RYBOWSKI, Jakub, KRZYŚKOWSKA, Sylwia, SZCZUPAJ, Maciej, POPIEL, Michał, GŁOWACZ, Julia and DZIEKOŃSKI, Kamil. The Impact of diet on wound healing after dental surgery - the role of micro- and macronutrients in the regeneration of oral tissues. Quality in Sport. 2025;39:59476. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.39.59476
https://apcz.umk.pl/QS/article/view/59476

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 16.03.2025. Revised: 25.03.2025. Accepted: 06.04.2025 Published: 08.04.2025.

The impact of diet on wound healing after dental surgery - the role of micro- and macronutrients in the regeneration of oral tissues

Jakub Rybowski[1] (ORCID:0009-0002-6860-7805) jakubrybowski22@gmail.com

Sylwia Krzyśkowska[2] (ORCID:0009-0001-4542-1357) sylwiakrzyskowska@gmail.com

Maciej Szczupaj[2] (ORCID:0009-0003-2598 -5694) maciekszczupaj@gmail.com

Julia Głowacz[3] (ORCID:0009-0000-3564-703X) glowaczjulia@interia.eu

Michał Popiel[4] (ORCID:0009-0002-9726-6296) michal.popiel7@gmail.com

Kamil Dziekoński[5] (ORCID:0009-0001-9958-1348) dziekondent@gmail.com

[1] Student Research Group at the Chair and Department of Oral Medicine, Medical University of Lublin, Lublin, Poland/Studenckie Koło Badawcze przy Katedrze i Zakładzie Medycyny Jamy Ustnej, Uniwersytet Medyczny w Lublinie, Lublin, Polska

[2] Student Research Group, Faculty of Medicine, Medical University of Lublin, Lublin, Poland/Studenckie Koło Badawcze, Wydział Lekarski, Uniwersytet Medyczny w Lublinie, Lublin, Polska

[3] Student Research Group, Faculty of Stomatology, Medical University of Lublin, Lublin, Poland/Studenckie Koło Badawcze, Wydział Lekarsko-Dentystyczny, Uniwersytet Medyczny w Lublinie, Lublin, Polska

[4] Hospicjum Małego Księcia w Lublinie, Lędzian 49, 20-828 Lublin, Poland/ The Little Prince Hospice of Lublin, Lędzian 49, 20-828 Lublin, Poland

[5] Corten Dental ul. Makolągwy 21 02-811 Warszawa

Address for correspondence: Jakub Rybowski, Student Research Group at the Chair and Department of Oral Medicine, Medical University of Lublin, Lublin, Poland
E-mail: jakubrybowski22@gmail.com

Abstract

Introduction: The process of wound healing after oral surgery is a complex biological phenomenon influenced by multiple factors, including proper nutrition. Nutrients, both micro- and macronutrients, play a crucial role in oral tissue regeneration by supporting collagen synthesis, cell proliferation, and modulation of inflammation. Vitamins, minerals, and an adequate intake of proteins, fats, and carbohydrates can accelerate the healing process and reduce the risk of complications. The aim of this study is to analyze the available literature on the impact of diet on regenerative processes in the oral cavity, with a particular focus on the role of micro- and macronutrients, as well as the microbiota, and to determine optimal dietary recommendations for patients undergoing oral surgical procedures.

Material and Methods: For a detailed analysis of the role of micro- and macronutrients in the wound healing processes following oral surgery, studies on the impact of oral microbiota on inflammatory processes and the effectiveness of diets supporting tissue regeneration were also considered.

Description of the state of knowledge: Existing research indicates that diet plays a key role in the wound healing process after oral surgery, affecting collagen synthesis, cell proliferation,

and the modulation of the inflammatory response. Micronutrients such as vitamins A, C, and D, as well as zinc and iron, support tissue regeneration and immune system function, while macronutrients—proteins, fats, and carbohydrates—provide essential energy and structural substrates. Another significant aspect is the influence of diet on oral microbiota, whose balance can either promote or hinder regeneration. A diet rich in prebiotics and probiotics supports beneficial microorganisms, whereas an excess of simple sugars and trans fats may contribute to inflammation. Increasing attention is also being paid to the impact of restrictive diets, such as the ketogenic diet, which can modify metabolism and the body's regenerative capacities, although their effects require further investigation.

Conclusions: Proper nutrition supports wound healing after oral surgical procedures by influencing tissue regeneration, inflammation control, and immunity. Key factors include micro- and macronutrients such as vitamins, minerals, proteins, and fatty acids, as well as the balance of oral microbiota. A diet rich in prebiotics and probiotics promotes regeneration, while excessive intake of simple sugars and trans fats may hinder it. Although restrictive diets, such as the ketogenic diet, are gaining interest, their impact on the healing process requires further research. A well-balanced diet can effectively support post-surgical recovery in oral surgery patients.

Key words: diet, wound healing, oral surgery, micronutrients, macronutrients, tissue regeneration, oral health

Introduction

The process of tissue regeneration following oral surgical procedures is a complex biological mechanism influenced by various factors, including the patient’s health status, the type of procedure performed, coexisting diseases, and environmental conditions [1,2]. A well-balanced diet providing essential micro- and macronutrients is a key element in supporting wound healing [3–6]. These nutrients, including proteins, vitamins, minerals, and fatty acids, play a crucial role in collagen synthesis, cell proliferation, angiogenesis, and inflammation control, directly impacting the speed and quality of the repair process [5].In oral surgery, wound healing occurs in an environment constantly exposed to microorganisms and variable physiological conditions, such as salivary pH and mechanical stress [1,5,7]. Adequate

intake of essential nutrients not only supports tissue regeneration but also helps reduce the risk of infections and postoperative complications [5,7]. Micronutrients, such as vitamins C and D, zinc, and iron, are particularly important in this process, as they contribute to tissue repair and the proper functioning of the immune system [4,5,7–10]. Meanwhile, macronutrients—including proteins, fats, and carbohydrates—serve not only as an energy source but also provide the structural components necessary for rebuilding damaged biological structures [5,7]. Diet also has a significant impact on the oral microbiome, which plays a crucial role in maintaining mucosal health and local immunity [5,7]. The consumption of prebiotics and probiotics can promote the growth of beneficial microorganisms, reducing the risk of infections and inflammatory conditions [5,7]. Conversely, excessive intake of simple sugars, trans fats, and a diet low in fiber and antioxidants contribute to dysbiosis, which may negatively affect the wound healing process [7,11]. In recent years, increasing attention has been given to restrictive diets, such as the ketogenic or elimination diet, which may influence metabolism and the body's ability to regenerate tissues effectively [7,12]. The aim of this study is to analyze the available literature on the role of diet in the wound healing process following oral surgery, with particular emphasis on micro- and macronutrients and their impact on the oral microbiome. A review of the research will help define optimal dietary recommendations for patients undergoing surgical interventions and identify potential risks associated with improper nutrition.

Material and methods

A literature review was conducted based on scientific articles from the PubMed and ResearchGate databases, published between 2014 and 2025. The analysis included clinical studies and systematic reviews on the role of micro- and macronutrients in the wound healing process following oral surgery. Studies examining the influence of oral microbiota on inflammatory processes and the effectiveness of diets supporting tissue regeneration were also considered. The literature search was performed using specific keywords, such as *diet, wound healing, oral surgery, micronutrients, macronutrients, tissue regeneration, and oral health.*

Description of the state of knowledge

The wound healing process following surgical procedures in the oral cavity is influenced by multiple factors, including the adequate supply of essential nutrients [5,13]. Both micro- and macronutrients play a crucial role in tissue regeneration by participating in collagen synthesis,

angiogenesis, and the regulation of inflammatory responses [5]. Additionally, dietary habits impact the oral microbiome, which can either support or disrupt reparative processes [5,7,14].

The role of microelements in oral tissue regeneration

Vitamins and minerals are essential components that play a crucial role in the wound healing process by regulating the inflammatory response, stimulating collagen synthesis, supporting cell proliferation, and modulating the immune system [5–7,10].

Vitamin A supports epithelial cell proliferation and proper immune function [5]. It participates in epithelialization, collagen biosynthesis, and the formation of new connective tissue [5,15]. A deficiency of this vitamin can lead to delayed wound regeneration and a weakened immune barrier, increasing the risk of infections. Moreover, vitamin A supplementation may counteract the negative effects of corticosteroid therapy, which impairs the body's repair processes [5,7,15].

B vitamins act as cofactors in numerous enzymatic reactions related to cellular metabolism, fibroblast proliferation, and leukocyte function [5,7].

Vitamin	**Function**
Vitamin B1 (Thiamine)	Supports cellular energy metabolism involved in the healing process.
Vitamin B2 (Riboflavin)	Influences cell migration and differentiation as well as collagen synthesis.
Vitamin B6 (Pyridoxine)	Participates in amino acid metabolism necessary for tissue regeneration.
Vitamin B9 (Folic Acid)	Supports cell proliferation and DNA synthesis. A deficiency is associated with an increased risk of oral inflammation.
Vitamin B12 (Cobalamin)	Involved in red blood cell production and protein synthesis, which are crucial for proper wound vascularization.

Table 1. The role of B vitamins in the human body [5,7,16].

Vitamin C plays a fundamental role in the entire tissue regeneration process, from the initiation of the inflammatory response and cell proliferation to the structural reconstruction of damaged tissues [7,17]. Ascorbic acid is essential for collagen production, a key component of the extracellular matrix and connective tissue [7]. It supports the activity of enzymes responsible for collagen fiber stabilization, enhancing their mechanical strength [7,18]. An insufficient amount of vitamin C results in weakened collagen structure, leading to poorer scar quality and prolonged healing time [7,19].As a powerful antioxidant, vitamin C neutralizes harmful reactive oxygen species (ROS), which can cause oxidative stress in the wound area [7,20,21]. It also regulates pro-inflammatory cytokines, promoting a faster transition to the reparative phase [7]. Moreover, vitamin C facilitates angiogenesis by stimulating endothelial cell proliferation, thereby improving oxygen and nutrient supply to regenerating tissues [7]. It also enhances fibroblast migration, contributing to more efficient tissue repair [7].Topical applications of vitamin C, such as gels or coatings on dental implants, may support implant integration with bone and aid periodontal regeneration [7,9]. In smokers, who are more susceptible to oxidative stress and oral tissue degeneration, vitamin C supplementation may help reduce tissue damage and improve repair processes [7].

Vitamin D plays a multifunctional role in regenerative processes, affecting the immune system, mineral metabolism, and the proliferation of epithelial and bone cells [7]. It exhibits immunomodulatory effects by activating macrophages and monocytes while simultaneously reducing excessive production of pro-inflammatory cytokines, such as TNF-α and IL-6, which may contribute to chronic inflammation and delayed healing [7,8]. Another critical function of vitamin D is its role in angiogenesis through the regulation of vascular endothelial growth factor (VEGF) expression, which improves blood supply and accelerates the restoration of damaged structures. This mechanism is particularly important in implantology and alveolar bone reconstruction procedures [7,22]. Vitamin D also regulates the intestinal absorption of calcium and phosphorus, maintaining their optimal levels in the body, which is essential for proper bone and tooth mineralization [7,22]. A deficiency in vitamin D weakens bone structure and increases the risk of bone resorption, potentially impairing proper dental implant integration [6–8]. Additionally, low vitamin D levels have been associated with more severe periodontal diseases and an increased susceptibility to bacterial infections, negatively affecting overall oral health [7,23].

Vitamin E functions primarily as an antioxidant, protecting cell membranes from oxidative damage [7]. However, its role in tissue regeneration remains unclear—some studies suggest that it may reduce inflammation and minimize scar formation, while others have not demonstrated a significant impact on repair processes [7,24].

Vitamin K is crucial in blood coagulation mechanisms, which is particularly important in the initial phases of wound healing [7]. A deficiency in this vitamin can lead to prolonged bleeding time and an increased risk of postoperative complications [7,23].

The role of minerals in oral tissue regeneration

Minerals are a key element in the process of tissue reconstruction after surgical interventions in the oral cavity. Their role includes influencing blood clotting, cell proliferation, inflammation regulation, and bone mineralization [7,17]. Iron is particularly significant, as it is a component of hemoglobin responsible for oxygen transport to regenerating tissues [7,25]. Deficiencies of this element can lead to hypoxia, weakened collagen synthesis, and prolonged healing time [7,17,25]. Additionally, iron participates in the activation of enzymes that stabilize the extracellular matrix, which affects proper connective tissue regeneration [7,25].

Zinc also plays a crucial role in the healing process by supporting fibroblast proliferation, DNA and RNA synthesis, and regulating immune response [7,25,26]. It is involved in activating macrophages and neutrophils, facilitating the removal of dead cells and pathogens from the wound site [7,25,26]. Zinc deficiency can impair the body's defense mechanisms, increasing susceptibility to infections and slowing down tissue regeneration [7,17,25,26].

Calcium is essential for blood clotting mechanisms and the activation of growth factors responsible for angiogenesis and fibroblast migration [7,22,27]. It supports the proliferation of epithelial cells and fibroblasts, contributing to effective tissue repair [7,13,22,28]. Magnesium also plays an important role in regeneration by stabilizing cell membranes, supporting mitochondrial function, and participating in the regulation of inflammatory responses [7]. Magnesium deficiency can lead to excessive secretion of pro-inflammatory cytokines, resulting in prolonged inflammation and delayed healing [7].

Phosphorus, as a key element of cellular metabolism, is involved in ATP synthesis, which provides energy for intensive regenerative processes [7,27,29]. Its role in bone and tooth mineralization is particularly significant after extractions and implant procedures [7,29].

Adequate intake of this element supports bone tissue reconstruction, potentially shortening recovery time and improving surgical treatment outcomes [7,27,29].

The role of macronutrients in oral tissue regeneration

Macronutrients such as proteins, fats, and carbohydrates play a fundamental role in the regenerative processes following oral surgery. They provide both energy and essential building materials needed for the reconstruction of damaged tissues. Adequate intake of these nutrients can accelerate repair processes and reduce the risk of complications [1,30].

Proteins and their importance in tissue regeneration

Proteins are a primary structural component of newly forming tissues and are essential at every stage of wound healing. In the body, they break down into amino acids, which are then used in the synthesis of collagen, elastin, and other proteins forming the extracellular matrix [10,12,31]. Proline and glycine are particularly important for regeneration as key amino acids in collagen synthesis, which ensures the stability and elasticity of newly formed tissue [31,32].Arginine is another crucial amino acid involved in the synthesis of nitric oxide, a substance that promotes angiogenesis—the formation of new blood vessels. It also supports fibroblast and epithelial cell proliferation, significantly accelerating wound healing [10,31,32]. Glutamine, on the other hand, plays an immunomodulatory and antioxidant role, stabilizing cell membranes and protecting them from oxidative stress [10,31,32]. Insufficient protein intake can slow down regeneration, weaken the structure of newly formed tissues, and increase the risk of infections [31].

Fats as regulators of inflammatory and structural processes

Fats play a vital role in tissue regeneration by providing energy and serving as key components of cell membranes [33]. Omega-3 and omega-6 fatty acids are particularly important as they influence the body's inflammatory response [34]. Omega-3 fatty acids, found in fish and plant oils, have anti-inflammatory properties and support the synthesis of lipid mediators such as resolvins and protectins, accelerating the healing process [33]. Omega-6 fatty acids, though often considered pro-inflammatory, are crucial in the early phase of wound healing by supporting the production of prostaglandins and leukotrienes [33]. The

right balance between omega-3 and omega-6 fatty acids can contribute to more effective healing by minimizing excessive inflammation while maintaining proper immune defense mechanisms [34]. Excessive consumption of saturated fats, commonly found in highly processed foods and animal products, may negatively impact tissue regeneration. High intake of these fats promotes chronic inflammation and increases the production of cytokines such as TNF-α and IL-6, potentially slowing down repair processes [35].

The ketogenic diet, characterized by minimal carbohydrate intake and high fat consumption, was initially developed as a treatment for drug-resistant epilepsy but has gained popularity due to its benefits in weight loss and blood glucose control [7,36,37]. However, significant carbohydrate restriction may negatively affect cells involved in regeneration, particularly fibroblasts, which rely on glucose as their primary energy source [36,37]. Glucose deficiency leads to reduced activity of the pentose phosphate pathway, resulting in lower NADPH production—an essential factor in oxidative stress neutralization and collagen synthesis [36–38].The state of ketosis, in which the body uses ketones as its main energy source, can have both positive and negative effects on healing [36,37]. Ketones exhibit certain immunomodulatory properties, but in some cases, they can increase the production of pro-inflammatory cytokines such as IL-6 and TNF-α, prolonging tissue regeneration time [36–38]. Additionally, the high saturated fat content in the ketogenic diet has been linked to increased chronic inflammation, which may inhibit angiogenesis and epithelial regeneration [36,38]. Studies on animal models indicate that a ketogenic diet may also negatively affect the oral microbiome and salivary gland function [12,36]. In animals consuming a high-fat diet, degenerative changes were observed in the submandibular glands and reduced saliva production, potentially disrupting the oral microbiome balance and increasing the risk of infections [12,36]. Furthermore, wound closure was slower in ketogenic diet groups compared to control groups, suggesting that carbohydrate restriction and high fat intake may impair fibroblast proliferation and the quality of newly formed tissue. While the ketogenic diet offers certain metabolic benefits, its impact on regenerative processes still requires further research. Limiting glucose intake and consuming high amounts of fats may affect the body's ability to repair tissues, especially in the context of post-surgical oral wound healing [7,12,36,39].

Carbohydrates as an energy source for regenerative processes

Carbohydrates play a crucial role as the primary energy source for cells involved in wound healing [40,41]. An adequate carbohydrate intake supports fibroblast proliferation, enhances

leukocyte activity, and stimulates the production of growth factors, including insulin, which is essential for the proliferative phase of healing [32,40].The distinction between simple and complex carbohydrates significantly influences repair processes [40,41]. Excessive intake of simple sugars can cause hyperglycemia, leading to impaired granulocyte function and increased inflammation [41]. Conversely, complex carbohydrates such as fiber and starch support the gut microbiome and stabilize blood glucose levels, facilitating better regulation of regenerative mechanisms [11]. A fiber-rich diet may further accelerate healing by influencing gut flora and its metabolites, such as short-chain fatty acids (SCFAs), which have anti-inflammatory effects and stimulate fibroblast and keratinocyte proliferation [11,40]. Animal studies suggest that increased fiber intake accelerates wound closure and enhances the production of cytokines responsible for angiogenesis and collagen synthesis [40].

Diet and oral microbiota composition

The oral microbiome plays a crucial role in maintaining biological balance and supporting tissue repair processes [42]. It consists of hundreds of bacterial, fungal, and viral species that form a complex community colonizing the mucous membranes, teeth, and tongue [43]. A well-balanced diet promotes the maintenance of a healthy microbiota, whereas unfavorable dietary habits can lead to dysbiosis, resulting in increased inflammation and slower tissue regeneration [44]. A high intake of simple sugars promotes the proliferation of cariogenic bacteria such as *Streptococcus mutans* and *Lactobacillus*, which contribute to dental caries and gingival inflammation [44]. Excessive consumption of simple carbohydrates facilitates bacterial biofilm accumulation and excessive acid production, accelerating enamel demineralization and weakening tooth structure [45]. In contrast, a diet rich in polyphenols, found in products such as green tea, cocoa, red wine, and fruits, exhibits anti-inflammatory and bacteriostatic properties [46]. Studies suggest that these compounds may inhibit the growth of pathogenic microorganisms by preventing biofilm formation and modulating cytokine activity associated with inflammation [47]. Regular consumption of polyphenol-rich foods may contribute to improved oral health by reducing inflammation and lowering the risk of periodontal disease [48]. Another factor supporting oral microbiome health is the presence of probiotics and prebiotics in the diet [49,50]. Strains such as *Lactobacillus reuteri*, *Lactobacillus brevis*, and *Streptococcus salivarius* may inhibit the growth of pathogenic microorganisms, reducing the risk of gingival inflammation and fungal infections [45,50]. Studies have shown that probiotic supplementation or the regular intake of fermented foods

may restore the balance of the oral microbiota, thereby promoting regenerative processes following dental procedures [50,51]. Restrictive diets, such as the ketogenic diet, may negatively impact the oral microbiome by altering bacterial composition [37,52,53]. Reducing carbohydrate intake while increasing fat consumption can lead to an overgrowth of *Streptococcus* species and a decline in nitrate-reducing microorganisms such as *Haemophilus, Prevotella*, and *Neisseria* [52]. Disruptions in these processes may have consequences for nitric oxide metabolism, blood pressure regulation, and indirectly affect tissue regeneration rates and mucosal health [37,48,52].

Conclusions

Proper nutrition plays a key role in the wound healing process following oral surgical procedures. Adequate intake of micro- and macronutrients supports tissue repair, regulates inflammatory responses, and contributes to efficient collagen synthesis. Vitamins A, C, and D, along with minerals such as zinc, calcium, and iron, are essential for immune function, angiogenesis, and bone regeneration. Deficiencies in these nutrients may slow healing and increase infection risk. Macronutrients, including proteins and omega-3 fatty acids, promote cellular regeneration, while carbohydrates provide the necessary energy for reparative processes.Diet also significantly influences the oral microbiome, which can either support or hinder tissue healing. The inclusion of prebiotics and probiotics in the diet may foster the growth of beneficial microbiota and reduce the risk of inflammation. Conversely, excessive consumption of simple sugars can lead to dysbiosis, negatively affecting oral health. Certain dietary patterns, such as the ketogenic diet, may alter microbiota composition and slow tissue regeneration. However, further research is needed to better understand the long-term effects of the ketogenic and other restrictive diets on tissue repair and overall oral health.

Disclosure:

Author's Contribution Statement:

Conceptualization: Jakub Rybowski, Sylwia Krzyśkowska, Kamil Dziekoński;
Methodology: Jakub Rybowski, Sylwia Krzyśkowska;
Writing - rough preparation: Jakub Rybowski, Julia Głowacz, Maciej Szczupaj,Michał Popiel;
Writing - review and editing: Jakub Rybowski, Sylwia Krzyśkowska,Kamil Dziekoński,Michał Popiel, Julia Głowacz;
Project administration: Jakub Rybowski, Maciej Szczupaj, Julia Głowacz, Michał Popiel;

All authors have read and agreed with the published version of the manuscript.

Funding Statement: The study did not receive special funding.

References

1. Giridhar Vu. Role of nutrition in oral and maxillofacial surgery patients. Natl. J. Maxillofac. Surg. 2016;7:3.
2. Wziątek-Kuczmik D, Wieczorek M, Rymarczyk M, Świątkowski A, Rogulski M, Niedzielska I. Interdyscyplinarna opieka nad chorymi po zabiegach z zakresu chirurgii szczękowo-twarzowej. Chir. Pol. 2023;24:1–9.
3. Jain S, Jain A, Palekar U, Shigli K, Pillai A, Pathak AD. Nutritional considerations for patients undergoing maxillofacial surgery – A literature review. Indian J. Dent. 2014;5:52–5.
4. Chu Y, Kong J, Xu J, Han G, Yu W, Xu X. Role of nutritional support in nursing practice for improving surgical site wound healing in patients post-surgery with risk of pressure ulcers. Int. Wound J. 2024;21:e14855.
5. Paine H, Jones F, Kinross J. Preparing the Bowel (Microbiome) for Surgery: Surgical Bioresilience. Clin. Colon Rectal Surg. 2023;36:138–45.
6. Aghaloo T. How Important Is Nutrition in Oral and Maxillofacial Surgery? J. Oral Maxillofac. Surg. 2023;81:1321–2.
7. Strączek A, Szałkowska J, Sutkowska P, Srebrna A, Puzio N, Piasecka A, et al. Impact of nutrition on the condition of the oral mucosa and periodontium: A narrative review. Dent. Med. Probl. 2023;60:697–707.
8. Razzaghi R, Pourbagheri H, Momen-Heravi M, Bahmani F, Shadi J, Soleimani Z, et al. The effects of vitamin D supplementation on wound healing and metabolic status in patients with diabetic foot ulcer: A randomized, double-blind, placebo-controlled trial. J. Diabetes Complications 2017;31:766–72.
9. Shimabukuro Y, Nakayama Y, Ogata Y, Tamazawa K, Shimauchi H, Nishida T, et al. Effects of an Ascorbic Acid–Derivative Dentifrice in Patients With Gingivitis: A Double-Masked, Randomized, Controlled Clinical Trial. J. Periodontol. 2015;86:27–35.
10. Barchitta M, Maugeri A, Favara G, Magnano San Lio R, Evola G, Agodi A, et al. Nutrition and Wound Healing: An Overview Focusing on the Beneficial Effects of Curcumin. Int. J. Mol. Sci. 2019;20:1119.

11. Tanes C, Bittinger K, Gao Y, Friedman ES, Nessel L, Roy Paladhi U, et al. Role of dietary fiber in the recovery of the human gut microbiome and its metabolome. Cell Host Microbe 2021;29:394-407.e5.
12. Aboulfotoh MM. The effects of ketogenic and chitosan-based diets on submandibular salivary gland in rat model: a comparative histological study. BMC Oral Health 2024;24:153.
13. Ghaly P, Iliopoulos J, Ahmad M. The role of nutrition in wound healing: an overview. Br. J. Nurs. 2021;30:S38–42.
14. Herberger K, Müller K, Protz K, Zyriax B, Augustin M, Hagenström K. Nutritional status and quality of nutrition in chronic wound patients. Int. Wound J. 2020;17:1246–54.
15. Polcz ME, Barbul A. The Role of Vitamin A in Wound Healing. Nutr. Clin. Pract. 2019;34:695–700.
16. Sun Y, Sun M, Liu B, Du Y, Rong S, Xu G, et al. Inverse Association Between Serum Vitamin B12 Concentration and Obesity Among Adults in the United States. Front. Endocrinol. 2019;10:414.
17. Hajj J, Sizemore B, Singh K. Impact of Epigenetics, Diet, and Nutrition-Related Pathologies on Wound Healing. Int. J. Mol. Sci. 2024;25:10474.
18. Pullar J, Carr A, Vissers M. The Roles of Vitamin C in Skin Health. Nutrients 2017;9:866.
19. Gunton JE, Girgis CM, Lau T, Vicaretti M, Begg L, Flood V. Vitamin C improves healing of foot ulcers: a randomised, double-blind, placebo-controlled trial. Br. J. Nutr. 2021;126:1451–8.
20. Bechara N, Flood VM, Gunton JE. A Systematic Review on the Role of Vitamin C in Tissue Healing. Antioxidants 2022;11:1605.
21. Muniz FWMG, Nogueira SB, Mendes FLV, Rösing CK, Moreira MMSM, De Andrade GM, et al. The impact of antioxidant agents complimentary to periodontal therapy on oxidative stress and periodontal outcomes: A systematic review. Arch. Oral Biol. 2015;60:1203–14.
22. Oda Y, Tu CL, Menendez A, Nguyen T, Bikle DD. Vitamin D and calcium regulation of epidermal wound healing. J. Steroid Biochem. Mol. Biol. 2016;164:379–85.
23. Aral K, Alkan BA, Saraymen R, Yay A, Şen A, Önder GÖ. Therapeutic Effects of Systemic Vitamin K2 and Vitamin D3 on Gingival Inflammation and Alveolar Bone in Rats With Experimentally Induced Periodontitis. J. Periodontol. 2015;86:666–73.

24. Tanaydin V, Conings J, Malyar M, Van Der Hulst R, Van Der Lei B. The Role of Topical Vitamin E in Scar Management: A Systematic Review. Aesthet. Surg. J. 2016;36:959–65.
25. Lynch RJM, Duckworth RM. Chapter 4: Microelements: Part I: Zn, Sn, Cu, Fe and I [Internet]. In: Zohoori FV, Duckworth RM, editors. Monographs in Oral Science. S. Karger AG; 2020 [cited 2025 Feb 28]. page 32–47.Available from: https://karger.com/books/book/335/chapter/5520979
26. Lin PH, Sermersheim M, Li H, Lee PHU, Steinberg SM, Ma J. Zinc in Wound Healing Modulation. Nutrients 2017;10:16.
27. Lippert F. Chapter 3: Macroelements: Ca, Na, K, P, Cl. Monogr. Oral Sci. 2020;28:22–31.
28. Najeeb S, Zafar M, Khurshid Z, Zohaib S, Almas K. The Role of Nutrition in Periodontal Health: An Update. Nutrients 2016;8:530.
29. Błaszczyk JW. Metabolites of Life: Phosphate. Metabolites 2023;13:860.
30. Molnar JA, Underdown MJ, Clark WA. Nutrition and Chronic Wounds. Adv. Wound Care 2014;3:663–81.
31. Watford M, Wu G. Protein. Adv. Nutr. 2018;9:651–3.
32. Arribas-López E, Zand N, Ojo O, Snowden MJ, Kochhar T. The Effect of Amino Acids on Wound Healing: A Systematic Review and Meta-Analysis on Arginine and Glutamine. Nutrients 2021;13:2498.
33. Jara CP, Mendes NF, Prado TPD, De Araújo EP. Bioactive Fatty Acids in the Resolution of Chronic Inflammation in Skin Wounds. Adv. Wound Care 2020;9:472–90.
34. Coniglio S, Shumskaya M, Vassiliou E. Unsaturated Fatty Acids and Their Immunomodulatory Properties. Biology 2023;12:279.
35. Astrup A, Teicholz N, Magkos F, Bier DM, Brenna JT, King JC, et al. Dietary Saturated Fats and Health: Are the U.S. Guidelines Evidence-Based? Nutrients 2021;13:3305.
36. Hew JJ, Parungao RJ, Mooney CP, Smyth JK, Kim S, Tsai KHY, et al. Low-protein diet accelerates wound healing in mice post-acute injury. Burns Trauma 2021;9:tkab010.
37. Woelber JP, Tennert C, Ernst SF, Vach K, Ratka-Krüger P, Bertz H, et al. Effects of a Non-Energy-Restricted Ketogenic Diet on Clinical Oral Parameters. An Exploratory Pilot Trial. Nutrients 2021;13:4229.
38. Arsyad A, Idris I, Rasyid AA, Usman RA, Faradillah KR, Latif WOU, et al. Long-Term Ketogenic Diet Induces Metabolic Acidosis, Anemia, and Oxidative Stress in Healthy

Wistar Rats. J. Nutr. Metab. 2020;2020:1–7.

39. Arnke K, Pfister P, Reid G, Vasella M, Ruhl T, Seitz AK, et al. Impact of a High-Fat Diet at a Young Age on Wound Healing in Mice. Int. J. Mol. Sci. 2023;24:17299.
40. Canesso MCC, Cassini-Vieira P, Moreira CF, Luong S, Rachid MA, Martins FS, et al. Dietary Fiber Improves Skin Wound Healing and Scar Formation through the Metabolite-Sensing Receptor GPR43. J. Invest. Dermatol. 2023;143:1850-1854.e6.
41. Puddu PE, Menotti A. Simple versus complex carbohydrates and health: A frequently neglected problem. Nutr. Metab. Cardiovasc. Dis. 2021;31:1949–52.
42. Lamont RJ, Koo H, Hajishengallis G. The oral microbiota: dynamic communities and host interactions. Nat. Rev. Microbiol. 2018;16:745–59.
43. Cugini C, Ramasubbu N, Tsiagbe VK, Fine DH. Dysbiosis From a Microbial and Host Perspective Relative to Oral Health and Disease. Front. Microbiol. 2021;12:617485.
44. Esberg A, Haworth S, Hasslöf P, Lif Holgerson P, Johansson I. Oral Microbiota Profile Associates with Sugar Intake and Taste Preference Genes. Nutrients 2020;12:681.
45. Liu Z, Guo H, Zhang W, Ni L. Salivary Microbiota Shifts under Sustained Consumption of Oolong Tea in Healthy Adults. Nutrients 2020;12:966.
46. Musarra-Pizzo M, Ginestra G, Smeriglio A, Pennisi R, Sciortino MT, Mandalari G. The Antimicrobial and Antiviral Activity of Polyphenols from Almond (Prunus dulcis L.) Skin. Nutrients 2019;11:2355.
47. Tsou SH, Hu SW, Yang JJ, Yan M, Lin YY. Potential Oral Health Care Agent from Coffee against Virulence Factor of Periodontitis. Nutrients 2019;11:2235.
48. Cueva C, Silva M, Pinillos I, Bartolomé B, Moreno-Arribas MV. Interplay between Dietary Polyphenols and Oral and Gut Microbiota in the Development of Colorectal Cancer. Nutrients 2020;12:625.
49. Yadav MK, Kumari I, Singh B, Sharma KK, Tiwari SK. Probiotics, prebiotics and synbiotics: Safe options for next-generation therapeutics. Appl. Microbiol. Biotechnol. 2022;106:505–21.
50. Ferrillo M, Giudice A, Migliario M, Renó F, Lippi L, Calafiore D, et al. Oral–Gut Microbiota, Periodontal Diseases, and Arthritis: Literature Overview on the Role of Probiotics. Int. J. Mol. Sci. 2023;24:4626.
51. Mahasneh S, Mahasneh A. Probiotics: A Promising Role in Dental Health. Dent. J. 2017;5:26.
52. Murtaza N, Burke LM, Vlahovich N, Charlesson B, O'Neill HM, Ross ML, et al.

Analysis of the Effects of Dietary Pattern on the Oral Microbiome of Elite Endurance Athletes. Nutrients 2019;11:614.

53. Rinninella E, Raoul P, Cintoni M, Franceschi F, Miggiano GAD, Gasbarrini A, et al. What is the Healthy Gut Microbiota Composition? A Changing Ecosystem across Age, Environment, Diet, and Diseases. Microorganisms 2019;7:14.