The Use of Autogenous Teeth Tissues Grafts for Alveolar Bone Reconstruction: a Systematic Review

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ABSTRACT

Objectives: Enough bone around the implant is an important factor in ensuring the stability and longevity of the implant. Therefore, alveolar bone regeneration procedures are often required. A relatively new bone substitute is made from autogenous teeth. There are more and more studies in the scientific literature that perform regenerative alveolar bone procedures using autogenous tissues substitutes made from extracted teeth. The objective of this systematic literature review is to systematize information and present conclusions about the effectiveness of this regenerative material.
Material and Methods: Scientific articles were selected using the PRISMA recommendations. Publications have been carried out since January 1, 2012 to January 1, 2022. The review includes articles in English, clinical studies in humans who underwent bone augmentation prior to or during dental implantation using an autogenous teeth tissues substitute.
Results: A total of 7 publications were included in this systematic literature review. Summarizing the data of the publications, 258 patients participated in the studies, 240 subjects were included in the results for various reasons, and a total of 298 implants were inserted. No statistically significant results were found in the five studies. Two studies comparing autogenous tooth graft with xenogeneic bone graft and autogenous teeth tissues showed statistically significant positive results in autogenous tooth group.
Conclusions: Within the limitations of this study, autogenous tissues graft derived from teeth are an effective material and can be used as an alternative to other bone grafts existing on the market. Further studies with a longer follow-up period are needed to validate these findings.

Keywords: alveolar ridge augmentation; bone grafting; bone substitute; dental implant; dental implantation; tooth extraction.

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INTRODUCTION

After tooth extraction, the resorption of alveolar process is highest during the first three months and reaches up to 50% of bone volume [1]. According to various authors [2,3] mean horizontal reduction in width of 3.8 mm and a mean vertical reduction in height of 1.24 mm occurs within 6 months after tooth extraction.

The amount of bone lost during extraction socket healing has a direct effect on the stability and longevity of the implant, so sufficient bone around the implant is one of the most important factors in ensuring the success of prosthetic rehabilitation. Reconstruction procedures for alveolar bone restoration may be performed to create sufficient bone. The efficacy of the bone substitute used is critical to the success of these procedures. At present, the 'gold standard' is an autogenous bone substitute that is taken from the patient and transplanted to the site of the defect. Despite its efficacy, autogenous bone substitute often causes significant postoperative discomfort to the patient, as well as an increased risk of infection at the donor site [4]. Inorganic or organic deproteinized, bone substitutes derived from bovine bone are often used as an alternative. These substitutes are well documented, osteoconductive, and biocompatible [5]. However, the use of bone substitutes derived from bovine remains at risk of transmitting prion disease [6]. As an alternative to regenerative alveolar bone reconstruction procedures, synthetic bone substitutes may be used.

Another autogenous bone substitute that is prepared from the patient's own extracted tooth has relatively recently appeared. The patient's tooth can be used without further processing, but only by removing mechanically the cement and enamel or by removing the cement and enamel layer by additional acid treatment and demineralization [6]. The most important part of a tooth for regeneration is dentin, which is very similar in its chemical properties and proportions to natural human bone [7]. The ratio of organic to inorganic tissue in the dentin is 25% and 62%, respectively, while the ratio of organic to inorganic tissue in the alveolar process of the jaw is 17.5% and 69%, respectively [8]. Both dentin and alveolar bone are largely composed of type I collagen fibres, and non-collagenous structural proteins, such as osteocalcin, osteonectin, phosphoprotein, and sialoprotein. Osteogenetic growth factors are also found - bone morphogenetic factor (BMP), transforming growth factor beta (TGF-β), insulin-like growth factor (IGF-2) [9,10]. Inorganic substances in the dentin and alveolar process of the jawbone are also almost identical [11]. It is important to note that dentin also has osseoinductive and osseoconductive properties and has been shown to successfully promote new bone formation in animal studies [12,13]. Substitutions from autogenous dentin also successfully promote implant osseointegration [14].

There is a growing number of studies in the scientific literature on the regeneration procedures of alveolar jawbone using an autogenous bone substitute produced from the teeth. However, it is still relevant to compare the efficacy of autogenous teeth tissues graft and autogenous bone and its substitutes used in clinical practice for augmentation of the alveolar ridge before or during dental implantation. It is also important to find out whether the transplantation of autogenous teeth tissues does not cause more complications than usual. The objective of the present systematic review is therefore to test the hypothesis that the bone substitutes derived from teeth are a suitable and effective material for alveolar jawbone reconstruction procedures.

MATERIAL AND METHODS

Protocol and registration

The current systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement for reporting systematic reviews [15]. This systematic review was registered in PROSPERO register under number CRD42022332476.

The protocol can be accessed at:
https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022332476

The local bioethics committee granted approval (No. BCE-OF-98) by the Department of Bioethics, Medical Academy Lithuanian University of Health Sciences Lithuania.

Focus question

The focus question was developed according to the Patient, Intervention, Comparison and Outcome (PICOS) framework as described in Table 1.

The focus question: Are autogenous bone substitutes produced from teeth a suitable and effective substance to restore the insufficient alveolar process of jawbone compared to other known bone substitutes?

Information sources

A MEDLINE (PubMed) and ScienceDirect databases search was conducted. Human studies published

Table 1. PICOS framework of the framed clinical question

Component	Description
Population (P)	Patients with insufficient alveolar process volume requiring dental implantation
Intervention (I)	Reconstructive procedures for alveolar jawbone using autogenous bone substitute produced from teeth in either particulate form or block form
Comparison (C)	Reconstruction of alveolar process using autogenous and other bone substitutes available on the market
Outcome (O)	Changes in the height and width of the alveolar process, the potential for new bone formation, implant stability, resorption of the bone substitute, possible complications during postoperative period
Study design	Randomized clinical trials, prospective studies and retrospective studies assessing alveolar bone reconstruction procedures with an autogenous bone substitute produced from teeth compared with other bone substitutes available on the market

in English between January 1, 2012 and January 1, 2022 were included. Grey literature, unpublished literature as well as other databases like Scopus, Google Scholar, or Research Gate were not included in the search strategy of the present systematic review.

Search

A thorough electronic search was carried out according to the PRISMA guidelines to determine the relevant studies [15]. The primary search inquiries used were: (["Root Graft"] OR ["Autogenous Tooth"] OR ["Tooth Root Graft"] OR ["Tooth Root"] OR ["Autogenous Dentin"]) AND (["Sinus Floor Augmentation"] OR ["Alveolar Ridge Augmentation"] OR ["Socket Augmentation"] OR ["Bone Regeneration"]).

Selection of studies

The titles of the identified reports were independently screened by two reviewers (G.P. and V.P.) based on the inclusion criteria. A third reviewer (G.J.) checked possible mistyping. The summary was evaluated when the title indicated that the study was relevant to the search topic. Full-text analysis was obtained for those with obvious relevance. The reviewers compared results and resolved differences through discussion, consulting senior researcher (G.J.) when consensus could not be reached. Reviewers were calibrated calculating inter-rater reliability Cohen's kappa coefficient (κ) values for title-abstract screening.

Types of publication

Human studies published in the English language were considered in the review. Letters, editorials, PhD theses, and abstracts were excluded.

Types of studies

The review included randomized clinical trials, prospective studies and retrospective studies assessing alveolar bone reconstruction procedures with an autogenous bone substitute produced from teeth compared with other bone substitutes available on the market published between January 1, 2012 and January 1, 2022.

Type of population

Patients with insufficient alveolar process volume requiring dental implantation.

Inclusion and exclusion criteria

Inclusion criteria for the selection

The following inclusion criteria were assessed for selection of articles:
Criteria for the study:

- Clinical trials conducted with humans, articles not older than 10 years, articles written in English.
- Studies in which horizontal alveolar process augmentation, alveolar process contour augmentation, maxillary sinus floor augmentation, or extraction socket augmentation after tooth extraction using autogenous bone substitute produced from teeth in either particulate form or block form have been performed. Other bone substitutes may be used in control groups.
- Patient jawbone reconstructive procedures were performed before or during implantation.
- Autogenous bone substitute produced from teeth may be used alone or in combination with other substitutes or membranes.
- The effectiveness of the procedure have been assessed using any of the following diagnostic methods: computed tomography, panoramic imaging, histological or histomorphometric analysis.
- Any of the following criteria have been evaluated: postoperative period, implant stability, changes in alveolar width and height dimensions, complications.

Criteria for study participants:

- Studies including at least 10 patients, who are healthy and free of systemic disease, over 18 years of age, undergoing dental implantation and reconstruction of alveolar process (horizontal alveolar process augmentation, alveolar process contour augmentation, maxillary sinus floor augmentation, extraction socket augmentation after tooth extraction).

Exclusion criteria for the selection

The following exclusion criteria were as follows:

- Animal studies, single case or case series studies, technical notes.
- Studies that do not mention the medical condition of the patients.
- Studies in which only the reconstruction of alveolar process without implantation was performed on the patients.

Sequential search strategy

The selection of articles was done in two stages. During the first stage of the search, the titles and abstracts of the publications were reviewed, and articles that were suitable for present review were selected. Duplicate articles were excluded, as well as articles that did not meet the selection criteria. In the second stage, full-text publications were analysed, and publications that did not meet the established selection criteria were excluded. Finally, the literature sources of the publications selected for the systematic literature review were reviewed to find potential publications that were not identified during the initial search.

Data extraction

The data was extracted independently from studies in the form of variables, in accordance with the present review's aims and themes that are described below. If the essential data was missing, the corresponding authors were contacted by electronic mail.

Data items

The following study data were searched in the selected publications:

- "Authors" and "Year of publication" - revealed the author and the publication year.
- "Number of subjects" - indicated the number of the investigated subjects.
- "Number of implants" - indicated the number of dental implants that were placed.
- "Jawbone reconstruction procedure" - indicated alveolar process augmentation method and localization.
- "Bone regenerative materials" - autogenous bone, autogenous bone substitute produced from teeth, bone plastic materials.
- "Type of implantation" - dental implant placement operation timing: immediate, delayed, late.
- "Follow-up period" - indicates the outcomes follow-up period in months.
- "Evaluation methods" - describes the tool which was used to investigate the outcome of jawbone regeneration procedure and implant stability.
- "Outcomes" - relates to the radiographic, computed tomography, implant stability test, histomorphometric and histological results after jawbone regeneration and dental implant installation procedures.

Assessment of methodological quality

To assess the quality of the included randomized clinical trials and identify possible bias, Cochrane Collaboration's Tool for assessing risk of bias was used [16]. The risk of bias for each selected publication was assessed according to the following parameters:

- Random sequence generation (-/+/?).
- Allocation concealment (-/+/?).
- Blinding of participants and personnel (-/+/?).
- Blinding of outcomes assessment (-/+/?).
- Incomplete outcome data (-/+/?).
- Selective reporting (-/+/?).

Methodological quality was categorized as follows: "low risk" if all criteria were met, "high risk" if one or more criteria were not met, and "unknown risk" when too few details were available for classification as high or low risk.

Newcastle-Ottawa scale was used for non-randomized studies to evaluate included studies on selection of studies, comparability of cohorts, and the ascertainment of either the exposure or outcome of interest [17]. Included non-randomized studies were categorized as low-quality (0 to 3 stars), moderate quality (4 to 6 stars), and high quality (7 to 9 stars).

Statistical analysis

Meta-analysis was not performed due to heterogenic parameters and lack of data for meta-analysis. The level of agreement between the two raters in selecting abstracts and studies to be read in full text were measured using Cohen's kappa coefficient (κ).

RESULTS

Study selection

The database search yielded 279 articles in MEDLINE (PubMed) and ScienceDirect databases. There were selected 10% of publications for Kappa calculation, based on title-abstract analysis. Inter-rater reliability Cohen's kappa coefficient of 0.82 was achieved. Figure 1 illustrates a summary of the article selection process using the PRISMA flow diagram. There were 274 articles remaining after duplicates were removed. During the first selection stage, the titles and abstracts of the articles were read, and 19 articles remained after applying the selection criteria. The full-text of the publications were read during the second stage of data selection. Examination of two articles [18,19] revealed that the same subjects participated in the studies and the results of the same intervention performed on the subjects were described. For this reason, a total of 12 studies [18,20-30] were excluded after full text assessment. After applying the selection criteria, 7 publications were included in the systematic literature review [19,31-36] (Figure 1).

Exclusion of studies

The reasons for excluding 12 studies [18,20-30] are given in Table 2.

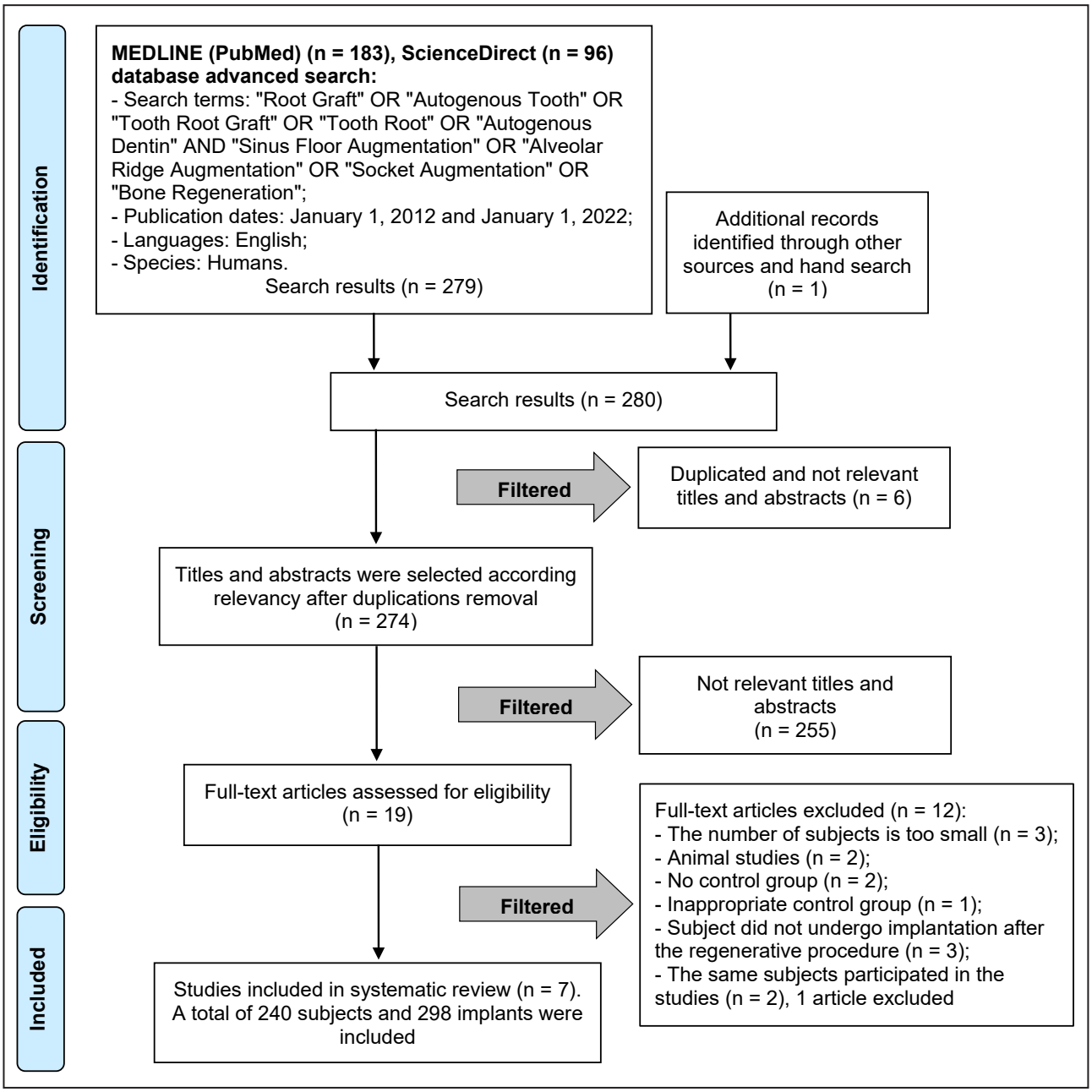

Figure 1. Flow diagram of study selection according to PRISMA guidelines.

Table 2. The reasons for rejecting articles

Study	Year of publication	Reason for rejection
Schwarz et al. [18]	2018	The same subjects participated in the 2 studies [18,19]
Li et al. [20]	2021	The number of subjects is too small
Andrade et al. [21]	2020	The number of subjects is too small
Schwarz et al. [22]	2016	The study was conducted on animals
Shejali et al. [23]	2020	No control group
Pohl et al. [24]	2016	The number of subjects is too small
Yüceer-Çetiner et al. [25]	2021	Inappropriate control group
Minamizato et al. [26]	2021	No control group
Elfana et al. [27]	2018	Subjects did not undergo implantation after the regenerative procedure
Kim et al. [28]	2021	The study was conducted on animals
Joshi et al. [29]	2016	Subjects did not undergo implantation after the regenerative procedure
Jeong et al. [30]	2014	Subjects did not undergo implantation after the regenerative procedure

Risk of bias assessment

Results of quality assessment of included studies are presented in Table 3 and 4. Pang et al. [31], Li et al. [32] and Santos et al. [33], using Cochrane Collaboration's Tool for assessing risk of bias [16], were considered low risk of bias. For evaluation of cohort studies, Newcastle-Ottawa scale [17] was used. All cohort studies [34-37] were evaluated as high-quality studies.

Characteristics of the studies included

Seven publications [19,31-36] were included in the systematic literature review (Table 5). Two publications [31,33] were randomized clinical trials, three publications [19,32,36] were prospective studies and the remaining two [34,35] were retrospective studies. Summing up patients from all studies, it was found that a total of 258 subjects were examined, and finally 240 subjects were included in the results. Study samples range from 13 to 59 subjects. Two publications [31,34] differed between the number of subjects enrolled at baseline and those included in the results, as not all subjects could be contacted within the specified follow-up period.

In the included publications, different regenerative procedures were performed: alveolar augmentation [31,32,36] maxillary sinus lift [34], horizontal alveolar augmentation [19,35] and alveolar preservation after tooth extraction [33]. Number of bone substitutes have been used for regenerative procedures: autogenous demineralized dentin [31,32,34], partially demineralized dentin [32], autogenous mineralized dentin [33], autogenous tooth root [19] and autogenous dentin [36].

Table 3. Cochrane Collaboration's risk of bias table for randomized clinical trials

Study	Year of publication	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Quality
Pang et al. [31]	2017	?	+	+	+	+	+	Low risk
Santos et al. [33]	2021	+	+	+	+	+	-	Low risk

? = unclear; + = yes; - = no.

Table 4. Newcastle-Ottawa Quality Assessment form for cohort studies

Study	Year of publication	Selection (maximum 4 stars)	Comparability (maximum 2 stars)	Outcome (maximum 3 stars)	Total score/quality
Schwarz et al. [19]	2018	★★★★	★★	★★★	9 stars/high quality
Li et al. [32]	2018	★★★★	★★	★★	8 stars/high quality
Kim et al. [34]	2014	★★★★	★★	★★	8 stars/high quality
Korsch and Peichl [35]	2021	★★★★	★★	★★	8 stars/high quality
Xiao et al. [36]	2019	★★★★	★★	★★★	9 stars/high quality

Table 5. Characteristics of the included studies

Study	No. of patient	Group/ No. of implant	Type of surgery	Graft description	Implant placement	Follow-up period
Schwarz et al. [19]	30	Tooth root: 15; Autogenous bone: 15	Lateral alveolar ridge augmentation	I group: tooth root (block); II group: autogenous bone	Staged implant placement after 26 weeks	26 weeks
Pang et al. [31]	At the beginning: 27; At the end: 24	Demineralized dentin group: 21; Bio-Oss® group: 12	Alveolar bone augmentation	I group: autogenous demineralized dentin (particulate); II group: anorganic bovine bone	Staged implant placement after 6 month	6 month
Li et al. [32]	40	Demineralized dentin group: 23; Bio-Oss® group: 22	Alveolar bone augmentation	I group: autogenous demineralized dentin (particulate): + membrane + PRF; II group: xenograft + membrane + PRF	Simultaneous implant placement	6, 18 months
Santos et al. [33]	52	Autogenous mineralized dentin: 33; Xenograft: 33	Alveolar ridge preservation	I group: autogenous mineralized dentin (particulate); II group: xenograft granules	Staged implant placement after 6 month	6, 12, 18 months
Kim et al. [34]	At the beginning: 37; At the end: 22	Demineralized dentin group: 18; Synthetic bone group: 26	Maxillary sinus floor lift	I group: autogenous demineralized dentin (particulate); II group: synthetic bone	Simultaneous, after sinus augmentation	1 year
Korsch and Peichl [35]	59	Partially demineralized dentin group: 28; Autogenous bone group: 31	Lateral alveolar ridge augmentation	I group: partially demineralized dentin (particulate); II group: autogenous bone block	Simultaneous implant placement	5 month
Xiao et al. [36]	13	Autogenous dentin: 10; Autogenous bone: 11	Alveolar bone augmentation	I group: autogenous dentin (particulate): + xenograft + collagen membrane + CGF II group: autogenous bone + xenograft + collagen membrane+ CGF	Staged implant placement after 6 month	24 weeks

PRF = platelet-rich fibrin; CGF = concentrated growth factor.

A total of 298 implants were placed in areas where regenerative procedures were performed. In four studies, the authors [19,31,33,36] performed delayed implantation after 6 months, and in the remaining three studies [32,34,35], immediate implantation. The duration of follow-up was variable in the selected studies, ranging from 6 months to 18 months.

Different examination methods have been used to determine the dimensions and quality of the grafted bone. Some researchers [19,31,33,35,36] have measured outcomes using cone beam computed tomography (CBCT), others [32,34] performed orthopantomography or dental X-rays [32,33]. In four studies [31-33,35], investigators used the Ostell™ ISQ (Integration. Diagnostics Ltd. Co.; Savedalen, Sweden) diagnostic system to assess implant stability. Some authors [31,33] performed histomorphometric analysis. In one study [33] postoperative pain was assessed using a visual analog scale (VAS). Essential information from the selected publications was collected and the data is organized in Table 5. A meta-analysis was not performed because the results of the studies were not homogeneous.

Preparation protocol of autogenous bone substitute extracted from teeth

All the studies mentioned in the literature review had a different preparation protocol for autogenous bone substitute extracted from teeth. The data and results of the publications included in the systematic literature review are summarized in Table 6.

Three studies investigated the efficacy of autogenous demineralized dentin in regenerative bone procedures [31,32,34]. Pang et al. [31], an autogenous demineralized dentin bone substitute prepared in a special laboratory at the Korea Dental Bank (KTB) by soaking the teeth in 75% alcohol and storing them in a refrigerator before transport to the laboratory. All remaining soft tissues were removed from the teeth, the teeth were ground into 300 and 800 μm particles, degreased, decalcified, lyophilized, and sterilized.

Table 6. Treatment outcomes reported in the included studies

Author	Type of surgery	Graft description	Type of result measurement	Outcomes	Complications
Schwarz et al. [19]	Lateral alveolar; ridge augmentation	Tooth root (block)	CBCT	-Gain in ridge width: tooth root 5.53 (SD 1.88) mm; bone 3.93 (SD 1.41) mm; P = 0.014 -Graft resorption: tooth root 0.13 (SD 0.97) mm; bone 1.03 (SD 1.15) mm; P = 0.029	In both groups after 26 weeks screw head was exposed in one patient, but not associated with any signs of wound infection
Pang et al. [31]	Alveolar bone augmentation	Autogenous demineralized dentin (particulate)	Resin templates and periodontal probe, histomorphometric analysis, ”Osstell™ ISQ” tool for implant stability	-Vertical bone gain: DDM 5.38 (SD 2.65) mm; Bio-Oss® 6.56 (SD 3.54) mm; P = 0.337 -Percentage of newly formed bone: DDM 31.24 (SD 13.87)%; Bio-Oss® 35 (SD 19.33)%; P = 0.606 -Percentage of residual graft material. DDM 8.95 (SD 6.15)%; Bio-Oss® 17.08 (SD 16.57)%; P = 0.245 -ISQ: DDM 72.8 (SD 10.81); Bio-Oss® 70 (SD 12.86); P = 0.755	No registered complications
Li et al. [32]	Alveolar bone augmentation	Autogenous demineralized dentin (particulate) + membrane + PRF	Panoramic and periapical radiography, ”Osstell™ ISQ” tool for implant stability	- ISQ: After surgery: Bio-Oss® 54.1 (SD 13); DDM 53.6 (SD 11.9); P = 0.14 After 6 months: Bio-Oss® 78.1 (SD 4.2); DDM 77.6 (SD 7.9); P = 0.11 After 18 months: Bio-Oss® 80.2 (SD 4.3); DDM 79.5 (SD 6); P = 0.09 - Marginal bone resorption: After 6 months: Bio-Oss® 1.8 (SD 0.1) mm; DDM 1.7 (SD 0.3) mm; P = 0.25 After 18 months: Bio-Oss® 2 (SD 0.5) mm; DDM 1.9 (SD 0.6) mm; P = 0.18	Failed osseointegration and infection in one implant in both groups
Santos et al. [33]	Alveolar ridge preservation	Autogenous mineralized dentin (particulate)	CBCT, periapical radiography, histomorphometric analysis, ”Osstell™ ISQ” tool for implant stability, “VAS” scale	- Primary ISQ: MDM 77.1 (SD 6.9); xenograft 77 (SD 5.9); P = 0.807 - Secondary ISQ after 2 months: MDM 81.8 (SD 5.1); xenograft 80.1 (SD 3.8); P = 0.054 - Percentage of newly formed bone: MDM 47.3 (SD 14.8)%; xenograft 34.9 (SD 13.2)%; P = 0.001 - Percentage of remaining bone substitute: MDM: 12.2 (SD 7.7)%; xenograft: 22.1 (SD 10.9)%; P = 0.001 - Reported pain: MDM: 10/26; xenograft: 10/26; P = 0.904	- Hematoma: MDM 26.5%; xenograft 18.8%; P = 0.596 - Dehiscence: MDM 38.2%; xenograft 46.9%; P = 0.549 - Membrane exposure: MDM 11.8%; xenograft 12.5%; P = 0.968 - Graft exposure: MDM 0%; xenograft 0%
Kim et al. [34]	Maxillary sinus floor lift	Autogenous demineralized dentin (particulate)	Panoramic radiography	- Vertical bone gain: DDM 4.89 mm; synthetic bone 6.22 mm; P = 0.46 - Bone resorption after 1 year: DDM 0.76 mm; synthetic bone 0.53 mm; P = 0.57	Failed osseointegration of one implant in synthetic bone group
Korsch and Peichl [35]	Lateral alveolar; ridge augmentation	Partially demineralized dentin block (particulate)	CBCT, ”Osstell™ ISQ” tool for implant stability	- ISQ: BST 74.7; TST 73.3 - Horizontal hard tissue loss (after 3months): BST (1 case) 0.5 mm; TST (1 case) 1 mm. - Integrity of the buccal lamella (after 3 months): TST - did not happen in most cases; BST - happen in most cases	- Wound dehiscences: BST 2 of 31; TST 1 of 28; P = 0.615 - Inflammations: BST 3 of 31; TST: 0 of 28; P = 0.091
Xiao et al. [36]	Alveolar bone augmentation	Autogenous dentin (particulate) + xenograft + collagen membrane + CGF	CBCT	- Vertical bone gain: dentin 2.91 (SD 3.75) mm; bone 2.79 (SD 3.95) mm; P = 0.886 - Vertical bone resorption: dentin 0.94 (SD 1.43) mm; bone 1.72 (SD 0.84) mm; P = 0.114 - Horizontal bone resorption at 2, 4 and 6 mm: Dentin: 2.41 (SD 2.11) mm; bone: 3.79 (SD 2.77) mm; P = 0.431 Dentin: 1.49 (SD 2.41) mm; bone: 1.94 (SD 1.84) mm; P = 0.283 Dentin: 1.2 (SD 153) mm; bone: 1 (SD 0.64) mm; P = 0.664	No registered complications

DDM = demineralized dentin matric; MDM = mineralized dentin matric; TST = tooth-shell technique; BST = bone-shell technique; CBCT = cone-beam computed tomography; ISQ = implant stability quotient.

Li et al. [32] removed the caries-damaged tissues, enamel and dentin from the extracted teeth with a dental handpiece and burs, the remaining dentin was ground into 300 to 1200 µm particles with a grinder and demineralized in 2% nitric acid solution for 20 minutes. After that, immersed in 75% alcohol and 5% peracetic acid solution for 10 minutes to remove bacteria and sticky layer. Finally, the dentin was rinsed with distilled water. A demineralized dentin bone substitute was used in combination with platelet-rich fibrin (PRF) and a collagen membrane.

Kim et al. [34] did not specify the preparation protocol for the autogenous demineralized dentin bone substitute, but the researchers mentioned that the extracted teeth were sent to the KTB, where the preparation procedure was performed.

Korsch and Peichl [35] used partially demineralized dentin that was prepared immediately after tooth extraction. Old fillings, caries, periodontal ligaments were removed mechanically using a diamond drill. Using a diamond disc, a piece of dentin 1 to 1.5 mm thick was cut longitudinally, and the remaining tooth was crushed into 300 to 1200 µm particles with a special grinder and immersed in a solution of sodium hydroxide and 20% ethanol. Later, with mechanical stirring, it was washed with physiological solution. Partially demineralized dentin was demineralized by immersion in a 10% ethylenediaminetetraacetic acid (EDTA) solution for 3 minutes. Santos et al. [33] used autogenous mineralized dentin, which was prepared by mechanically removing the soft tissues and drying the tooth. Later, the tooth was crushed into 250 to 1200 µm particles, immersed in a physiological disinfectant solution and in a physiological solution.

Xiao et al. [36] applied an autogenous dentin wall by removing enamel and cementum from the tooth and cutting a 2-millimeter-wide dentin plate in the remaining dentin, and the gap between the dentin wall was filled with xenogeneic bone and concentrated growth factors and coated with a collagen resorbing membrane.

It is interesting to note that Schwarz et al. [19] used a tooth root in block form that was prepared by removing the crown of the tooth at the cemento-enamel junction with a carbide bur, leaving the pulp in the root canals, removing the cementum, and mechanically attaching the root of the tooth to the defect site.

Efficacy of autogenous demineralized dentin

Two studies compared autogenous demineralized dentin with xenogeneic bone [31,32] in alveolar process augmentation. Additionally, Li et al. [32] autogenous demineralized dentin combined with platelet-enriched fibrin and collagen membrane. Both studies in addition to measuring the implant stability quotient (ISQ), measured different parameters, and used different measurement methods (Table 6). However, after the augmentation of alveolar process no statistically significant differences were found between xenogeneic bone and autogenous demineralized dentin in any parameter. Histomorphometric analysis [31] indicated that the amount of remaining bone substitute in demineralized dentin group was 8.95 (SD 6.15)% and in Bio-Oss® group 17.08 (SD 16.57)% (P = 0.245). The percentage of newly formed bone in demineralized dentin group was 31.24 (SD 13.87)% and in Bio-Oss® group 35 (SD 19.33)% (P = 0.606). Li et al. [32] concluded, that after 18 months after the regenerative procedure, the amount of bone loss in Bio-Oss® group was 2 (SD 0.5) mm and in demineralized dentin group 1.9 (SD 0.6) mm (P = 0.18). Furthermore, Li et al. [32] registered failed osseointegration and infection in one implant in both groups.

Kim et al. [34] compared autogenous demineralized dentin with synthetic bone in maxillary sinus lift operation. The author measured the change in bone height immediately after implantation and maxillary sinus lift and one year after the procedure, but no statistically significant differences were found between the two bone substitutes used in the study. Vertical bone gain after sinus lift operation in demineralized dentin group was 4.89 mm and in synthetic bone group 6.22 mm (P = 0.46). Bone resorption after 1 year in demineralized dentin group was 0.76 mm and in synthetic bone group 0.53 mm (P = 0.57). One implant was lost due to failed osseointegration in synthetic bone group. Autogenous demineralized dentin was an equally effective bone substitute compared to synthetic bone.

Efficacy of autogenous mineralized and partially demineralized dentin

Santos et al. [33], comparing mineralized dentin with xenogeneic bone in bone augmentation procedures, both types of bone substitutes coated with a collagen resorbable membrane (Table 6). Authors of the study also measured pre-implant ISQ and ISQ after 2 months, but the statistical significance of the results was similar between the two groups. Six months after the regenerative procedure, a histomorphometric analysis was performed, the percentage of newly formed bone was measured, which was statistically significantly higher in the autogenous dentin group compared to the xenogeneic bone substitute group:

47.3 (SD 14.8)% and 34.9 (SD 13.2)% (P = 0.001) accordingly. In contrast, the percentage of remaining bone substitute, was statistically significantly lower in the autogenous mineralized dentin group compared to the xenogeneic bone substitute group: 12.2 (SD 7.7) and 22.1 (SD 10.9) (P = 0.001) accordingly. Furthermore, authors evaluated the postoperative pain using the VAS scale, but no statistically significant difference was found between the two groups. Postoperative complications registration, such as membrane exposure, haemangioma, separation of the wound margins, revealed no statistically significant differences between groups (Table 6).

Schwarz et al. [19] used an intact tooth root in block form after mechanical cementum removal for horizontal alveolar bone augmentation. The efficacy of this bone substitute has been compared with autogenous bone. Authors measured the change in alveolar process width after 26 weeks. The results showed that in the autogenous dentin group, the results were statistically significantly higher comparing to the autogenous bone group: 5.53 (SD 1.88) mm and 3.93 (SD 1.41) mm (P = 0.014) accordingly. In contrast, resorption of bone substitutes was statistically significantly lower in the autogenous dentin group compared to autogenous bone: 0.13 (SD 0.97) mm and 1.03 (SD 1.15) mm (P = 0.029) accordingly. In both groups after 26 weeks screw head was exposed in one patient, but not associated with any signs of wound infection.

Korsch and Peichl [35] compared autogenous partially demineralized dentin with autogenous bone substitute. Three months after horizontal alveolar augmentation and immediate implantation, the ISQ of the implants was measured, but no statistically significant differences were found between the two groups (Table 6). Horizontal bone loss and assessment of the amount of remaining bone substitute using CBCT revealed the same tendency: 1 mm bone loss in one autogenous partially demineralized dentin case and 0.5 mm in one autogenous bone case. When comparing complications such as dehiscence and infection, there was also no statistically significant difference between the compared groups.

Efficacy of autogenous mineralized dentin used in combination with xenogeneic bone

In Xiao et al. [36] study autogenous mineralized dentin was used in combination with xenogeneic bone, using the dentine layer as a wall, and filling the gap between it with xenogeneic bone and covering it with a collagen resorbable membrane. In the control group, autogenous bone was used instead of autogenous dentin. To evaluate the result, CBCT was performed, and bone gain was measured in the vertical direction. The results obtained in both groups were similar and no statistically significant differences were found: vertical bone height in dentin group was 2.91 (SD 3.75) mm and in bone group 2.79 (SD 3.95) mm; (P = 0.886). Bone resorption was assessed also in a horizontal direction by measuring the alveolar bone at three levels, 2, 4, and 6 mm from the top of the vestibular side of the alveolar process (Table 6). However, there was no statistically significant difference in the measurement of these parameters between both groups. In addition, there were no registered complications in both groups.

DISCUSSION

Present systematic literature review is based on the results of an analysis of seven publications [19,31-36]. Investigators of the included studies compared autogenous teeth tissues substitutes with almost all bone substitutes on the market, such as xenogeneic bone, synthetic bone, and the 'gold standard' autogenous bone. Although the investigators used different measures for research evaluation, the results of all publications indicate that autogenous bone substitutes derived from teeth are an effective means of restoring missing alveolar bone and can be successfully used as an alternative material in alveolar bone regenerative procedures. Most publications report that similar outcomes were observed between autogenous teeth tissues substitutes and controls, but a few studies reported statistically significantly superior outcomes. In study of Santos et al. [33], in which the alveolar process preservation procedure after tooth extraction was performed using autogenous mineralized dentin, and xenogeneic bone in the control group, histomorphometric analysis showed statistically significantly better results and a higher percentage of newly formed bone in the autogenous mineralized dentin group. Also, in the histomorphometric analysis performed in this study, a statistically significantly lower percentage of remaining bone substitute was found in the group of autogenous mineralized dentin bone substitute compared to xenogeneic bone.

Schwarz et al. [19] horizontal alveolar augmentation performed, using an intact autogenous tooth root from which the cementum was mechanically removed. Autogenous bone was used in the control group. The results of the study revealed that the gain of the bone in alveolar process was statistically significantly greater in the autogenous root dentin group compared

to the autogenous bone in the control group. It is also important to mention that this study also found a statistically significantly lower resorption of the used bone substitute in the autogenous root dentin group compared to autogenous bone.

Moreover, in the publications included in this literature review, in addition to histomorphometric analysis and radiographic parameters, postoperative sensitivity, various complications and implant stability were evaluated, but none of these parameters showed statistically significant results between autogenous bone substitutes extracted from teeth and the control group.

It is important to mention that the results indicated in this review are like the results of previous systematic literature reviews [37,38]. In the aforementioned systematic literature reviews, autogenous bone substitutes extracted from teeth are recognized as an effective regenerative material that can become an alternative in regenerative bone regrowth procedures. However, one of the literature reviews [38] emphasizes that autogenous bone substitutes extracted from teeth are a limited material in terms of their possibilities, because due to the limited size of the substitute, it is not possible to perform large-scale regenerative procedures and the alveolar process augmentation is often limited to the areas of single teeth. It is also emphasized in previous literature reviews [37,38] that there is a lack of a unified material preparation protocol in clinical trials, so it is difficult to compare the efficacy of the regenerative material. Furthermore, there is a lack of studies with large samples and longer follow-up periods to draw important conclusions. In contrast, to previous studies [37,38], present systematic literature review analysed only those studies that included controls and compared autogenous bone substitutes derived from teeth. Furthermore, in all analysed studies, implantation was performed after regenerative procedures or during a regenerative procedure.

Limitations

The results discussed in the studies mentioned in this literature review may have been influenced by the skills of the dentists who performed the regenerative procedures and implantation, the quality of the materials used, and insufficiently careful execution of the procedure protocol. In addition, it is important to consider that all the publications mentioned in this literature review used a different protocol for the preparation of autogenous bone substitutes extracted from teeth. It is also important to mention that not all clinicians used the same group of teeth, some of them used impacted teeth with intact crowns and roots, other used teeth with a poor prognosis for treatment or prosthetic restoration procedures. An equally important factor that could have influenced the quality of the study was that in two publications subjects were randomly assigned to the study groups, in the remaining studies subjects were assigned to the group of autogenous bone substitutes extracted from teeth when the subject had either an impacted tooth or a tooth with an unfavourable prognosis. The results of the systematic literature review may have been influenced by the fact that different alveolar bone regenerative procedures were performed in the selected publications, as well as the fact that the type of implantation in the publications included in the literature review was different.

The follow-up period of the examined study results was different. The relatively small study sample could also have influenced the results. The results of this systematic literature review could have been more significant if a quantitative analysis of the results (meta-analysis) had been performed, but considering the fact that the data of the selected publications were heterogeneous, this could not be done. Finally, the results of this systematic literature review do not reveal which autogenous teeth tissues graft preparation protocol should be followed to achieve the best results of the regenerative procedure.

CONCLUSIONS

Within the limitations of this study, autogenous tissues graft derived from teeth are an effective material and can be used as an alternative to other bone grafts existing on the market. Further studies with a longer follow-up period are needed to validate these findings.

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