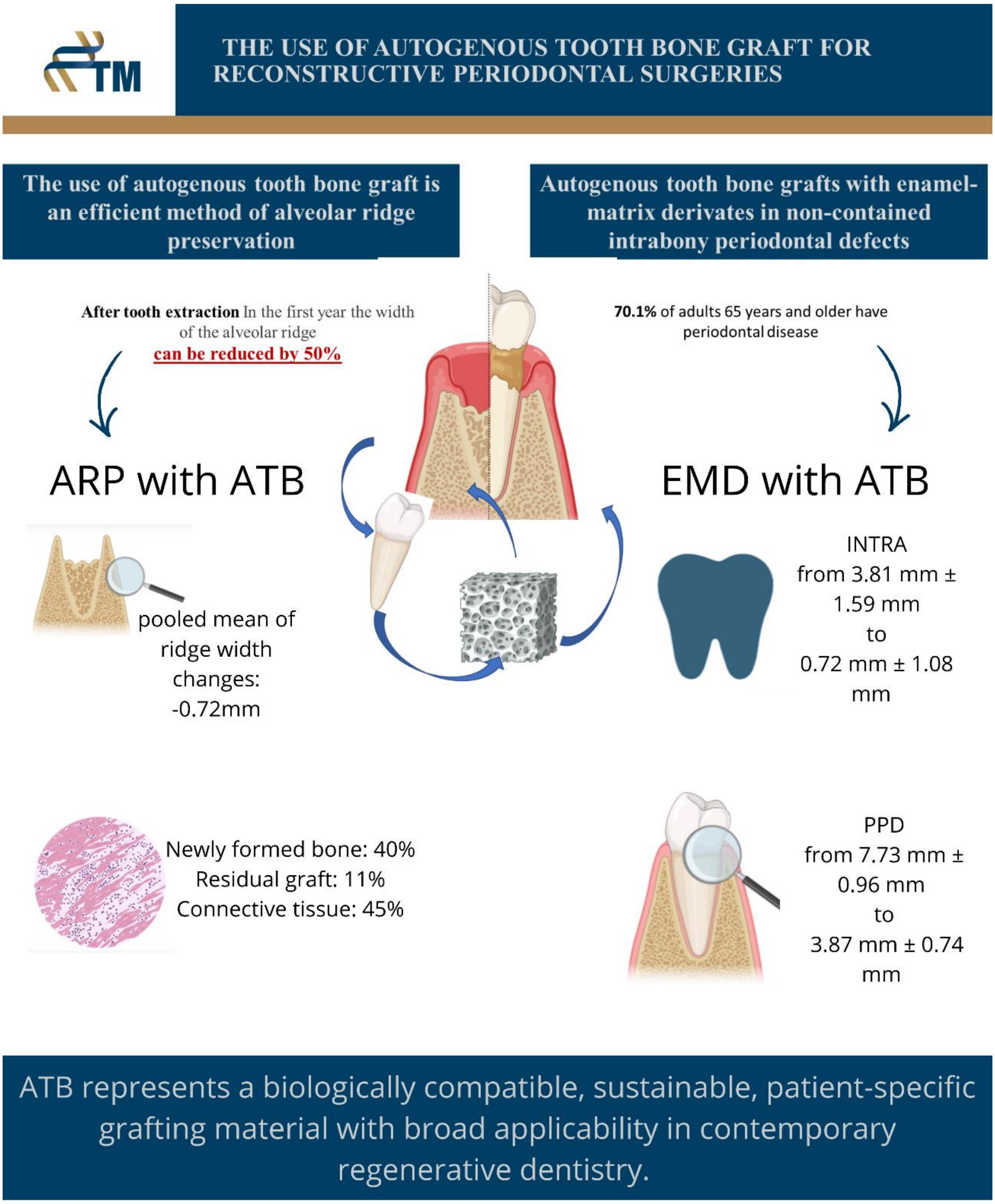
The aim of this PhD thesis was to evaluate the clinical and biological performance of autogenous tooth-derived bone grafts in alveolar ridge preservation and reconstructive periodontal therapy. To address this objective, a combined methodological approach was applied.

Study I demonstrated that autogenous tooth bone grafts are effective in preserving alveolar ridge dimensions following tooth extraction and exhibit a favorable remodeling profile, characterized by increased new bone formation and reduced persistence of residual graft material. These outcomes were comparable to those reported for commonly used particulate graft materials.

Study II showed in a retrospective clinical case series that the combined application of autogenous tooth-derived bone grafts and enamel matrix derivative resulted in clinically and radiographically meaningful improvements in non-contained periodontal intrabony defects, including reductions in probing pocket depth and radiographic evidence of defect fill.

Overall, the findings indicate that autogenous tooth-derived bone grafts represent a viable grafting option in both post-extraction and periodontal regenerative procedures, particularly in clinical situations where physiological graft remodeling is desirable.

4. Graphical abstract



THE USE OF AUTOGENOUS TOOTH BONE GRAFT FOR RECONSTRUCTIVE PERIODONTAL SURGERIES

The use of autogenous tooth bone graft is an efficient method of alveolar ridge preservation

After tooth extraction In the first year the width of the alveolar ridge **can be reduced by 50%**

ARP with ATB

pooled mean of ridge width changes: -0.72mm

Newly formed bone: 40%
Residual graft: 11%
Connective tissue: 45%

Autogenous tooth bone grafts with enamel-matrix derivates in non-contained intrabony periodontal defects

70.1% of adults 65 years and older have periodontal disease

EMD with ATB

INTRA
from 3.81 mm ± 1.59 mm
to
0.72 mm ± 1.08 mm

PPD
from 7.73 mm ± 0.96 mm
to
3.87 mm ± 0.74 mm

ATB represents a biologically compatible, sustainable, patient-specific grafting material with broad applicability in contemporary regenerative dentistry.

5. Introduction

5.1. Overview of the topic

5.1.1. What is the topic?

Our primary objective was to evaluate the efficacy of autogenous tooth bone grafts (ATBs) in alveolar ridge preservation (ARP) and to retrospectively analyze our data on the use of ATBs in reconstructive periodontal surgeries.

5.1.2. What is the problem to solve?

Traditionally used bone graft materials often fail to meet all the biological and clinical requirements necessary for successful reconstructive periodontal surgery. Periodontal and post-extraction defects present particular challenges due to their complex vascular supply. One of the major limitations of many conventional grafting materials is their minimal or absent remodelling capacity. Therefore, it is essential to employ graft materials that are both biologically compatible and capable of supporting true periodontal regeneration.

5.1.3. What is the importance of the topic?

Tooth extraction is among the most frequently performed surgical interventions in dental practice and is commonly followed by regenerative procedures aimed at managing post-extraction defects and enabling future implant placement. As a consequence, the clinical demand for predictable, biocompatible, and cost-effective bone graft materials in periodontal and implant-related therapies continues to increase (1). In periodontal reconstructive therapy, the principal therapeutic aim is to preserve the existing hard and soft tissue architecture while restoring lost periodontal tissues with their original structure and function (2, 3). In current clinical practice, xenogeneic bone substitutes are among the most widely applied graft materials due to their favorable handling properties and ability to maintain space. However, their biological performance is often limited by slow or incomplete remodeling, and residual graft particles, up to 40%, frequently observed even after extended healing periods. For this reason, xenogenic graft materials can not fulfil the requirement of full periodontal reconstruction(4-6).

Despite its mineralized structure and biological origin, the extracted tooth is conventionally regarded as biological waste and is not reused, although it represents a readily available autogenous source of graft material. Owing to their compositional similarity to alveolar bone—particularly with respect to hydroxyapatite and collagen content—these grafts exhibit favorable osteoconductive properties and may support physiological bone remodeling. Moreover, the use of autogenous material eliminates the risk of immune reactions and disease transmission and avoids ethical or cultural concerns associated with allogeneic and xenogeneic grafts(7-9).

Within this context, the investigation of autogenous tooth-derived grafts is of particular relevance for improving clinical strategies in alveolar ridge preservation and periodontal regeneration, and for addressing the limitations associated with currently available grafting materials.

5.1.4. What would be the impact of our research results?

The results of this research may significantly contribute to the advancement of regenerative periodontal therapy by providing further clinical evidence supporting the use of autogenous tooth-derived graft materials. Demonstrating the safety, efficacy, and biological compatibility of such grafts could lead to a paradigm shift in bone regeneration, encouraging clinicians to adopt more sustainable and patient-specific approaches. This could reduce reliance on expensive synthetic or xenogeneic grafts, improve clinical outcomes in challenging cases, and enhance patient acceptance by utilizing a material that would otherwise be considered medical waste. In the broader context, our findings could pave the way for standardized protocols for tooth graft preparation and application, potentially expanding its use across multiple disciplines within oral and periodontal surgery.

5.2. Changes after tooth extractions

After tooth extraction-without any type of intervention- the greatest loss of alveolar bone volume takes place within the first 6 months after extraction, with horizontal reduction ranging from 29% to 63% and vertical loss between 11% and 22%. (10). This deficiency of the facial bone anatomy is a critical causative factor for implant failures and has a negative impact of early implant complications (11).

The morphology of the extraction socket—including the condition of the hard and soft tissues, as well as the integrity of adjacent structures—plays an important role in determining the feasibility and complexity of subsequent implant placement. Several classification systems have been developed to categorize extraction defects, most of which rely on the extent of buccal bony deficiency, as this parameter is strongly associated with the potential need for further augmentation procedure (12-14).

Post-extraction defects may be classified by the Extraction Defect Sounding (EDS) categories based on the dimensional characteristics of the hard and soft tissues. These classifications serve as a clinical guideline for subsequent implant-related treatment planning. In EDS class 1 and 2 defects, the buccal bone wall remains intact, allowing for immediate implant placement. In contrast, EDS class 3 and 4 defects are characterized by advanced hard- and soft-tissue loss, necessitating staged surgical rehabilitation prior to implant placement (15).

In cases of critical buccal bone loss, like EDS class 3 and 4 cases, ARP has been proposed as a means to minimize the need for later staged reconstructive procedures. Although ARP has been utilized since the late 1990s, its overall clinical effectiveness continues to be debated. Evidence suggests that ARP can reduce the magnitude of horizontal and vertical ridge resorption by approximately 16–40% compared with unassisted healing, yet the clinical relevance of these differences remains unclear (16-18).

A wide range of surgical techniques and grafting materials have been advocated for ARP; however, none have consistently achieved predictably superior outcomes. Both particulate and non-particulate biomaterials may be utilized. Non-particulate grafts tend to undergo complete remodeling but offer limited space maintenance, while particulate materials are easy to handle and provide structural support within the socket (19, 20). Xenogeneic grafts with slow resorption rates have been particularly effective in preserving ridge dimensions, yet residual graft particles are frequently identified at implant placement. The persistence of such remnants has been suggested to interfere with natural bone replacement and may influence implant osseointegration. Indeed, some authors have reported that no currently available graft material consistently yields a higher proportion of newly formed bone than spontaneous healing alone (5, 19, 21).

5.3. Periodontal defect morphologies

Periodontal regeneration is highly dependent on the morphology of the underlying osseous defect, as defect configuration directly influences vascular supply, blood clot stability, space maintenance, and cellular invagination. Unlike post-extraction sockets, periodontal defects are typically characterized by chronic inflammation, compromised blood supply, and limited regenerative potential, making their management particularly challenging (22-24).

In 1957 Goldman and Cohen established the first classification for periodontal intrabony defects. Based on the number of remaining bony walls, intrabony periodontal defects are classified as one-wall, hemiseptal defects two-wall, or three-wall defects. Three-wall defects provide the most favorable environment for periodontal regeneration, as their contained morphology supports blood clot stabilization and facilitates angiogenesis and osteogenic cell migration. Two-wall defects exhibit moderate regenerative potential, while one-wall defects and non-contained defects represent the most unfavorable scenarios due to the lack of structural support and reduced vascular contribution from surrounding bone. Hemiseptal defects are a specific type of one-wall bony defect. In these scenarios a bone septum remains over the root surface of one tooth (22, 25-28).

In clinical practice, periodontal defects often present as combined or irregular morphologies rather than idealized configurations. Horizontal bone loss frequently coexists with vertical components, further complicating reconstructive efforts. As defect containment decreases, the predictability of regenerative outcomes diminishes, emphasizing the importance of both surgical technique and graft material selection(22, 29).

In non-contained intrabony defects, the biological behavior of the graft material becomes particularly critical. Grafts with limited remodeling capacity or prolonged persistence may interfere with physiological bone regeneration, especially in environments characterized by reduced vascularity and impaired healing potential. Consequently, defect morphology must be considered a decisive factor when selecting regenerative strategies and biomaterials for periodontal reconstruction(22, 30).

5.4. Periodontal reconstructive techniques

Periodontal reconstructive procedures are based on the principle of creating a protected healing environment that supports selective cellular repopulation and stable wound healing. Fundamental biological requirements include the prevention of apical epithelial migration, the stabilization of the blood clot, adequate space maintenance within the defect, and the achievement of tension-free primary wound closure. Failure to fulfill any of these conditions may result in repair rather than true regeneration (3, 24, 31).

Various surgical techniques have been developed to meet these biological requirements. Open flap debridement allows effective decontamination of the root surface but provides limited regenerative potential (32, 33). Guided tissue regeneration techniques aim to enhance outcomes by excluding epithelial cells and maintaining a secluded space for regeneration; however, their predictability decreases in defects with unfavorable morphology due to membrane instability, exposure, and compromised vascular supply. Minimally invasive flap designs and biologically oriented surgical approaches have improved wound stability and soft tissue preservation, yet their success remains highly dependent on defect configuration(34-36).

The introduction of biologically active agents, such as enamel matrix derivative (EMD), represented a major step forward by directly modulating cellular behavior and wound healing processes. While biologics can enhance regenerative outcomes, they do not provide intrinsic structural support and therefore require combination with a suitable scaffold in defects lacking sufficient containment(37, 38).

Bone grafting procedures play a central role in periodontal reconstruction by providing space maintenance and mechanical stability. The increasing number of available regenerative materials and surgical approaches has complicated clinical decision-making. Data from the American Academy of Periodontology indicate that regenerative outcomes may be improved through the use of combination therapies incorporating biologically active agents (39). In this context, a recent meta-analysis demonstrated that the adjunctive use of a graft material with enamel matrix derivative resulted in greater defect fill and a more pronounced reduction in gingival recession compared with EMD alone (40). Similarly, another meta-analysis reported significantly larger reductions in probing pocket depth and greater clinical attachment level gains when EMD was combined with a graft material, highlighting the clinical benefit of combination approaches over the use of EMD as a sole regenerative modality (41).

Taken together, these considerations indicate that successful periodontal reconstruction depends on the complex interaction between defect morphology, surgical techniques, and the biological behavior of the applied regenerative materials. In particular, graft materials capable of participating in physiological remodeling may offer advantages in challenging intrabony defects where vascular supply is compromised and unfavourable defect morphologies are present.

5.5. Autogenous tooth bone graft

Autogenous tooth bone grafts combine structural scaffold function with the potential for active biological participation in the regenerative process. Owing to their collagen-rich matrix and hydroxyapatite content, these grafts may support osteoconduction while facilitating physiological bone turnover. Within the context of periodontal defects characterized by compromised vascularity and unfavourable morphology, such properties may be of particular clinical relevance.

The following section focuses on the biological background, preparation methods, and clinical applicability of autogenous tooth-derived bone grafts in reconstructive periodontal therapy.

5.5.1. Demineralization process

The concept of using tooth-derived material as a graft substrate dates back to the pioneering work of Yeomans and Urist (1967), who first demonstrated that decalcified dentin could support bone formation when implanted into various anatomical sites in New Zealand rabbits, including intramuscular spaces, surgically created mandibular defects, and extraction sockets(42). Their preparation protocol relied on 0.6 M hydrochloric acid for demineralization, followed by sterilization in 70% ethanol. They also observed that undemineralized dentin resorbed more slowly, suggesting that demineralization accelerates remodeling and enhances biological interaction.

Linden and colleagues later reproduced these findings (1974), refining the protocol by removing the enamel layer, which allowed for more predictable interactions between dentin and surrounding tissues. They reported substantially faster and more robust bone formation with dentin grafts than with undecalcified material, reinforcing the potential osteogenic benefits of demineralization(43).

Further investigation by Bang et al. (1972) evaluated 168 dentin samples exposed to hydrochloric acid at concentrations ranging from 0.2 M to 2.0 M. Their results indicated that higher acid concentrations (>0.6 M) impaired bone formation, likely due to damaging alterations in the collagen matrix or denaturation of bioactive molecules. These findings provided early evidence that the extent and method of demineralization profoundly influence graft bioactivity (44).

Subsequent in vitro studies helped elucidate the cellular mechanisms underlying this phenomenon. Koga et al. demonstrated that osteoblasts preferentially adhere to partially or fully demineralized dentin surfaces, whereas undemineralized surfaces show minimal cellular attachment. This aligns with the observation that demineralization exposes collagen fibrils and enlarges dentinal tubules, thereby creating a more favorable microarchitecture for cell adhesion, migration, and matrix deposition (45).

Kim and colleagues further confirmed that the demineralization process facilitates the release of growth factors such as BMPs, TGF-β, and various non-collagenous proteins. Importantly, they showed that—even after demineralization—the dentin matrix retains significant amounts of these bioactive molecules, supporting its intrinsic osteoinductive potential (46).

Today, more than 50 distinct dentin processing protocols have been described in the literature, differing in demineralizing agents, exposure times, mechanical preparation techniques, sterilization procedures, and granule size specifications. Despite this variability, contemporary methods converge on three principal categories of graft materials, classified by their degree of demineralization(7, 8, 47):

Undemineralized dentin matrix (UDDM): retains full mineral content, offering structural rigidity and slow resorption.

Partially demineralized dentin matrix (PDDM): maintains a portion of the mineral phase while exposing the collagen framework, balancing mechanical stability with biological activity.

Demineralized dentin matrix (DDM): nearly fully demineralized, maximizing growth factor exposure and potentially enhancing osteoinductive properties(47).

These material distinctions are of clinical relevance because they directly influence resorption kinetics, scaffold stability, tissue integration, and the biological mechanisms underpinning bone regeneration. Ongoing research aims to clarify the degree of demineralization that offers optimal outcomes across various clinical settings.

5.2.2. Grinding method and granule sizes

Following thorough debridement—removal of calculus, caries, soft tissues, and restorative materials—the next essential step in ATB preparation is mechanical fragmentation of the tooth into granules. Different protocols rely on distinct techniques for this process. Some employ hammer-and-pestle crushing to obtain coarse fragments before grinding, while others section the tooth using rotary burs to create smaller, more uniform pieces prior to milling (48-50).

Grinding itself may be performed using either high-speed or low-speed systems:

High-speed grinding: rapid and efficient but often produces a broader range of particle sizes. Excessive speed also risks overheating the dentin.

Low-speed grinding: slower but results in more homogeneous granule sizes and imposes less thermal stress on the protein matrix.

Temperature control is critical because exposure to temperatures above 44 °C may denature matrix proteins and diminish osteoinductive potential (51).

Several experimental models have investigated optimal particle size for bone regeneration. Dozza et al. evaluated different scaffold particle sizes in sheep cortical bone defects and reported superior outcomes with medium-sized particles (0.5–1 mm)(52). Similarly, Koga et al. found in vitro that granules in the range of 500–1000 μm displayed the highest turnover rates and the lowest proportion of residual graft material during early healing. Smaller particles tended to resorb too rapidly, potentially compromising volumetric stability and scaffold function (45).

These findings highlight that granule size is a critical parameter, balancing resorption dynamics, handling properties, and the mechanical support required for predictable tissue regeneration.

6. Objectives

6.1. Study I. – Investigating the efficacy of autogenous tooth bone grafts in alveolar ridge preservation

The objective of this systematic review and meta-analysis on the topic was to evaluate the efficacy of ATB in alveolar ridge preservation following tooth extraction. Given the emergence of multiple devices and processing protocols in recent years, the study also aimed to investigate how variations in ATB preparation—particularly the degree of demineralization and whether the graft was derived from the root portion alone or from the entire tooth—affect healing outcomes, graft remodeling dynamics, and overall graft turnover.

6.2. Study II. – Investigating the efficacy of ATB in periodontal vertical bony defects

The objective of this retrospective proof-of-concept study was to evaluate the clinical and radiographic outcomes of ATB combined with enamel matrix derivative (EMD) in the treatment of non-contained intrabony periodontal defects. The study aimed to determine whether this biologically enhanced combination improves probing pocket depth, clinical attachment level, and defect fill compared with baseline values, and to explore its potential as a predictable regenerative alternative.

7. Methods

7.1 Study I – Investigating the efficacy of autogenous tooth bone grafts in alveolar ridge preservation

7.1.1. Methodology and Protocol

Our systematic reviews and meta-analyses are reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 Statement(53). The Cochrane Handbook's recommendations for Systematic Reviews of Interventions Version 6.1.0 and Cochrane Prognosis Methods Group were followed and the review protocols were registered on PROSPERO (Study I.: *CRD42021287890*).

7.1.2. Inclusion criteria

Eligible studies included randomized and non-randomized clinical trials as well as case series. Participants were required to be adults (> 18 years) with good oral hygiene, and ATB had to be applied with a minimum healing period of three months. Exclusion criteria encompassed uncontrolled systemic disease, previous radiotherapy, bisphosphonate therapy, heavy smoking, absence of CBCT-based linear ridge width measurements, lack of histomorphometric analysis, immediate implant placement, and incomplete datasets.

7.1.3. Outcomes

The primary outcome was the ridge width change, measured in millimetres (mm). Regarding the change, we radiographically compared the baseline alveolar ridge width to the alveolar ridge width 4-6 months postoperatively.

The secondary outcomes were the proportion of residual graft, newly formed bone and connective tissue in the histological sample expressed in percentage and the patient follow-up period.

Additional outcomes were the adverse events and postoperative inflammation.

7.1.4. Search and selections

A comprehensive literature search was performed in four electronic databases—Cochrane CENTRAL, Embase, MEDLINE (via PubMed), and Scopus—from inception to 31 November 2021. Using the search key of the following domains: ("Socket preservation" OR "alveolar ridge preservation" OR ARP OR "alveolar preservation" OR "socket grafting" OR extract* tooth OR extract* teeth) AND (autogen* graft OR autolog* graft) AND ("human dentin" OR "dentin matrix" OR "dentin graft" OR ATB OR AutoBT OR ATG OR "tooth graft" OR teeth graft OR teeth derived graft OR tooth derived graft OR autologous tooth bone graft OR "Autologous Tooth Structure" OR autogen* tooth bone graft).

The search was limited to English-language studies and supplemented by manual screening of reference lists and grey literature. The dates of the searches and the queries used are detailed in the original publication.

Study selection was guided by a predefined PICO framework. We included all the studies with (P) patients undergoing ARP with (I) particulate ATB graft. The primary outcome (O) was the ridge width change, measured in millimetres (mm). Regarding the change, we radiographically compared (C) the baseline alveolar ridge width to alveolar ridge width to the 4-6 months postoperatively. The measurement methods were quite heterogenous, therefore the vertical dimension changes could not be measured.

7.1.5. Data extraction

We used EndNote X9 (Clarivate Analytics, Philadelphia, PA, USA) for the selection of the articles. Two independent authors screened the publications separately for the title, abstract, and full text, and disagreements were resolved by a third author.

Two authors independently extracted data into a predefined Excel spreadsheet (Office 365, Microsoft, Redmond, WA, USA), and a third reviewer resolved the discrepancies.

The following data were collected from each eligible article: data regarding the article (first author, year of publication, DOI, language, study design, study duration, original study/data source). Extracted data also included study design, ATB processing protocol (degree of demineralization, use of root-only vs. whole tooth), membrane application, defect morphology, and its measurement methods, complications.

7.1.6. Risk of bias and quality of evidence assessment

The methodological quality of the included studies was evaluated using established risk-of-bias tools recommended by the Cochrane Prognosis Methods Group. Randomized controlled trials were assessed with the ROB-2 tool (54), whereas non-randomized clinical studies were evaluated using the ROBINS-I tool (55). Two reviewers independently performed the assessments, and any discrepancies were resolved through consultation with a third reviewer. For each quantitative outcome, the certainty of evidence was further appraised using the GRADE framework (56, 57).

7.1.7. Synthesis methods

Data extracted from the included studies were synthesized following a predefined analytical framework. For continuous radiographic outcomes—specifically horizontal ridge width changes—means and standard deviations were collected or calculated, and the pooled mean difference (MD) with corresponding 95% confidence intervals (CI) was computed. Histological parameters, including the proportion of newly formed bone, residual graft material, and connective tissue, were analyzed as pooled mean percentages with 95% CIs.

All statistical analyses were performed using R software (version 4.1.1) with the meta package (v5.2.0). A random-effects model was applied throughout to account for clinical and methodological heterogeneity across studies. Statistical heterogeneity was quantified using the I^2 statistic, with values above 50% considered to reflect substantial heterogeneity. The alpha level was set at 0.05.

In addition to the primary analyses, several subgroup analyses were conducted to explore potential sources of heterogeneity and to assess the impact of methodological variations in autogenous tooth bone graft (ATB) preparation. These subgroups included: a) Measurement level of ridge width (crestal vs. 1 mm apical); b) Degree of ATB demineralization (UDDM, PDDM, DDM); c) Graft composition (root-only vs. whole-tooth grafts).

Where possible, funnel plots were visually inspected to evaluate publication bias and additional sources of heterogeneity. Due to the limited number of studies, formal outlier or influence analyses were not feasible. The overall certainty of evidence for each pooled outcome was subsequently evaluated using the GRADE approach.

7.2. Study II. – Investigating the efficacy of ATB in periodontal vertical bony defects

7.2.1. Study design and ethical approval

This retrospective, single-center case series was conducted at the Department of Periodontology, Semmelweis University, between October 2023 and January 2024. The study adhered to the Declaration of Helsinki and received approval from the institutional ethics committee (SE RKEB: 116/2023). All participants provided written informed consent.

7.2.2. Participants and exclusion criterias

We collected all the data of the patients presenting non-contained intrabony periodontal defects treated with ATB and EMD. Inclusion required ≥4 mm deep intrabony defects and the availability of a hopeless tooth—located in a different quadrant—to be used for autogenous tooth graft preparation.

Exclusion criteria included:

– systemic risk factors (irradiation, uncontrolled diabetes, bisphosphonates, pregnancy, infection),

– age <18 years,

– smoking >5 cigarettes/day,

– poor oral hygiene (FMPS or FMBS >25%),

– periodontal defect types incompatible with regenerative therapy (furcations, endo-perio lesions, horizontal or multi-tooth defects).

7.2.3. Interventions

The surgical interventions were performed following completion of cause-related periodontal therapy. At the donor site, a hopeless tooth located in a different quadrant from the defect site was extracted under local anesthesia. The tooth was subsequently cleaned, processed, ground, and sterilized according to the manufacturer's protocol to produce autogenous tooth bone graft particles (425–1500 µm).

After local anaesthesia (Ultracain DS forte, Sanofi-Aventis) at the defect site, a full-thickness mucoperiosteal flap was elevated using either the Modified or Simplified Papilla Preservation Technique, depending on the width of the interdental space(34, 35). Following flap reflection, all granulation tissue was removed, and the root surfaces were thoroughly debrided using curettes and ultrasonic instruments. Root conditioning was performed with 24% EDTA gel for 2 minutes, followed by rinsing with sterile saline.

Emdogain® (EMD, Straumann, Basel, Switzerland) was applied to the conditioned root surface and mixed with the ATB particles. The graft was placed into the intrabony defect, ensuring complete fill of the defect morphology. The flap was then repositioned and secured with tension-free primary closure using 6-0 monofilament sutures (Chiraflon, Vitrex MedicalA/S, Herlev, Denmark). Patients received standardized postoperative instructions, including chlorhexidine rinsing for two weeks and avoidance of mechanical plaque removal at the surgical site. Sutures were removed after 14 days.

7.2.4. Outcome measurements

Clinical and radiographic outcomes were evaluated at baseline (T0) and at 6 months postoperatively (T1).

7.2.4.1. Clinical parameters

Measurements were recorded at six sites per tooth (mesiobuccal, buccal, distobuccal, mesiolingual, lingual, distolingual) by two calibrated examiners blinded to the surgical procedures. All clinical measurements were performed by two calibrated examiners who were blinded to the surgical details, using a UNC-15 periodontal probe at six sites per treated tooth and the adjacent teeth. The clinical examination included probing pocket depth (PPD), clinical attachment level (CAL), and gingival recession (GR), which were recorded as linear distances relative to the gingival margin and cementoenamel junction. In addition, the presence of plaque and bleeding on probing was assessed, and FMPS and FMBS were documented to ensure adequate periodontal stability during the healing period. These parameters provided a comprehensive evaluation of soft tissue inflammatory status and attachment changes following regenerative therapy.

7.2.4.2. Radiographic parameters

Radiographic evaluation was performed using standardized periapical intraoral radiographs obtained with the parallel-cone technique. To ensure reproducible measurements, each radiograph was calibrated using a 10 mm reference line placed outside the surgical field. Digitized images were analyzed using FIJI–ImageJ software by two blinded investigators with radiographic expertise, and in cases of disagreement, a third examiner adjudicated the measurement. The radiographic assessment focused on three parameters characterizing the morphology of the intrabony defect: (1) defect depth (INTRA), measured as the linear extent of the vertical intrabony component; (2) defect width (WIDTH), representing the horizontal dimension of the defect at its coronal aspect; and (3) defect angle (ANGLE), reflecting the divergence of the bony walls surrounding the defect. These measurements allowed detailed evaluation of radiographic changes in defect morphology and bone fill over the six-month healing period.

7.2.5. Statistical analysis

All statistical analyses were carried out using the R statistical software (R Core Team, version 4.0.3). Descriptive statistics were applied to summarize all variables, which are presented as mean values accompanied by their standard deviations. No missing data were identified in the dataset. Statistical significance was evaluated using inferential statistical methods with a predefined alpha level of 0.05.

The distribution of the investigated variables was examined both analytically and visually. Normality was assessed using the Shapiro–Wilk test and further inspected by means of quantile–quantile plots for each variable. The clinical parameters, including probing pocket depth, clinical attachment level, and gingival recession, followed a normal distribution. Consequently, comparisons between baseline (T0) and follow-up (T1) measurements for these variables were performed using paired t-tests.

In contrast, the assumptions of normality were not met for the radiographic variables, namely intrabony defect depth, defect width, and defect angle. Therefore, differences between T0 and T1 values for these parameters were analyzed using the Wilcoxon matched-pairs signed-rank test. Graphical visualization of the results was provided using box plots.

8. Results

8.1 Study I

8.1.1. Study selection and data extraction

After the search 2558 studies were identified. Following the removal of duplicates, 2235 unique articles remained for screening. Titles and abstracts were evaluated according to the predefined inclusion and exclusion criteria, resulting in 46 studies selected for full-text assessment. During full-text evaluation, studies were excluded for reasons including insufficient reporting of ridge-width outcomes, absence of CBCT-based measurements, inappropriate study design, inadequate follow-up duration, or lack of histomorphometric data. After applying all criteria, 12 studies met the eligibility requirements for inclusion in the qualitative synthesis.

Of these, eight studies provided sufficient and comparable quantitative data to be incorporated into the meta-analysis. The screening process demonstrated excellent reproducibility: the inter-rater agreement for title and abstract screening reached $\kappa = 0.98$, indicating near-perfect concordance between reviewers. Agreement during full-text evaluation remained high, with $\kappa = 0.87$, reflecting consistent application of eligibility criteria across evaluators. Details of the selection are visualized in the PRISMA flowchart in Figure 1, while details of the included studies can be seen in Table 1.

Figure 1. Flowchart of the selection process based on PRISMA 2020 statement. The ‘n’ indicates the total number of studies at each selection level(58).

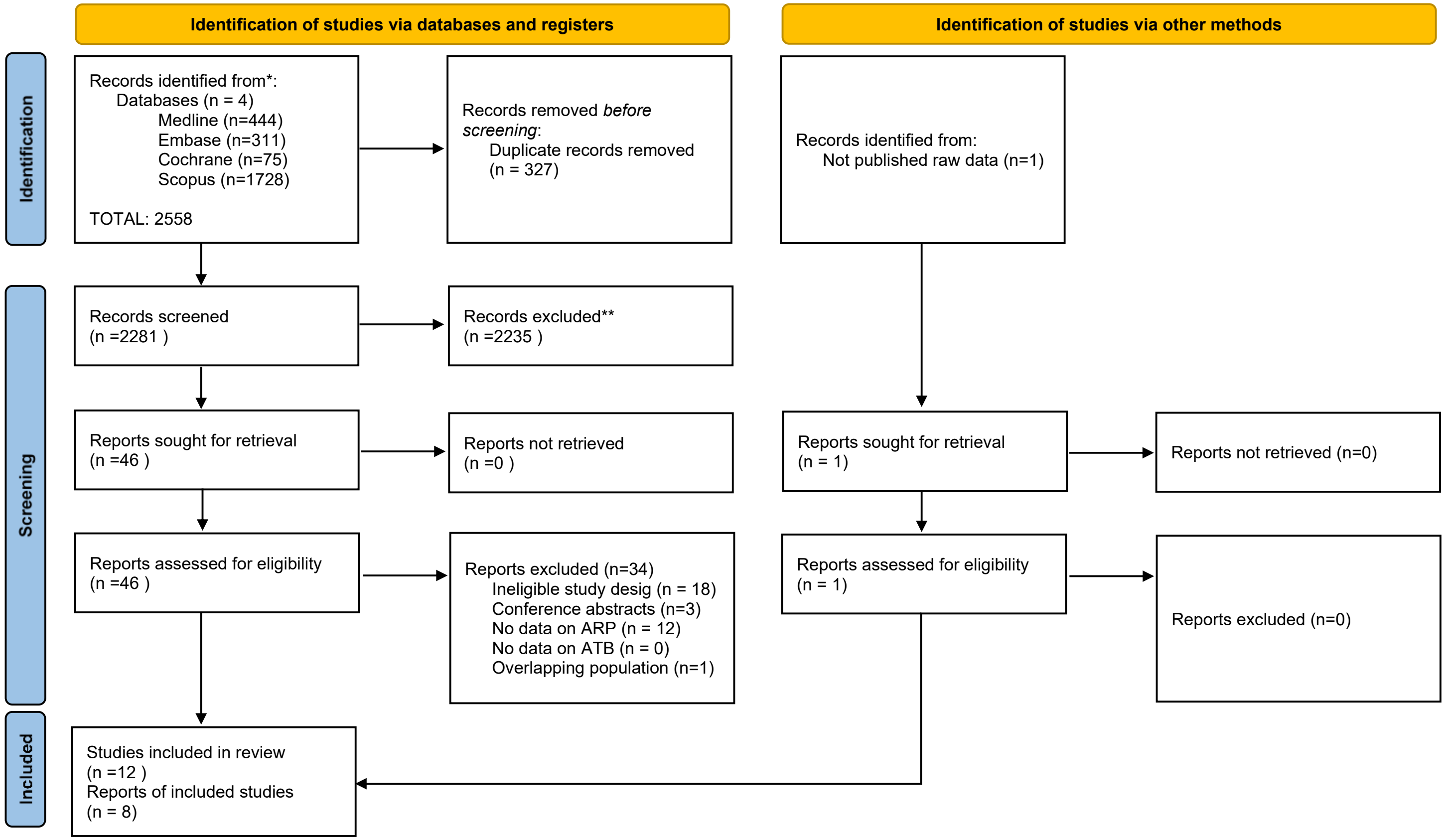


Table 1. Characteristics of the studies included in the quantitative assessment (58).

Author and year	**Study design**	**Nr of patients**	**Test group**	**Control group**	**Follow-up (months)**	**Membrane**
I. W. Um et al. 2019	Case series	T: 10 C: 6	DDM+rhBMP-2	DDM	3-6	no
C. P. Joshi et al. 2016	RCT	T_1: 15 T_2: 15 C: 15	T_1: ATG T_2: β-TCP	ungrafted	4	yes
A. Dwivedi et al., 2020	Case series	30	ATG	NA	4	no
Z. Radoczy-Drajko et al. 2021	Case series	9	ATB	NA	6	yes
A. Elfana et al., 2021	RCT	T: 10 C: 10	AWTG	ADDG	6	yes
G. U. Jung et al., 2018	RCT	T_1: 8 T_2: 8 C: 8	T_1: DDM T_2: DDM +rhBMP-2	Bio-Oss Collagen	4	yes
K. M. Pang et al., 2017	RCT	T: 21 C: 12	AutoBT	Bio-Oss	6	no
A. Santos et al., 2021	RCT	T: 34 C: 32	MDM	Bio-Oss	6	yes

RCT: randomized controlled trial, DDM: demineralized dentin matrix, rhBMP-2: recombinant human Bone Morphogenetic Protein-2, ATG: autogenous tooth graft, ATB: autogenous tooth bone graft, AWTG: autogenous whole tooth graft, ADDG: autogenous demineralized dentin graft, AutoBT: autogenous tooth graft biomaterial, MDM: mineralized dentin matrix

8.1.2. Description of the included studies

Initial defect morphology showed substantial variability across the included studies. Two studies did not report baseline socket anatomy, while others applied different classification systems. Joshi et al. investigated only four-walled, well-preserved sockets(59), whereas Drajko et al. included EDS class 3–4 defects, indicating at least 3 mm hard-tissue loss(60). Santos et al. used the Elian classification and analyzed only Type II defects, characterized by partial labial plate deficiency(61). Dimensional criteria were also applied: Elfana et al. included defects with <5 mm buccal bone loss, Pang et al. examined sites with ≥4 mm vertical loss in multiple walls, and Jung et al. assessed sockets with <50% buccal plate resorption(62). Overall, the studies represented a wide range of extraction socket morphologies, from intact four-wall defects to significantly compromised sites, underscoring the heterogeneity that must be considered when interpreting regenerative outcomes.

Across the included studies, postoperative complications were infrequently reported, and no major adverse events attributable to ATB were documented. Minor complications, when present, were generally limited to mild postoperative swelling, transient discomfort, or localized inflammatory reactions, all of which resolved with conventional postoperative care(63). None of the articles mention any further augmentation procedures after the healing process.

8.1.3. Primary outcome

A total of eight studies contributed quantitative data to the meta-analysis of horizontal ridge width changes. Due to methodological differences among the included studies—specifically the crestal level at which linear ridge width measurements were taken—a subgroup analysis was required. Some studies reported measurements at the crestal level(59, 60, 64, 65), whereas others assessed ridge width 1 mm apical to the crest(60, 62, 63), necessitating separate analytical subgroups to ensure methodological consistency.

Additionally, Elfana et al. presented two distinct intervention groups within their study, each using different ATB processing protocols. To maintain analytical accuracy, these groups were treated as independent data entries within the meta-analysis(62). The pooled analysis demonstrated an overall mean ridge width change of –0.72 mm (95% CI: –1.03 to –0.42), with substantial heterogeneity (I² = 91%, p < 0.01). At the crestal measurement level, the subgroup effect size was –0.46 mm (95% CI: –0.81 to –0.10; I² = 75%, p < 0.01). Measurements taken 1 mm apical to the crest showed a mean change of –0.95 mm (95% CI: –1.15 to –0.76), with no heterogeneity (I² = 0%, p = 0.44).

A statistically significant difference was observed between these two subgroups (p = 0.02), indicating that the degree of ridge width change varied depending on the vertical position of the measurement. These findings are summarized in the forest plot and funnel plots (Figure. 2-3) and in Table 2.

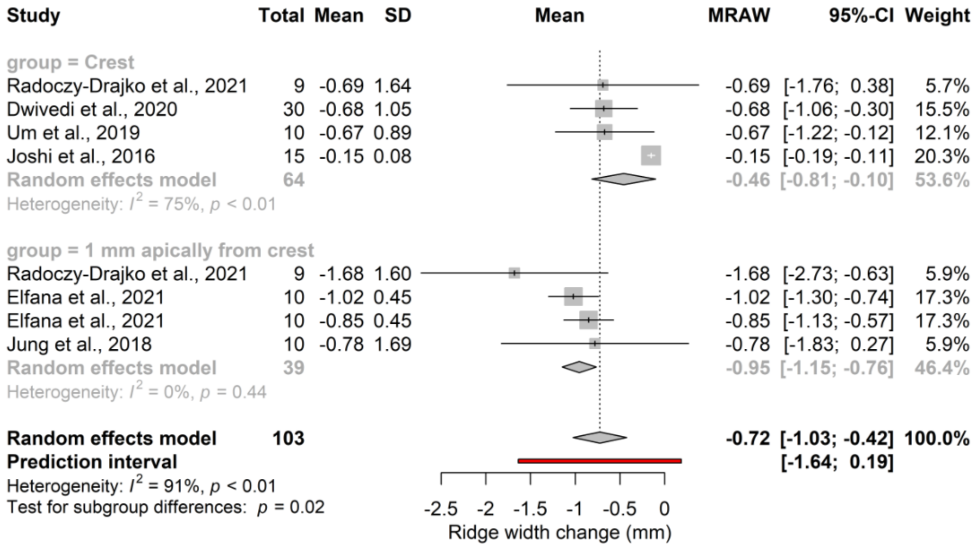


Figure 2 Primary outcome: pooled mean of ridge width changes in mm. A statistically significant alveolar ridge preservation effect can be observed(58).

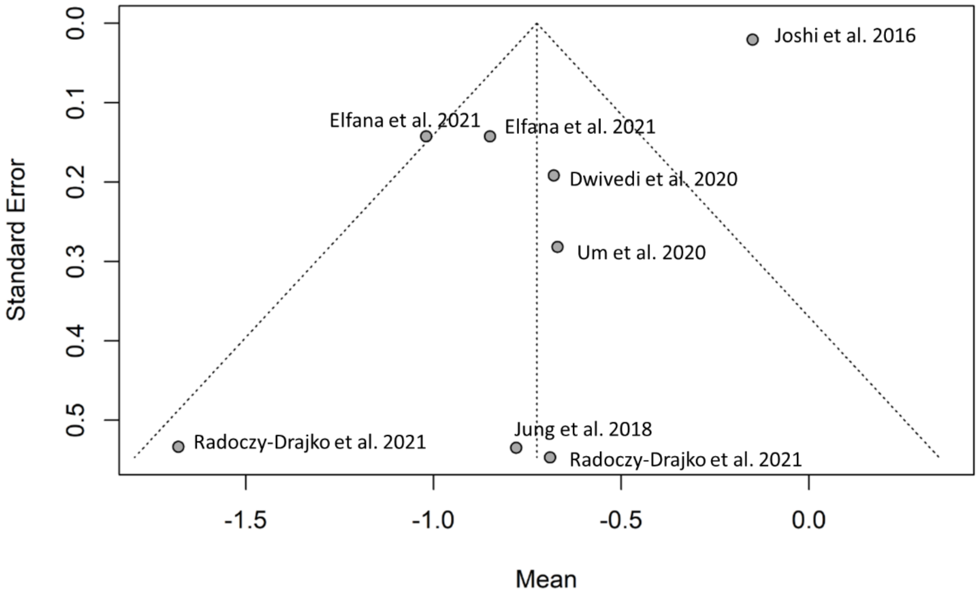


Figure 3. Funnel plots indicates the presence of statistical heterogeneity and cofounding factors affecting the primary outcome (alveolar ridge width changes)(58).

Table 3. Changes in alveolar ridge width (mean ± standard deviation [SD]). Raw data of Radoczy Drajko et al. was also used (measurement at the crestal level)(58).

Measurement at the crestal level

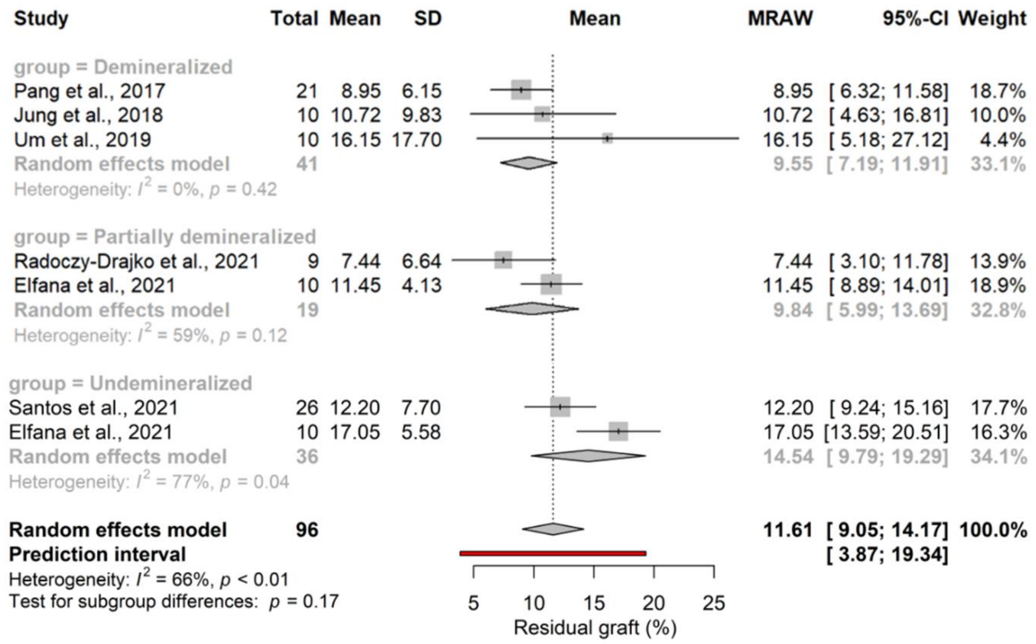
Author and year	mean difference	SD
I. W. Um et al. 2019	-0.67	0.89
C. P. Joshi et al. 2016	-0.15	0.08
A. Dwivedi et al., 2020	-0.68	1.05
Z. Radoczy-Drajko et al. 2021	-0.69	1.64
effect size	- 0.46	CI [-0.81; -0.10]
Measurement 1 mm apical to the crestal level		
Z. Radoczy-Drajko et al. 2021	-1.68	1.60
A. Elfana et al., 2021	-1.02	0.45
A. Elfana et al., 2021	-0.85	0.45
G. U. Jung et al.,2018	-0.78	1.69
effect size	-0.95 mm	CI [-1.15; -0.76]
overall effect size	-0.72 mm	CI [-1.03; -0.42]

8.1.4. Secondary outcome measurements

Histological outcomes were available from six studies, allowing quantitative synthesis of graft turnover and tissue composition following alveolar ridge preservation(60-63, 65, 66).

8.1.4.1. Residual graft proportion

The pooled mean proportion of residual graft material was 11.61% (95% CI: 9.05–14.17), indicating a relatively low amount of remaining particles after early healing. Although moderate heterogeneity was observed (I² = 66%), the overall trend suggested promising graft turnover (Figure 4).



Study	Total	Mean	SD	MRAW	95%-CI	Weight
group = Demineralized						
Pang et al., 2017	21	8.95	6.15	8.95	[6.32; 11.58]	18.7%
Jung et al., 2018	10	10.72	9.83	10.72	[4.63; 16.81]	10.0%
Um et al., 2019	10	16.15	17.70	16.15	[5.18; 27.12]	4.4%
Random effects model	41			9.55	[7.19; 11.91]	33.1%
Heterogeneity: $I^2 = 0\%$, $p = 0.42$						
group = Partially demineralized						
Radoczy-Drajko et al., 2021	9	7.44	6.64	7.44	[3.10; 11.78]	13.9%
Elfana et al., 2021	10	11.45	4.13	11.45	[8.89; 14.01]	18.9%
Random effects model	19			9.84	[5.99; 13.69]	32.8%
Heterogeneity: $I^2 = 59\%$, $p = 0.12$						
group = Undemineralized						
Santos et al., 2021	26	12.20	7.70	12.20	[9.24; 15.16]	17.7%
Elfana et al., 2021	10	17.05	5.58	17.05	[13.59; 20.51]	16.3%
Random effects model	36			14.54	[9.79; 19.29]	34.1%
Heterogeneity: $I^2 = 77\%$, $p = 0.04$						
Random effects model	**96**			**11.61**	**[9.05; 14.17]**	**100.0%**
Prediction interval					**[3.87; 19.34]**	
Heterogeneity: $I^2 = 66\%$, $p < 0.01$						
Test for subgroup differences: $p = 0.17$						

Figure 4. Pooled mean of residual graft proportion (%). No statistical significant difference can be observed between the subgroups (58).

Subgroup analysis was conducted according to the degree of ATB demineralization. The residual graft proportion was 9.55% (95% CI: 7.19–11.91; I² = 0%) for fully demineralized dentin (DDM), 9.84% (95% CI: 5.99–13.69; I² = 59%) for partially demineralized dentin (PDDM), and 14.54% (95% CI: 9.79–19.29; I² = 77%) for undemineralized dentin (UDDM). No statistically significant differences were found between these three subgroups (p = 0.93), suggesting that the degree of demineralization did not meaningfully affect graft turnover.

When comparing grafts prepared solely from the root portion with those prepared from the entire tooth structure, the pooled means were 12.00% (95% CI: 6.67–17.33; I² = 0%)

and 11.27% (95% CI: 7.27–15.26; I² = 82%), respectively. Again, no statistically significant difference was observed between the subgroups (p = 0.93), indicating that tooth composition did not influence the turnover rate of ATB particles. The findings are illustrated in the forest plot in Figure 5.

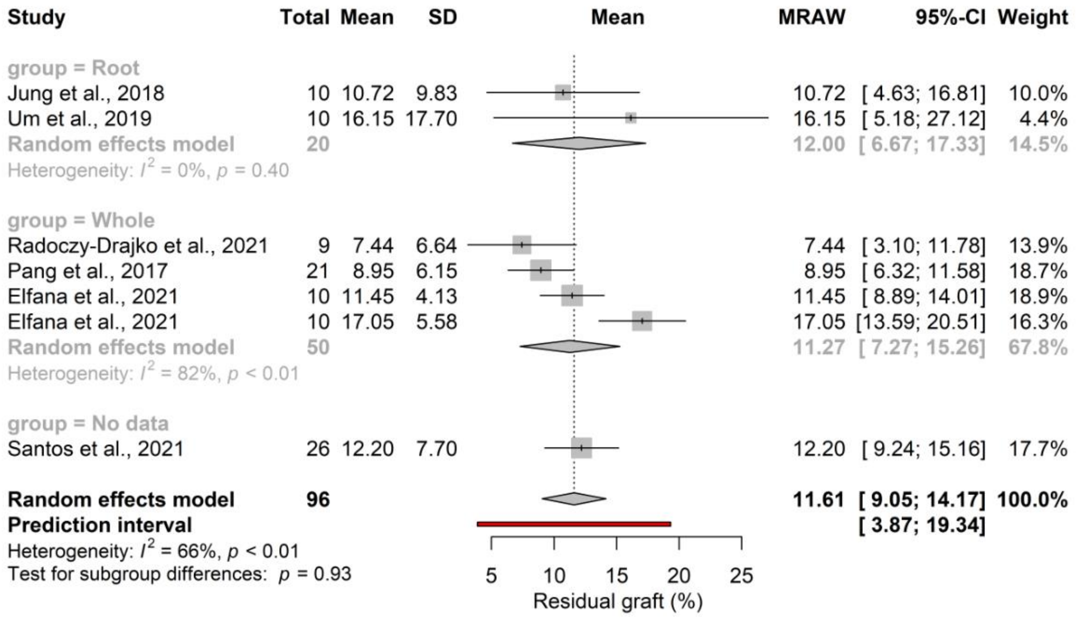


Figure 5. Pooled mean of residual graft proportion. Neither clinical, nor statistical significant difference can be observed between the subgroups (58).

8.1.4.2. Newly formed bone proportion

Across the six studies included in the analysis, the pooled mean proportion of newly formed bone was 40.23% (95% CI: 33.04–47.42), although considerable heterogeneity was present among studies (I² = 85%), visualized on the Funnel plot, Figure 6.

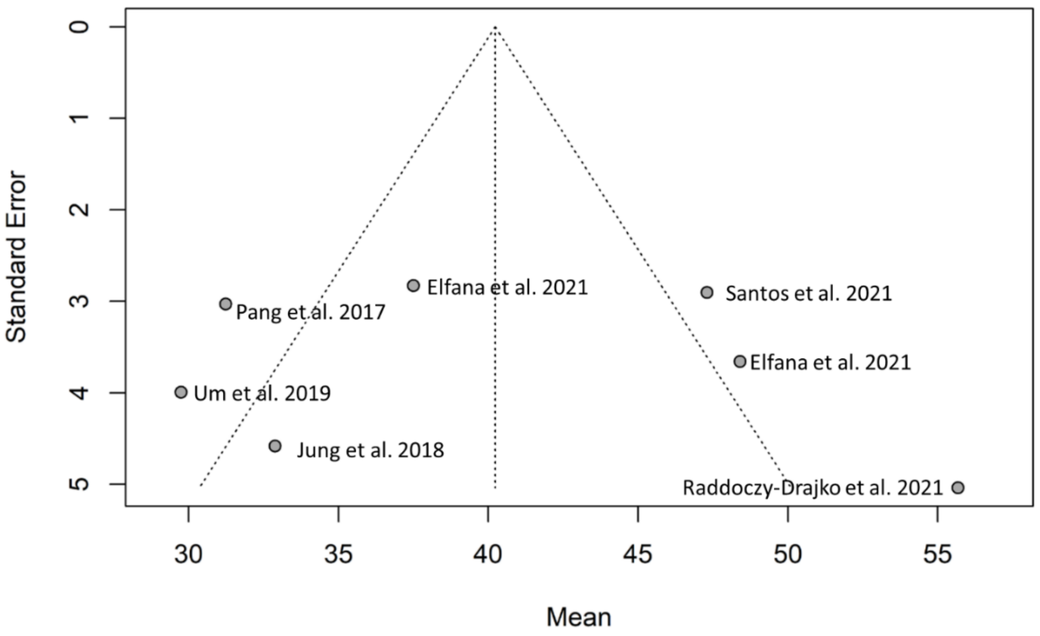


Figure 6. Funnel plots indicates the presence of statistical heterogeneity and cofounding factors affecting the newly formed bone proportion (%) (58).

To further explore potential sources of variability, subgroup analyses were performed according to the degree of ATB demineralization. Sites treated with fully demineralized dentin (DDM) showed a mean new bone proportion of 31.17% (95% CI: 26.99–35.35), whereas partially demineralized dentin (PDDM) resulted in a substantially higher mean value of 51.21% (95% CI: 44.27–58.15). The undemineralized dentin (UDDM) subgroup demonstrated an intermediate mean of 42.38% (95% CI: 32.77–51.98). A statistically significant difference was observed between the DDM and PDDM subgroups, suggesting that partial demineralization may enhance the regenerative potential of ATB, whereas complete demineralization tends to result in lower amounts of newly formed bone (Figure 7).

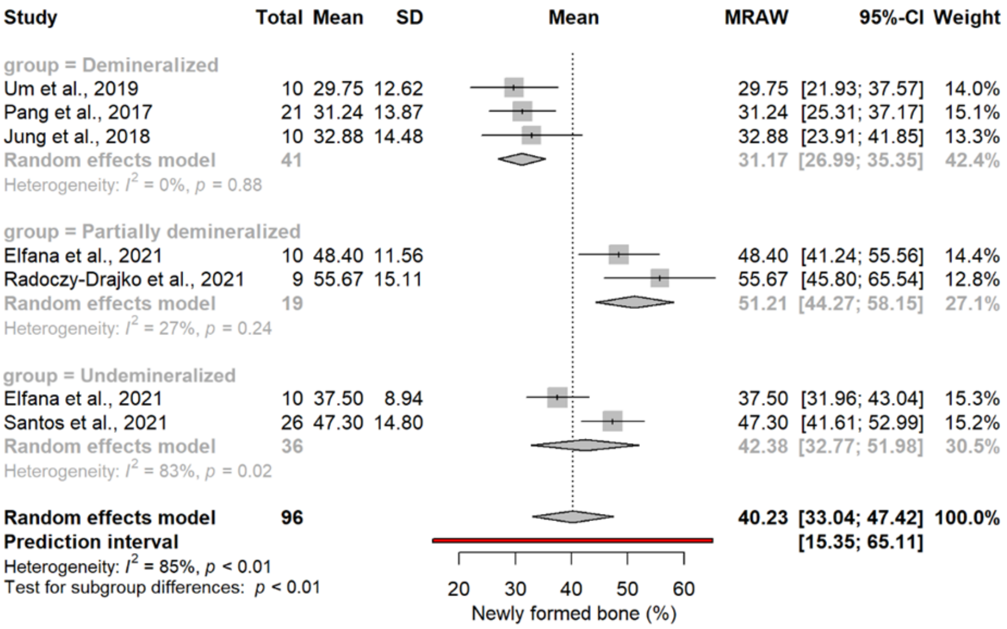


Figure 7. Pooled mean of newly formed bone proportion (%). A statistical significant difference between the DDM and PDDM group can be observed (58).

The composition of the graft material also influenced bone regeneration. When ATB was prepared from the entire tooth structure (root + crown), the pooled mean new bone proportion was 42.72% (95% CI: 32.24–53.20), significantly higher (p < 0.01) than that observed in grafts derived solely from the root portion, which showed a mean of 31.10% (95% CI: 25.20–37.00). This finding suggests that incorporating both enamel–dentin complexes may contribute to a more favorable regenerative environment (Fig. 8).

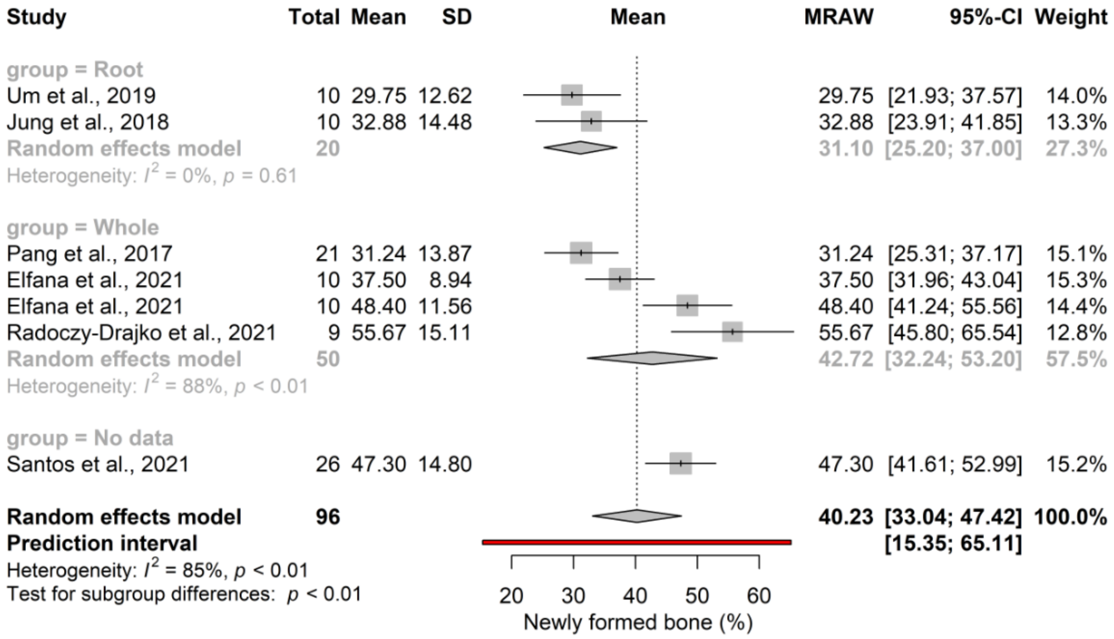


Figure 8. Pooled mean of newly formed bone proportion. A statistical significant difference can be observed between the subgroups (58).

8.1.4.3. connective tissue proportion

The pooled mean connective tissue proportion was 45.39% (95% CI: 38.48–52.31), accompanied by substantial heterogeneity across studies ($I^2 = 66\%$) (Fig. 9). To investigate potential sources of variability, subgroup analyses were performed according to the degree of ATB demineralization.

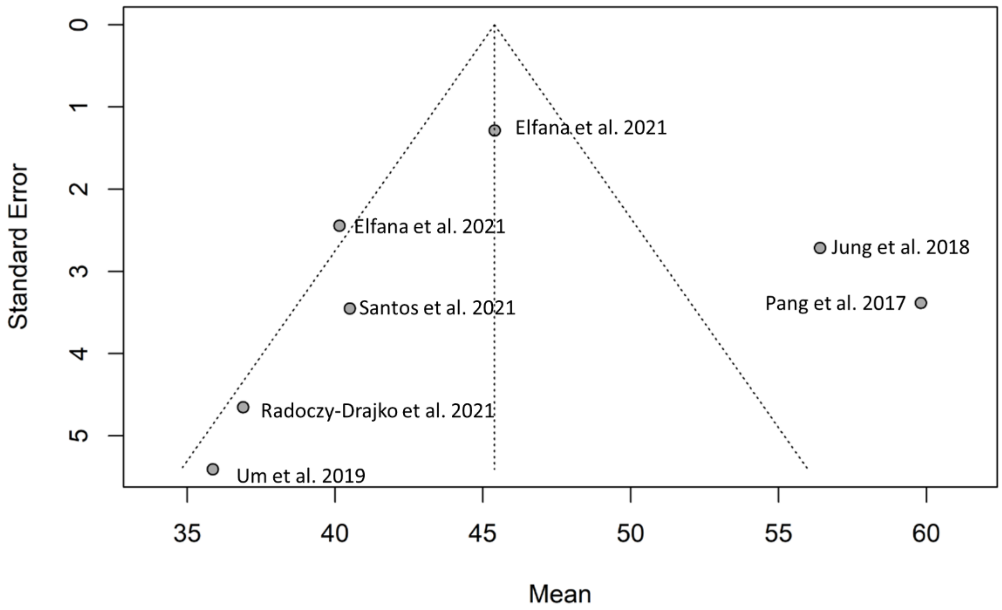


Figure 9. Funnel plots indicates the presence of statistical heterogeneity and cofounding factors affecting the connective tissue proportion (%) (58).

In the fully demineralized dentin (DDM) subgroup, the pooled mean connective tissue proportion was 51.29% (95% CI: 37.29–65.29; I² = 86%). The partially demineralized dentin (PDDM) subgroup demonstrated a mean of 39.44% (95% CI: 35.20–43.69; I² = 0%), while the undemineralized dentin (UDDM) subgroup showed a pooled mean of 42.38% (95% CI: 39.66–48.34; I² = 44%). Despite numerical variation among these groups, no statistically significant differences were observed, indicating that the degree of demineralization did not meaningfully influence the connective tissue proportion (Fig. 10).

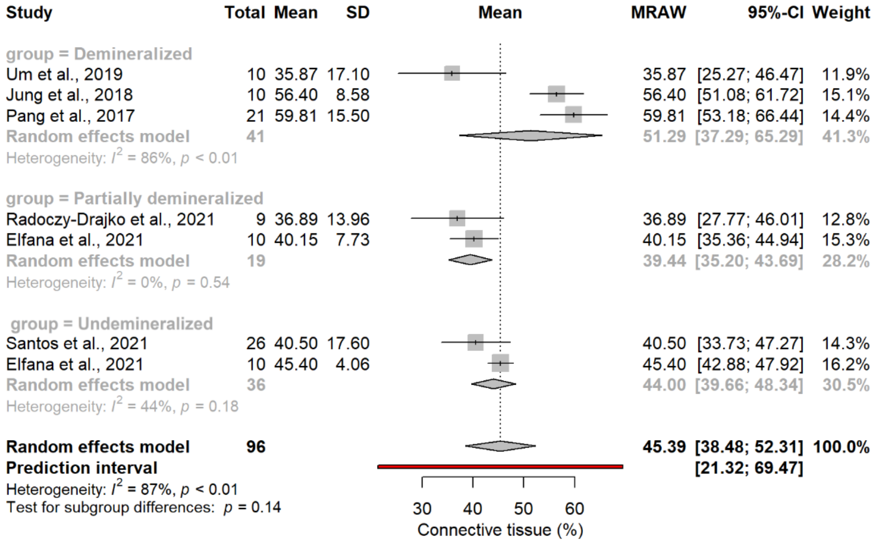


Figure 10. Pooled mean of connective tissue proportion (%). No statistical significant difference can be observed between the subgroups (58).

A separate subgroup analysis was conducted to assess whether the portion of the tooth used for graft preparation affected the connective tissue composition. The pooled mean for grafts prepared exclusively from the root portion was 46.64% (95% CI: 26.58–66.76; $I^2 = 91\%$), whereas grafts incorporating both root and crown components showed a similar mean of 45.68% (95% CI: 36.10–55.26; $I^2 = 89\%$). Again, no statistically significant difference was found between these subgroups ($p = 0.63$), (Fig.11).

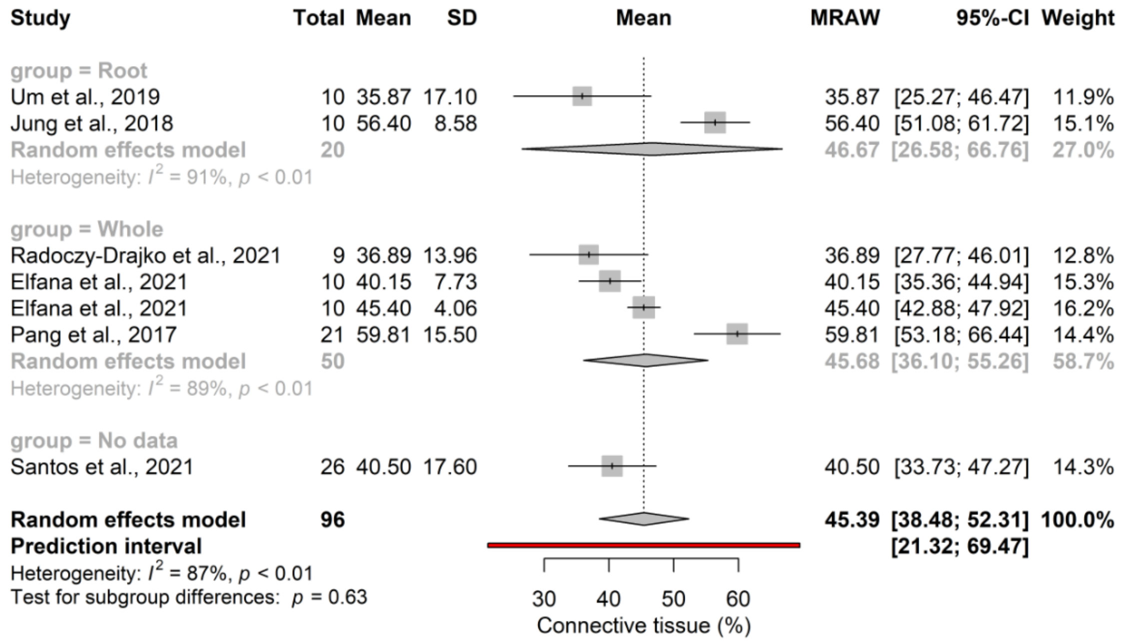
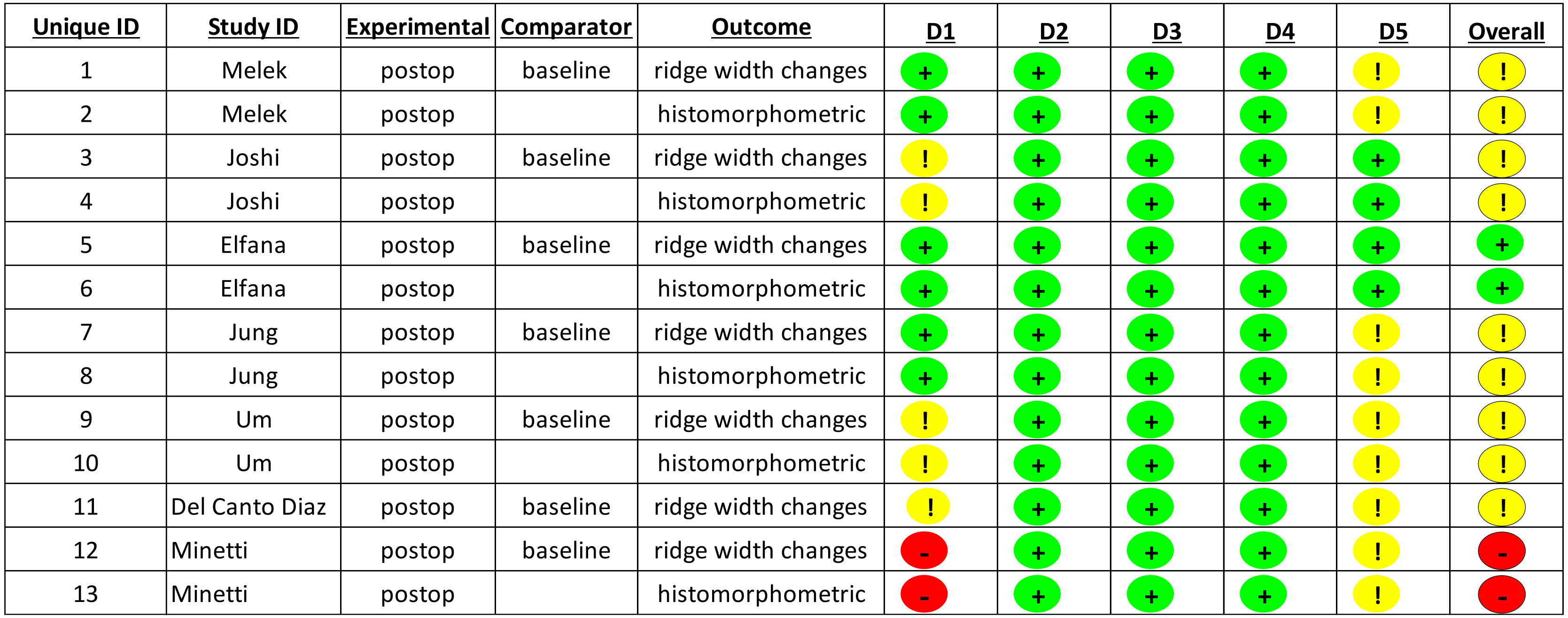


Figure 11. Pooled mean of connective tissue proportion. No statistical significant difference can be observed between the subgroups (58).

Collectively, these findings suggest that neither the degree of dentin demineralization nor the anatomical origin of the ATB material has a substantial impact on the proportion of connective tissue within the regenerated site.

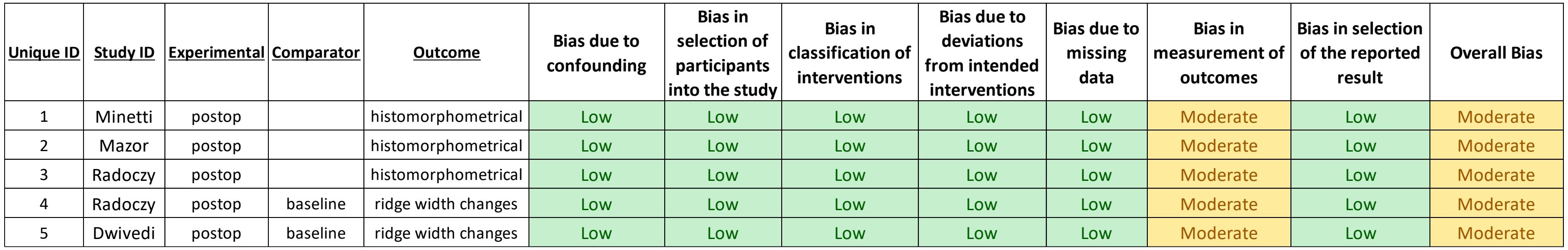
8.1.5. Risk of bias assessment

The risk of bias assessment demonstrated an overall moderate risk of bias among the included studies. As shown in Figure11-12, several methodological domains contributed to this evaluation. The most frequent concerns related to variability in outcome measurement methods, inconsistency in graft preparation protocols, and limitations inherent to small sample sizes. Although some studies employed rigorous clinical and radiographic assessment techniques, the heterogeneity in study design and methodological execution resulted in an overall moderate level of confidence in the internal validity of the findings.



Unique ID	Study ID	Experimental	Comparator	Outcome	D1	D2	D3	D4	D5	Overall
1	Melek	postop	baseline	ridge width changes	+	+	+	+	!	!
2	Melek	postop		histomorphometric	+	+	+	+	!	!
3	Joshi	postop	baseline	ridge width changes	!	+	+	+	+	!
4	Joshi	postop		histomorphometric	!	+	+	+	+	!
5	Elfana	postop	baseline	ridge width changes	+	+	+	+	+	+
6	Elfana	postop		histomorphometric	+	+	+	+	+	+
7	Jung	postop	baseline	ridge width changes	+	+	+	+	!	!
8	Jung	postop		histomorphometric	+	+	+	+	!	!
9	Um	postop	baseline	ridge width changes	!	+	+	+	!	!
10	Um	postop		histomorphometric	!	+	+	+	!	!
11	Del Canto Diaz	postop	baseline	ridge width changes	!	+	+	+	!	!
12	Minetti	postop	baseline	ridge width changes	-	+	+	+	!	-
13	Minetti	postop		histomorphometric	-	+	+	+	!	-

Figure 11. Quality assessment based on Cochrane Risk of Bias Tool 2 (RoB 2) for randomized controlled trials. Domains: D1: Risk arising from the randomization process, D2: Bias due to deviations from intended intervention, D3: Bias due to missing outcome data, D4: Bias in the measurement of the outcome, D5: Bias in the selection of the reported result. For Risk Of Bias In Non-Randomized Studies - of Interventions (ROBINS-I) tool: D1: Bias due to confounding, D2: Bias due to selection of participants, D3: Bias in classification of interventions, D4: Bias due to deviations from intended interventions, D5: Bias due to missing data, D6: Bias in measurement of outcomes, D7: Bias in selection of the reported results (58).



Unique ID	Study ID	Experimental	Comparator	Outcome	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall Bias
1	Minetti	postop		histomorphometrical	Low	Low	Low	Low	Low	Moderate	Low	Moderate
2	Mazor	postop		histomorphometrical	Low	Low	Low	Low	Low	Moderate	Low	Moderate
3	Radoczy	postop		histomorphometrical	Low	Low	Low	Low	Low	Moderate	Low	Moderate
4	Radoczy	postop	baseline	ridge width changes	Low	Low	Low	Low	Low	Moderate	Low	Moderate
5	Dwivedi	postop	baseline	ridge width changes	Low	Low	Low	Low	Low	Moderate	Low	Moderate

Figure 12. Quality assessment based on Cochrane risk of bias tool to assess non-randomized studies of interventions (ROBINS-I) for non-randomized studies of interventions (58).

8.1.6. Quality of evidence

The certainty of evidence was further evaluated using the GRADE approach (Table 4). All three principal outcomes—horizontal ridge width change, newly formed bone proportion, and connective tissue proportion—were rated as having low certainty. Downgrading was primarily due to serious imprecision, arising from small study populations, as well as serious indirectness, particularly because some studies used grafts derived from the entire tooth, while others used only the root portion, limiting direct comparability. In addition, a serious inconsistency was observed across several outcomes due to the use of different linear measurement techniques and variable imaging protocols.

Table 4. Certainty of evidence for each meta-analysis based on the GRADE approach

Participants (studies) Follow-up	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty of evidence	Study event rates (%)		Relative effect (95% CI)	Anticipated absolute effects	
							With Autologous tooth bone graft	With Baseline		Risk with Autologous tooth bone graft	Risk difference with Baseline
Ridge width changes (mm) (follow-up: range 3 months to 6 months)											
103 (6 RCTs)	not serious	not serious	serious[a]	serious[b]	none	⊕⊕◯◯ Low		103	-	The mean ridge width changes (mm) was **0**	mean **0.72 lower** (1.03 lower to 0.42 lower)

Residual graft proportion (%) (follow-up: range 3 months to 6 months; assessed with: percentage)

96 (6 RCTs)	not serious	serious[c]	not serious	serious[b]	strong association	⊕⊕⊕◯ Moderate		96	-	The mean residual graft proportion (%) was **0**	mean **11.61 higher** (9.05 higher to 14.17 higher)

Newly formed bone proportion (%) (follow-up: range 3 months to 6 months)

96 (6 RCTs)	not serious	serious[c]	not serious	serious[b]	none	⊕⊕◯◯ Low		96	-	The mean newly formed bone proportion (%) was **0** %	MD **40.23 % more** (33.04 more to 47.42 more)

Connective tissue proportion (%) (follow-up: range 3 months to 6 months)

96 (6 RCTs)	not serious	serious[c]	not serious	serious[b]	none	⊕⊕◯◯ Low		96	-	The mean connective tissue proportion (%) was **0**	mean **45.39 higher** (38.48 higher to 52.31 higher)

Visual inspection of funnel plots (Fig.3, 6, 9) suggested the presence of statistical heterogeneity and potential confounding factors, further contributing to the downgrading of evidence certainty. These findings indicate that, although the available data support the potential clinical utility of autogenous tooth bone grafts in alveolar ridge preservation, the overall strength of the evidence remains limited and should be interpreted with caution.

8.2. Study II

8.2.1. Patient characteristics

After screening and eligibility assessment, a total of nine systemically healthy patients met the inclusion criteria and were enrolled in the study, contributing 15 intrabony periodontal defects for analysis.

The characteristics of the participants and defect morphology summarized in Table 5.

Table 5. Baseline patient and defect characteristics (67)

Variable	*Value / Description*
Number of patients (n)	9
Number of treated defects (n)	15
Age (years, mean ± SD)	35 ± 5.4
Sex (M/F)	3/6
Smokers (<5 cigarettes/day)	3 (33.3 %)
Systemic health	All patients generally healthy
Defect location	Maxilla: 9; Mandible: 6
Tooth type	Single-rooted: 8; Multi-rooted: 7
Defect morphology	One-wall: 8; Two-wall: 7
Full-mouth plaque score (FMPS, %)	< 25
Full-mouth bleeding score (FMBS, %)	< 25
Follow-up period (months)	6

8.2.2. Clinical outcomes

Healing was uneventful in all treated sites, and no intra- or postoperative complications were observed throughout the six-month follow-up period.

The primary clinical outcome, probing pocket depth (PPD), demonstrated a statistically significant improvement from 7.73 ± 0.96 mm at baseline (T0) to 3.87 ± 0.74 mm at six months (T1) ($P < 0.001$).

Gingival recession (GR) measurements showed minimal change, with values of 1.47 ± 0.99 mm at T0 and 1.66 ± 0.82 mm at T1, a difference that was not statistically significant ($P = 0.19$).

Clinical attachment level (CAL) improved significantly, decreasing from 9.20 ± 1.47 mm at baseline to 5.53 ± 1.36 mm at six months ($P < 0.001$).

Boxplots illustrating the distribution of PPD, GR, and CAL at baseline and follow-up are presented in Figure 13.

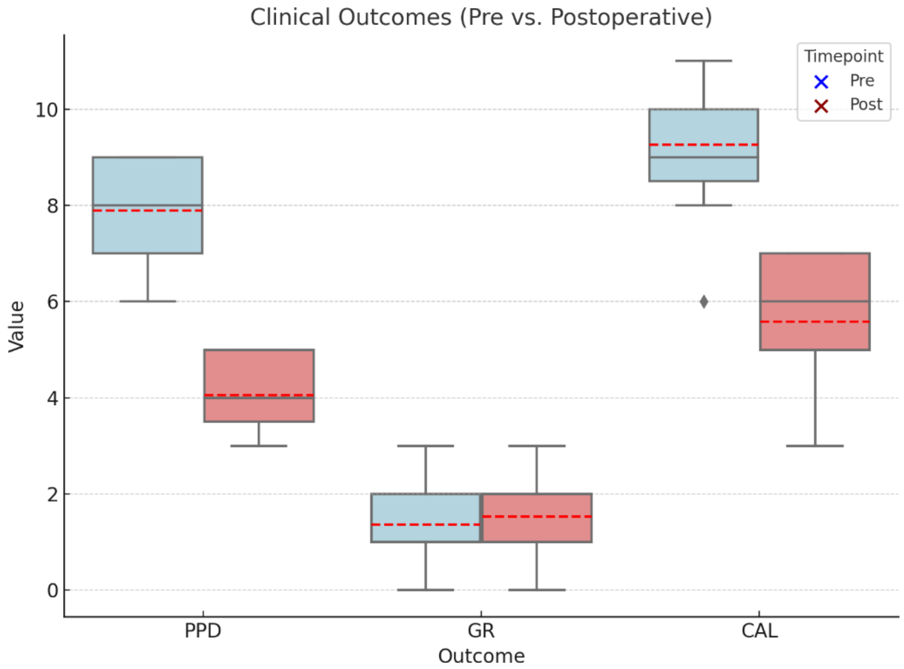


Figure 13. Boxplots representing the clinical outcomes: pre-and postoperative (6 months) probing pocket depth(PPD),gingival recession(GR), and clinical attachment loss(CAL).(67)

Examination of individual defects confirmed consistent improvements in both PPD and CAL across all treated sites, whereas GR showed only minor and clinically negligible fluctuations (Table 6).

Table 6. Table represents the mean, standard deviation, minimum, median, and maximum for T0 and T1 measurement and the paired t-test (67)

	PPD		GR		CAL	
	Baseline (T0)	**6-month follow-up (T1)**	**Baseline (T0)**	**6-month follow-up (T1)**	**Baseline (T0)**	**6-month follow-up (T1)**
Mean (SD)	7.73 (0.96)	3.87 (0.74)	1.47 (0.99)	1.67 (0.82)	9.20 (1.47)	5.53 (1.36)
Minimum	6	3	0	0	6	3
Median	8	4	2	2	9	6
Maximum	9	5	3	3	11	7
p-value	<0.001		0.190		<0.001	

8.2.3. Radiographic outcomes

Radiographic analysis was performed using standardized intraoral radiographs with calibration, and the inter-observer agreement was 94%, indicating excellent reliability.

Significant reductions were observed in all radiographically assessed defect dimensions. The vertical defect depth (INTRA) decreased from 3.81 ± 1.59 mm at T0 to 0.72 ± 1.08 mm at T1 ($P < 0.001$). The horizontal defect width (WIDTH) similarly improved, decreasing from 2.56 ± 0.75 mm to 0.44 ± 0.70 mm ($P < 0.001$). Defect angle (ANGLE) showed a marked reduction from 33.83° ± 13.38° at baseline to 9.15° ± 13.83° at six months ($P = 0.0012$). Figure 13 presents the distribution of pre- and postoperative measurements.

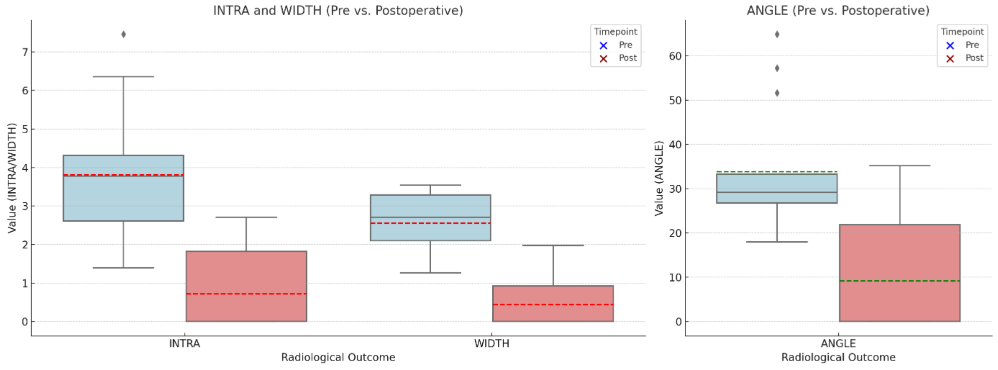
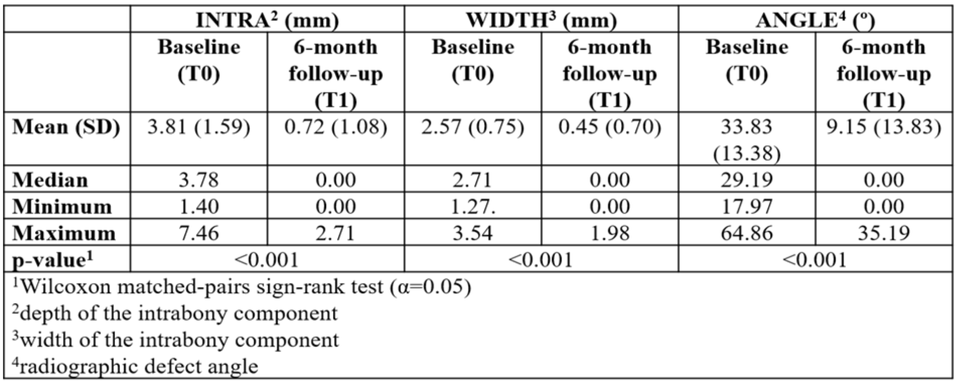


Figure 13. Clinical outcomes of preoperative and postoperative (6 months) depth; width and angle of intrabony components (67)

These changes reflect substantial radiographic improvement and defect fill following regenerative therapy with ATB + EMD. Detailed descriptive statistics are summarized in Table 7.



	INTRA[2] (mm)		WIDTH[3] (mm)		ANGLE[4] (°)	
	Baseline (T0)	**6-month follow-up (T1)**	**Baseline (T0)**	**6-month follow-up (T1)**	**Baseline (T0)**	**6-month follow-up (T1)**
Mean (SD)	3.81 (1.59)	0.72 (1.08)	2.57 (0.75)	0.45 (0.70)	33.83 (13.38)	9.15 (13.83)
Median	3.78	0.00	2.71	0.00	29.19	0.00
Minimum	1.40	0.00	1.27.	0.00	17.97	0.00
Maximum	7.46	2.71	3.54	1.98	64.86	35.19
p-value[1]	<0.001		<0.001		<0.001	

[1] Wilcoxon matched-pairs sign-rank test (α=0.05)
[2] depth of the intrabony component
[3] width of the intrabony component
[4] radiographic defect angle

Table 7. Table represents the mean, standard deviation, minimum, median, and maximum for T0 and T1 measurement and the paired t-test(67)

9. Discussion

9.1 Summary of findings and international comparisons

The present PhD thesis evaluated the clinical and biological performance of autogenous tooth-derived bone grafts in two distinct but related regenerative scenarios: alveolar ridge preservation and reconstructive periodontal therapy of intrabony defects. Despite differences in anatomical location and biological environment, both indications share a common clinical challenge—maintaining hard tissue volume while supporting physiological bone regeneration.

In the context of alveolar ridge preservation, the findings of our meta-analysis indicate that autogenous tooth bone grafts are effective in limiting post-extraction ridge resorption. The magnitude of horizontal ridge width reduction observed in ATB-treated sites was comparable to that reported for the most widely studied xenogeneic graft materials (19, 68).

Due to the different study population a considerable heterogeneity can be detected. Joshi et al. investigated only four wall extraction defects which might positively influenced the regeneration capacity. However, Radoczy-Drajko et al. investigated severe EDS 3-4 defects which might negatively influence the healing.

Owing to substantial variability in measurement protocols across the included studies, our meta-analysis was unable to directly compare socket dimensional changes following alveolar ridge preservation with autogenous tooth bone grafts to those observed after unassisted socket healing. Nevertheless, evidence from individual clinical investigations supports a ridge-preserving effect of ATB. In a split-mouth study, Del Canto-Díaz et al. reported markedly reduced horizontal bone loss in sites treated with ATB compared with untreated extraction sockets, with mean vestibular width reductions of 0.46 mm and 1.91 mm, respectively, assessed 1 mm apical to the alveolar crest. This is consistent with our findings (69).

With respect to graft resorption and remodeling behavior, autogenous tooth bone grafts appear to demonstrate a more favorable biological profile compared with conventional particulate graft materials. Previous meta-analytic evidence has shown that xenogeneic grafts used for alveolar ridge preservation are often characterized by limited new bone formation and a substantial amount of residual graft material up to 40% (6, 70). In contrast, our analysis suggests that ATB is associated with a higher proportion of newly formed bone with a mean value of 40% and a lower persistence of graft remnants of 11%, indicating a more physiological remodeling process (58). Owing to the limited number of available studies, definitive conclusions regarding the comparative efficacy of different ATB processing protocols resulting in varying degrees of mineralization cannot be drawn. Nevertheless, observable trends suggest that differences in clinical and histological outcomes may exist among demineralized, partially demineralized, and undemineralized graft materials.

In particular, partially demineralized dentin-based grafts appear to be associated with more favorable new bone formation with a mean value of 51% compared with fully demineralized grafts with a mean value of 31%, while differences in connective tissue proportions were less pronounced. These observations suggest that partial demineralization may enhance bone regenerative capacity. From a biological perspective, this effect may be attributed to increased osteoinductive potential resulting from greater exposure of collagenous and non-collagenous matrix proteins and growth factors, as well as improved osteoconductive properties related to increased surface area and porosity (47, 71). In contrast, excessive demineralization may compromise graft structure and reduce the availability of biologically active molecules. These interpretations are in agreement with previously reported preclinical and clinical observations (47, 62-64, 69, 72-74).

With regard to graft persistence, no statistically significant differences were identified among the mineralization subgroups. However, variations in the extent of residual graft material may be of clinical relevance and warrant further investigation in studies with larger sample sizes and standardized protocols.

From a practical standpoint, the inclusion of both the crown and root portions during ATB preparation increases the total amount of graft material obtainable from a single extracted tooth, which may be advantageous in larger defects or when multiple sites require reconstruction. While some protocols recommend using only the root portion due to its higher dentin content, restricting graft preparation to the root inevitably limits graft availability.

Grafts prepared from the entire tooth structure, incorporating both root and crown components, appear to support greater new bone formation compared with grafts derived from the root portion alone. Differences in graft turnover and connective tissue proportions were less evident between these subgroups. This suggests that incorporating the enamel component does not adversely affect graft remodeling, while simultaneously improving material availability. Consequently, the use of whole-tooth ATB may represent a pragmatic approach that maximizes graft yield without compromising biological performance. Nonetheless, further controlled studies are required to confirm whether enamel inclusion influences long-term regenerative outcomes.

The biological behavior of graft materials appears to be particularly relevant in periodontal intrabony defects, especially in non-contained one- and two-wall morphologies where vascular supply and intrinsic defect stability are limited. In such defects, surgical approaches alone are often insufficient to ensure clot stability, and the choice of graft material becomes a decisive factor.

Our clinical study demonstrated that the combination of ATB with enamel matrix derivative resulted in clinically meaningful improvements in probing pocket depth and attachment levels, supporting the reconstructive potential of this biologically enhanced approach. Although retrospective in design, this study can be considered exploratory and pioneering, as it provides the first clinical insight into the use of autogenous tooth bone grafts in combination with enamel matrix derivative for periodontal regeneration.

Several clinical trials have shown that combining enamel matrix derivative with particulate graft materials yields superior outcomes compared with the use of EMD alone (75-77). While previous studies have primarily focused on autogenous bone or xenogeneic grafts as adjuncts to EMD, my thesis extends this concept by introducing autogenous tooth-derived grafts into periodontal regenerative therapy. Unlike conventional particulate grafts, which function predominantly as osteoconductive scaffolds, dentin-based grafts contain collagenous and non-collagenous proteins that may contribute to osteoinductive signaling and active remodeling. This biological advantage may be particularly relevant in periodontal defects where prolonged graft persistence can compromise true regeneration.

The findings of the present work are consistent with earlier preclinical and clinical investigations demonstrating the biocompatibility and regenerative potential of dentin-derived graft materials. Experimental studies have shown that demineralized dentin matrix undergoes gradual resorption and replacement by newly formed bone within months, while clinical case series and pilot studies have reported improvements in periodontal parameters and radiographic bone fill following the use of autogenous dentin grafts (74, 78, 79). By integrating evidence from alveolar ridge preservation and periodontal reconstruction, the present thesis supports the concept that graft materials capable of active physiological remodeling may offer advantages across different regenerative contexts.

Taken together, these findings position autogenous tooth bone grafts as a biocompatible and clinically relevant grafting option. Compared with conventional xenogeneic materials, ATB demonstrates comparable space-maintaining ability while exhibiting a more favorable remodeling profile. In combination with biologic agents such as enamel matrix derivative, ATB may further enhance regenerative outcomes in challenging periodontal defects, where both scaffold stability and biological activity are required for predictable healing.

9.2. Strengths (including all studies)

The present thesis is strengthened by its combined methodological approach, integrating a systematically conducted and pre-registered meta-analysis with a retrospective clinical case series. While previous publications on autogenous tooth-derived bone grafts have been limited to systematic reviews, this work provides the first quantitative synthesis of the available evidence.

A further strength lies in the translational design of the thesis. One of the strengths of our retrospective study lies in its exploratory nature, as it offers the first clinical insight into the combined application of autogenous tooth bone grafts and enamel matrix derivative in challenging intrabony periodontal defects. In addition, the inclusion of both clinical and radiographic outcome measures allowed a comprehensive assessment of treatment effects beyond purely clinical parameters.

9.3. Limitations (including all studies)

It is important to note that the present thesis is not without its limitations, which necessitate a cautious interpretation of its findings. In the meta-analysis, high heterogeneity and the limited number of randomized controlled trials necessitated the inclusion of non-randomized studies, which may have increased variability in the pooled outcomes. Differences in ATB preparation protocols, defect morphology, and follow-up periods further limited direct comparability between studies.

The retrospective clinical case series is subject to inherent limitations related to study design, including a small sample size, lack of a control group, and short-term follow-up. Moreover, radiographic assessments cannot provide histological confirmation of true periodontal regeneration. Future prospective, controlled studies with standardized protocols and longer follow-up are therefore required.

10. Conclusion

Across two complementary investigations—a systematic review and meta-analysis on alveolar ridge preservation and a retrospective clinical study on non-contained intrabony periodontal defects—this thesis provides comprehensive evidence supporting the feasibility and biological potential of autogenous tooth bone grafts (ATB) in various reconstructive periodontal applications.

The meta-analysis demonstrated that ATB is effective in mitigating post-extraction dimensional changes and exhibits a favorable histological profile, with low residual graft proportions and substantial newly formed bone. Importantly, neither the degree of dentin demineralization nor the anatomical portion of the tooth used appeared to compromise clinical or histological outcomes.

In reconstructive periodontal surgery, ATB combined with enamel matrix derivative resulted in significant improvements in probing pocket depth, clinical attachment level, and radiographic defect morphology, even in challenging non-contained defects. Healing was uneventful in all cases, highlighting the predictable handling characteristics and biocompatibility of ATB.

Collectively, the findings indicate that ATB represents a biologically compatible, sustainable, patient-specific grafting material with broad applicability in contemporary regenerative dentistry. While further high-quality studies are required, the current evidence supports the integration of ATB into clinical practice as a viable alternative to conventional autogenous and xenogeneic grafts.

11. Implementation for practice

The results of this thesis hold several practical implications for clinicians involved in periodontal regeneration and oral surgery.

First, chairside production of ATB offers the possibility of using a patient-specific, autogenous graft without the morbidity, cost, and logistical burden associated with extraoral donor sites. This aligns with modern trends toward minimally invasive, biologically driven, and personalized regenerative approaches.

Second, ATB demonstrates handling characteristics similar to conventional particulate biomaterials, making it readily adaptable to existing surgical workflows. Its osteoconductive scaffold, combined with the potential release of growth factors from the dentin matrix, represents a biologically attractive option in defects requiring space maintenance and remodeling, including intrabony defects and post-extraction sockets.

Third, ATB may be particularly advantageous in clinical scenarios where soft-tissue conditions or defect morphology limit the predictability of traditional materials. Its capacity for turnover, coupled with low residual graft proportions, suggests a reduced risk of long-term graft sequestration, a common challenge observed with slowly resorbing xenografts.

Overall, the safe and predictable performance of ATB supports its gradual incorporation into regenerative protocols, provided that preparation is performed according to validated protocols and that clinicians receive appropriate training in its use.

12. Implementation for research

The findings of this thesis highlight several key areas where further investigation is required to establish the full clinical potential of ATB.

First, despite encouraging outcomes, the current body of evidence—particularly in alveolar ridge preservation—is limited by sample size, variability in processing methods, and heterogeneity in outcome reporting. Well-designed, multicenter randomized controlled trials are necessary to determine the comparative effectiveness of ATB versus other autogenous, allogeneic, and xenogeneic grafts.

Second, the biological mechanisms underlying ATB-mediated regeneration require additional clarification. Differences in cellular response, remodeling kinetics, and growth-factor release between UDDM, PDDM, and DDM remain incompletely understood. Standardized biochemical and histological assays could help identify the optimal degree of demineralization for specific clinical indications.

Third, research is needed to refine and validate standardized chairside protocols for ATB preparation. Comparative studies between available devices may inform evidence-based recommendations for granule size, processing duration, and sterilization methods.

Finally, the integration of ATB into digital workflows, including 3D-printed graft templates and guided graft placement, represents an emerging research frontier with the potential to improve accuracy and reproducibility.

13. Implementations for policymakers

The findings of the present thesis may have several implications for healthcare policymakers and regulatory bodies involved in oral healthcare planning and resource allocation. Tooth extraction remains one of the most frequently performed dental procedures; therefore, decision-makers should prioritize tooth preservation and, in cases of tooth loss, consider replacement with dental implants, yet the extracted tooth is conventionally discarded as biological waste despite its potential value as an autogenous graft material. The utilization of autogenous tooth-derived bone grafts represents an opportunity to transform an existing clinical byproduct into a regenerative resource.

From a health system perspective, the use of autogenous tooth-derived grafts may contribute to more sustainable regenerative strategies by reducing reliance on commercially produced xenogeneic or allogeneic biomaterials. This approach may lower long-term material-related costs and decrease the environmental burden associated with graft material production, processing, and distribution. Such considerations are increasingly relevant in the context of cost containment and sustainability-oriented healthcare policies.

In addition, the application of autogenous graft materials aligns with principles of personalized medicine and patient-centered care. By utilizing the patient’s own biological tissues, potential ethical, cultural, and religious concerns associated with animal- or donor-derived graft materials may be minimized. Policymakers may therefore consider supporting regulatory frameworks and clinical guidelines that facilitate the safe and standardized use of autogenous tooth-derived grafts in appropriate clinical indications.

Finally, the heterogeneity of dentin processing protocols identified in the literature highlights the need for standardization and quality assurance. Policymakers and professional organizations could play a key role in encouraging the development of evidence-based guidelines, training requirements, and certification pathways to ensure consistent clinical outcomes and patient safety. Support for well-designed prospective clinical trials may further inform future recommendations and reimbursement policies related to regenerative periodontal and implant-related procedures.

14. Future perspectives

Looking ahead, autogenous tooth bone grafts hold significant promise as a cornerstone material in personalized regenerative dentistry. Several developments may shape their future clinical use. The integration of ATB into clinical and research frameworks represents a meaningful step toward biologically personalized, sustainable, and minimally invasive regenerative dentistry. Continued innovation and rigorous investigation are expected to expand its role in the coming years.

15. References

1. Mohamed AG, Ibrahim AEE, Abdusalam A. Milad M. Tooth Extraction using Vertical, Conventional, and Surgical Techniques in Sebha Dental College: A Descriptive “Cross-sectional Study”. The Open Dentistry Journal. 2023;17.

2. Becker W, Becker BE. Periodontal Regeneration Updated. The Journal of the American Dental Association. 1993;124(7):37-43.

3. Nyman S, Lindhe J, Karring T, Rylander H. New attachment following surgical treatment of human periodontal disease. J Clin Periodontol. 1982;9(4):290-6.

4. Bosshardt DD, Sculean A. Does periodontal tissue regeneration really work? Periodontology 2000. 2009;51(1):208-19.

5. Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: clinical results with different bone grafts and bone-substitute materials. Int J Oral Maxillofac Implants. 2009;24 Suppl:218-36.

6. De Risi V, Clementini M, Vittorini G, Mannocci A, De Sanctis M. Alveolar ridge preservation techniques: a systematic review and meta-analysis of histological and histomorphometrical data. Clin Oral Implants Res. 2015;26(1):50-68.

7. Minetti E, Berardini M, Trisi P. A New Tooth Processing Apparatus Allowing to Obtain Dentin Grafts for Bone Augmentation: The Tooth Transformer. The Open Dentistry Journal. 2019;13.

8. Kim YK, Kim SG, Byeon JH, Lee HJ, Um IU, Lim SC, et al. Development of a novel bone grafting material using autogenous teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;109(4):496-503.

9. Murata M, Akazawa T, Mitsugi M, Kabir M, Minamida Y, Um I-W, et al. Autograft of Dentin Materials for Bone Regeneration. 2013.

10. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. J Clin Periodontol. 2005;32(2):212-8.

11. Chen ST, Buser D. Esthetic outcomes following immediate and early implant placement in the anterior maxilla--a systematic review. Int J Oral Maxillofac Implants. 2014;29 Suppl:186-215.

12. Elian N, Cho SC, Froum S, Smith RB, Tarnow DP. A simplified socket classification and repair technique. Pract Proced Aesthet Dent. 2007;19(2):99-104; quiz 6.

13. Fu JH, Yeh CY, Chan HL, Tatarakis N, Leong DJ, Wang HL. Tissue biotype and its relation to the underlying bone morphology. J Periodontol. 2010;81(4):569-74.

14. Buser D, Chappuis V, Belser UC, Chen S. Implant placement post extraction in esthetic single tooth sites: when immediate, when early, when late? Periodontol 2000. 2017;73(1):84-102.

15. Caplanis N, Lozada JL, Kan JY. Extraction defect assessment, classification, and management. J Calif Dent Assoc. 2005;33(11):853-63.

16. Iasella JM, Greenwell H, Miller RL, Hill M, Drisko C, Bohra AA, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: a clinical and histologic study in humans. J Periodontol. 2003;74(7):990-9.

17. Lekovic V, Camargo PM, Klokkevold PR, Weinlaender M, Kenney EB, Dimitrijevic B, et al. Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. J Periodontol. 1998;69(9):1044-9.

18. Lekovic V, Kenney EB, Weinlaender M, Han T, Klokkevold P, Nedic M, et al. A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. J Periodontol. 1997;68(6):563-70.

19. Avila-Ortiz G, Elangovan S, Kramer KW, Blanchette D, Dawson DV. Effect of alveolar ridge preservation after tooth extraction: a systematic review and meta-analysis. J Dent Res. 2014;93(10):950-8.

20. Quisiguiña Salem C, Ruiz Delgado E, Crespo Reinoso PA, Robalino JJ. Alveolar ridge preservation: A review of concepts and controversies. Natl J Maxillofac Surg. 2023;14(2):167-76.

21. Araujo M, Linder E, Lindhe J. Effect of a xenograft on early bone formation in extraction sockets: an experimental study in dog. Clin Oral Implants Res. 2009;20(1):1-6.

22. Cortellini P, Tonetti MS. Clinical concepts for regenerative therapy in intrabony defects. Periodontology 2000. 2015;68(1):282-307.

23. Polimeni G, Xiropaidis AV, Wikesjö UM. Biology and principles of periodontal wound healing/regeneration. Periodontol 2000. 2006;41:30-47.

24. Melcher AH. On the repair potential of periodontal tissues. J Periodontol. 1976;47(5):256-60.

25. Goldman HM, Cohen DW. The Infrabony Pocket: Classification and Treatment. The Journal of Periodontology. 1958;29(4):272-91.

26. Papapanou PN, Tonetti MS. Diagnosis and epidemiology of periodontal osseous lesions. Periodontol 2000. 2000;22:8-21.

27. Vastardis S. Re: Periodontal terminology revisited. Weinberg MA, Eskow RN (2003;74:563-565). Journal of periodontology. 2003;74:1394.

28. Saari JT, Hurt WC, Biggs NL. Periodontal bony defects on the dry skull. J Periodontol. 1968;39(5):278-83.

29. Tonetti MS, Lang NP, Cortellini P, Suvan JE, Adriaens P, Dubravec D, et al. Enamel matrix proteins in the regenerative therapy of deep intrabony defects. Journal of Clinical Periodontology. 2002;29(4):317-25.

30. Sculean A, Nikolidakis D, Nikou G, Ivanovic A, Chapple IL, Stavropoulos A. Biomaterials for promoting periodontal regeneration in human intrabony defects: a systematic review. Periodontol 2000. 2015;68(1):182-216.

31. Gottlow J, Nyman S, Lindhe J, Karring T, Wennström J. New attachment formation in the human periodontium by guided tissue regeneration Case reports. Journal of Clinical Periodontology. 1986;13(6):604-16.

32. Rosling B, Nyman S, Lindhe J, Jern B. The healing potential of the periodontal tissues following different techniques of periodontal surgery in plaque-free dentitions. A 2-year clinical study. J Clin Periodontol. 1976;3(4):233-50.

33. Heitz-Mayfield LJ, Lang NP. Surgical and nonsurgical periodontal therapy. Learned and unlearned concepts. Periodontol 2000. 2013;62(1):218-31.

34. Cortellini P, Prato GP, Tonetti MS. The simplified papilla preservation flap. A novel surgical approach for the management of soft tissues in regenerative procedures. Int J Periodontics Restorative Dent. 1999;19(6):589-99.

35. Cortellini P, Prato GP, Tonetti MS. The modified papilla preservation technique. A new surgical approach for interproximal regenerative procedures. J Periodontol. 1995;66(4):261-6.

36. Cortellini P, Tonetti MS. Clinical concepts for regenerative therapy in intrabony defects. Periodontology 2000. 2015;68 1:282-307.

37. Sculean A, Windisch P, Döri F, Keglevich T, Molnár B, Gera I. Emdogain in regenerative periodontal therapy. A review of the literature. Fogorv Sz. 2007;100(5):220-32, 11-9.

38. Heijl L, Heden G, Svärdström G, Ostgren A. Enamel matrix derivative (EMDOGAIN) in the treatment of intrabony periodontal defects. J Clin Periodontol. 1997;24(9 Pt 2):705-14.

39. Kao RT, Nares S, Reynolds MA. Periodontal regeneration - intrabony defects: a systematic review from the AAP Regeneration Workshop. J Periodontol. 2015;86(2 Suppl):S77-104.

40. Li W, Xiao L, Hu J. The use of enamel matrix derivative alone versus in combination with bone grafts to treat patients with periodontal intrabony defects: a meta-analysis. J Am Dent Assoc. 2012;143(9):e46-56.

41. Matarasso M, Iorio-Siciliano V, Blasi A, Ramaglia L, Salvi GE, Sculean A. Enamel matrix derivative and bone grafts for periodontal regeneration of intrabony defects. A systematic review and meta-analysis. Clin Oral Investig. 2015;19(7):1581-93.

42. Yeomans JD, Urist MR. Bone induction by decalcified dentine implanted into oral, osseous and muscle tissues. Arch Oral Biol. 1967;12(8):999-1008.

43. Linden GJ. Bone induction in implants of decalcified bone and dentine. J Anat. 1975;119(Pt 2):359-67.

44. Bang G. Induction of heterotopic bone formation by demineralized dentin: an experimental model in guinea pigs. European Journal of Oral Sciences. 1973;81(3):240-50.

45. Koga T, Minamizato T, Kawai Y, Miura K, I T, Nakatani Y, et al. Bone Regeneration Using Dentin Matrix Depends on the Degree of Demineralization and Particle Size. PLoS One. 2016;11(1):e0147235.

46. Kim TW, Seo EW, Song SI. Open reduction and internal fixation of mandibular fracture in an 11-month-old infant: a case report. J Korean Assoc Oral Maxillofac Surg. 2013;39(2):90-3.

47. Gual-Vaqués P, Polis-Yanes C, Estrugo-Devesa A, Ayuso-Montero R, Mari-Roig A, López-López J. Autogenous teeth used for bone grafting: A systematic review. Med Oral Patol Oral Cir Bucal. 2018;23(1):e112-e9.

48. Pallesen L, Schou S, Aaboe M, Hjørting-Hansen E, Nattestad A, Melsen F. Influence of particle size of autogenous bone grafts on the early stages of bone regeneration: a histologic and stereologic study in rabbit calvarium. Int J Oral Maxillofac Implants. 2002;17(4):498-506.

49. Shapoff CA, Bowers GM, Levy B, Mellonig JT, Yukna RA. The effect of particle size on the osteogenic activity of composite grafts of allogeneic freeze-dried bone and autogenous marrow. J Periodontol. 1980;51(11):625-30.

50. Campana V, Milano G, Pagano E, Barba M, Cicione C, Salonna G, et al. Bone substitutes in orthopaedic surgery: from basic science to clinical practice. J Mater Sci Mater Med. 2014;25(10):2445-61.

51. Bischof JC, He X. Thermal stability of proteins. Ann N Y Acad Sci. 2005;1066:12-33.

52. Dozza B, Lesci IG, Duchi S, Della Bella E, Martini L, Salamanna F, et al. When size matters: differences in demineralized bone matrix particles affect collagen structure, mesenchymal stem cell behavior, and osteogenic potential. J Biomed Mater Res A. 2017;105(4):1019-33.

53. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Bmj. 2021;372:n71.

54. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. Bmj. 2019;366:l4898.

55. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. Bmj. 2016;355:i4919.

56. GRADE handbook for Grading quality of evidence and strength of recommendations. 2021.

57. Schünemann HJ, Oxman AD, Brozek J, Glasziou P, Jaeschke R, Vist GE, et al. Grading quality of evidence and strength of recommendations for diagnostic tests and strategies. Bmj. 2008;336(7653):1106-10.

58. Solyom E, Szalai E, Czumbel ML, Szabo B, Váncsa S, Mikulas K, et al. The use of autogenous tooth bone graft is an efficient method of alveolar ridge preservation - meta-analysis and systematic review. BMC Oral Health. 2023;23(1):226.

59. Joshi CP, Dani NH, Khedkar SU. Alveolar ridge preservation using autogenous tooth graft versus beta-tricalcium phosphate alloplast: A randomized, controlled, prospective, clinical pilot study. J Indian Soc Periodontol. 2016;20(4):429-34.

60. Radoczy-Drajko Z, Windisch P, Svidro E, Tajti P, Molnar B, Gerber G. Clinical, radiographical and histological evaluation of alveolar ridge preservation with an autogenous tooth derived particulate graft in EDS class 3-4 defects. BMC Oral Health. 2021;21(1):63.

61. Santos A, Botelho J, Machado V, Borrecho G, Proença L, Mendes JJ, et al. Autogenous Mineralized Dentin versus Xenograft granules in Ridge Preservation for Delayed Implantation in Post-extraction Sites: A Randomized controlled clinical trial with an 18 months follow-up. Clin Oral Implants Res. 2021;32(8):905-15.

62. Elfana A, El-Kholy S, Saleh HA, Fawzy El-Sayed K. Alveolar ridge preservation using autogenous whole-tooth versus demineralized dentin grafts: A randomized controlled clinical trial. Clin Oral Implants Res. 2021;32(5):539-48.

63. Jung G-U, Jeon T-H, Kang M-H, Um I-W, Song I-S, Ryu J-J, et al. Volumetric, Radiographic, and Histologic Analyses of Demineralized Dentin Matrix Combined with Recombinant Human Bone Morphogenetic Protein-2 for Ridge Preservation: A Prospective Randomized Controlled Trial in Comparison with Xenograft. Applied Sciences. 2018;8(8).

64. Dwivedi A, Kour M. A neoteric procedure for alveolar ridge preservation using autogenous fresh mineralized tooth graft prepared at chair side. J Oral Biol Craniofac Res. 2020;10(4):535-41.

65. Um I-W, Kim Y-K, Park J-C, Lee J-H. Clinical application of autogenous demineralized dentin matrix loaded with recombinant human bone morphogenetic-2 for socket preservation: A case series. Clinical Implant Dentistry and Related Research. 2019;21(1):4-10.

66. Pang KM, Um IW, Kim YK, Woo JM, Kim SM, Lee JH. Autogenous demineralized dentin matrix from extracted tooth for the augmentation of alveolar bone defect: a prospective randomized clinical trial in comparison with anorganic bovine bone. Clin Oral Implants Res. 2017;28(7):809-15.

67. Solyom E, Forgó K, Somodi K, Palkovics D, Vancsa S, Windisch P, et al. Autogenous Tooth Bone Grafts with Enamel Matrix Derivates in Non-Contained Intrabony Periodontal Defects-A Case Series Study. Biomedicines. 2025;14(1).

68. Atieh MA, Alsabeeha NHM, Payne AGT, Ali S, Faggion CM, Jr., Esposito M. Interventions for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development. Cochrane Database of Systematic Reviews. 2021(4).

69. Del Canto-Díaz A, de Elío-Oliveros J, Del Canto-Díaz M, Alobera-Gracia MA, Del Canto-Pingarrón M, Martínez-González JM. Use of autologous tooth-derived graft material in the post-extraction dental socket. Pilot study. Med Oral Patol Oral Cir Bucal. 2019;24(1):e53-e60.

70. Horváth A, Mardas N, Mezzomo LA, Needleman IG, Donos N. Alveolar ridge preservation. A systematic review. Clin Oral Investig. 2013;17(2):341-63.

71. Minetti E, Palermo A, Ferrante F, Schmitz JH, Lung Ho HK, Dih Hann SN, et al. Autologous Tooth Graft after Endodontical Treated Used for Socket Preservation: A Multicenter Clinical Study. Applied Sciences. 2019;9(24):5396.

72. Kim YK, Kim SG, Oh JS, Jin SC, Son JS, Kim SY, et al. Analysis of the inorganic component of autogenous tooth bone graft material. J Nanosci Nanotechnol. 2011;11(8):7442-5.

73. Dhuvad JM, Mehta D. Does an autogenous demineralized dentin (ADDM) graft has the ability to form a new bone? Natl J Maxillofac Surg. 2021;12(2):181-7.

74. Elsherbini FS, Abdulrahman M, El-Shennawi MM. Evaluation of autogenous tooth graft in regeneration of periodontal vertical alveolar defects: clinical, radiographic, and experimental study. Journal of Stomatology. 2023;76(2):84-3.

75. Yilmaz S, Cakar G, Yildirim B, Sculean A. Healing of two and three wall intrabony periodontal defects following treatment with an enamel matrix derivative combined with autogenous bone. J Clin Periodontol. 2010;37(6):544-50.

76. Cochran DL, Jones A, Heijl L, Mellonig JT, Schoolfield J, King GN. Periodontal regeneration with a combination of enamel matrix proteins and autogenous bone grafting. J Periodontol. 2003;74(9):1269-81.

77. Sculean A, Chiantella GC, Windisch P, Gera I, Reich E. Clinical evaluation of an enamel matrix protein derivative (Emdogain) combined with a bovine-derived xenograft (Bio-Oss) for the treatment of intrabony periodontal defects in humans. Int J Periodontics Restorative Dent. 2002;22(3):259-67.

78. Upadhyay P, Blaggana V, Tripathi P, Jindal M. Treatment of Furcation Involvement Using Autogenous Tooth Graft With 1-Year Follow-Up: A Case Series. Clin Adv Periodontics. 2019;9(1):4-8.

79. Sánchez-Labrador L, Martín-Ares M, Cortés-Bretón Brinkmann J, López-Quiles J, Martínez-González JM. Assessment of Changes in the Outcome of Autogenous Tooth Grafts Over Time: A Clinical Study Evaluating Periodontal Healing in Bone Defects After Lower Third Molar Removal. Journal of Oral and Maxillofacial Surgery. 2024;82(9):1121-8.

16. Bibliography

16.1. Publications Related to the Thesis

E. Solyom, E. Szalai, M. L. Czumbel, B. Szabo, S. Váncsa, K. Mikulas, Z. Radoczy-Drajko, G. Varga, P. Hegyi, B. Molnar, and R. Fazekas, “The use of autogenous tooth bone graft is an efficient method of alveolar ridge preservation – meta-analysis and systematic review,” BMC ORAL HEALTH, vol. 23, no. 1, 2023.

Q1; IF 3.1

E. Solyom, K. Forgó, K. Somodi, D. Palkovics, S. Vancsa, P. Windisch, B. Molnar, and R. Fazekas, “Autogenous Tooth Bone Grafts with Enamel Matrix Derivates in Non-Contained Intrabony Periodontal Defects—A Case Series Study,” vol. 14, p. 56, 2026.

Q1; IF 3.9

16.2. Publications not Related to the Thesis

. Palkovics, E. Solyom, K. Somodi, C. Pinter, P. Windisch, F. Bartha, and B. Molnar, “Three-dimensional volumetric assessment of hard tissue alterations following horizontal guided bone regeneration using a split-thickness flap design: A case series,” BMC ORAL HEALTH, vol. 23, no. 1, 2023.

Q1; IF 3.1

V. Vitai, A. Németh, E. Sólyom, L. M. Czumbel, B. Szabó, R. Fazekas, G. Gerber, P. Hegyi, P. Hermann, and J. Borbély, “Evaluation of the accuracy of intraoral scanners for complete-arch scanning : A systematic review and network meta-analysis,” JOURNAL OF DENTISTRY, vol. 137, 2023.

D1; IF 5.5

R. Fazekas, R. Veress, K. Weninger, F. Bartha, E. Solyom, O. Lang, J. Vag, and B. Molnar, “Blood flow kinetics of full- and split thicknessflaps following alveolar ridge

augmentation proceduremeasured by laser speckle contrast imaging," JOURNAL OF CLINICAL PERIODONTOLOGY, vol. 49, no. S23, pp. 69–69, 2022.

D1; IF 6.8

B. K. Csifó-Nagy, E. Sólyom, and F. Dőri, "Healing of intrabony defects following treatment with a new-generation platelet-rich fibrin or EMD: A randomized clinical trial," JOURNAL OF CLINICAL PERIODONTOLOGY, vol. 49, no. S23, pp. 44–44, 2022.

D1; IF 6.8

D. Palkovics, E. Solyom, B. Molnar, C. Pinter, and P. Windisch, "Digital Hybrid Model Preparation for Virtual Planning of Reconstructive Dentoalveolar Surgical Procedures," JOVE-JOURNAL OF VISUALIZED EXPERIMENTS, vol. 2021, no. 174, 2021.

Q3; IF 1

B. K. Csifó-Nagy, E. Sólyom, V. L. Bognár, A. Nevelits, and F. Dőri, "Efficacy of a new-generation platelet-rich fibrin in the treatment of periodontal intrabony defects: a randomized clinical trial," BMC ORAL HEALTH, vol. 21, no. 1, 2021.

Q1; IF 3.1

Tajti, P., Solyom, E., Czumbel, L. M., Szabó, B., Fazekas, R., Németh, O., … Mikulás, K. (2024). Monolithic zirconia as a valid alternative to metal-ceramic for implant-supported single crowns in the posterior region: A systematic review and meta-analysis of randomized controlled trials. JOURNAL OF PROSTHETIC DENTISTRY, 132(5), 881–889. http://doi.org/10.1016/j.prosdent.2023.05.006

Q1; IF4.8

Tajti, P., Solyom, E., Váncsa, S., Mátrai, P., Hegyi, P., Varga, G., … Mikulás, K. (2024). Less marginal bone loss around bone-level implants restored with long abutments : A systematic review and meta-analysis. PERIODONTOLOGY 2000, 94(1), 627–638. http://doi.org/10.1111/prd.12534

Q1; IF: 15.7

Würsching, T., Mészáros, B., Sólyom, E., Molnár, B., Bogdán, S., Németh, Z., & Nagy, K. (2025). Long-Term Results of Autologous Tooth Bone Grafting in Alveolar Cleft Reconstruction: A Retrospective Cohort Study. BIOMEDICINES, 13(7). http://doi.org/10.3390/biomedicines13071735

Q1; IF:3.9

Molnár, B., Würsching, T., Sólyom, E., Pálvölgyi, L., Radóczy-Drajkó, Z., Palkovics, D., & Nagy, K. (2024). Alveolar cleft reconstruction utilizing a particulate autogenous tooth graft and a novel split-thickness papilla curtain flap — A retrospective study. JOURNAL OF CRANIO-MAXILLOFACIAL SURGERY, 52(1), 77–84. http://doi.org/10.1016/j.jcms.2023.10.006

Q2; IF: 2.1

Somodi, K., Dobos, A., Bartha, F., Solyom, E., Windisch, P., Palkovics, D., & Molnar, B. (2024). Changes in soft tissue dimensions following horizontal guided bone regeneration with a split-thickness flap design – evaluation of 8 cases with a digital method. HEAD AND FACE MEDICINE, 20(1). http://doi.org/10.1186/s13005-024-00456-8

Q2; IF: 2.6

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