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Performance of Autologous mineralized Dentin as an immediate Socket Graft – A review

A new approach for alveolar ridge preservation

Alice Françoise Aline Antoine Sabine Pré

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

Gandra, 5 de setembro de 2022

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Trabalho realizado sob a Orientação de Mestre Marco Infante da Câmara

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RESUMO

As extrações são um procedimento cirúrgico amplamente realizado que cria uma cicatriz óssea. A preservação da crista alveolar (ARP) é um passo fundamental para assegurar a viabilidade e estabilidade protética futura. A matriz de dentina mineralizada autóloga (AMDM) parece ser um material de enxerto ideal, com um procedimento «chair-side»

Objetivo: Efetuar uma revisão integrativa dos resultados clínicos do enxerto de alvéolo imediato com AMDM.

Material e métodos: Realizou-se uma pesquisa bibliográfica no PUBMED e no Google Scholar e um total de 12 artigos foram selecionados após a aplicação dos critérios de inclusão e exclusão.

Resultados/Discussão: Estes artigos descrevem e avaliam a eficácia da AMDM para preservar as dimensões das cristas alveolares. As avaliações histológicas e histomorfométricas também foram positivas. O volume e as qualidades ósseas foram bastante suficientes para uma posterior reabilitação protética através de implantes

Conclusão: AMDM poderia ser a próxima norma de ouro de material de enxerto alveolar. Apresenta excelentes resultados como biomaterial de enxerto, transforma um resíduo clínico em material de enxerto autógeno e elimina alguma desvantagem do enxerto ósseo autógeno, tal como a morbilidade do local de amostragem e o tempo de operação.

Palavras-chave: enxerto de dentina, preservação do alvéolo, substituto ósseo, moedor de dentina, enxerto de dentina autógena, dentina autóloga mineralizada

ABSTRACT

Extractions are a widely performed surgical procedure that create an osseous scar. Alveolar ridge preservation (ARP) is a key step to ensure future prosthetic feasibility and stability. Autologous mineralized dentin matrix (AMDM) seems to be an ideal graft material, with a chair-side procedure.

Aim: Carry out an integrative review on the clinical results of immediate socket grafting with AMDM.

Material and methods: A literature search was carried out in PUBMED and Google Scholar and a total of 12 articles were selected after applying the inclusion and exclusion criteria.

Results/Discussion: These articles describe and asses the efficacity of AMDM to preserve alveolar ridge dimensions. Histological and histomorphometrical evaluations were also positive. Bone volume and qualities were greatly sufficient for further prosthetic rehabilitation by implants.

Conclusion: Autogenous mineralized particulated dentin could be the next gold standard of socket graft material. It shows excellent results as a grafting material, turn a clinical waste into autogenous grafting material and eliminate some autogenous bone graft disadvantage such as morbidity of the sampling site.

Keywords: dentin graft, socket preservation, bone substitute, dentin grinder, autogenous dentin graft, mineralized autologous dentin.

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LIST OF ABBREVIATIONS

ADDM: Autologous Demineralized Dentin Matrix

AMDM: Autologous Mineralized Dentin Matrix

ARP: Alveolar ridge preservation

BMP: Bone morphogenetic proteins

CBCT: Cone-beam computed tomography scans

CM: Collagen membranes

DFDBA: Demineralized Freeze-Dried Bone Allograft

GBR: Guided bone regeneration

Mm: Millimeters

Nm: Nanometers

OPG: Orthopantomogram

PD: Probing Depth

PDGF: Platelet-derived growth factor

PRF: Platelet-Rich Fibrin

RPM: Revolutions per minutes

SDG: 'Smart Dentin Grinder'

TGF: Transforming growth factor

VEGF: Vascular endothelial growth factor

β-TCP: beta-tricalcium-phosphate

µm: Micrometers

1. INTRODUCTION

One of the most often carried out dental operations is tooth extraction. [1] Whenever a tooth must be surgically removed, due to decay, trauma, periodontal disease, malposition, or lack of space, the adjacent hard and soft tissues undergo remodeling. After extraction, the alveolar bone undergoes a three-dimensional physiological atrophy, the loss created by this scarring can reach 50% of the bone volume in 1 year. Most bone remodeling takes place during the first 12 months after extraction and two-thirds of the reduction takes place in the first 3 months. The bone resorbs more buccally than lingually. The basal part is only affected in extreme cases in the posterior lateral regions of the mandible. It is, therefore, the alveolar bone that is at stake. [1][2]

Leaving the site to spontaneously heal lead to some problems. Those repercussions are esthetic, even more in the visible smile, and functional with alteration of the mastication. It affects the confidence and quality of life of the patient. Losing points of contacts between teeth lead to migration of the neighboring teeth, and modification of interdental spaces. Hygienization difficulties can appear and offer opportunities for caries disease. Remaining teeth are going to compensate masticatory forces, it can create dental mobility, periodontal disease but also dental fractures. The antagonist tooth is also subject to those migration and subsequent problems. [3]

Various techniques have been developed to avoid those negative outcomes, called "alveolar ridge preservation" (ARP). Immediate socket grafts in the extraction socket are well developed. The principal qualities for a grafting biomaterial are high osteoinductive and angiogenic potentials, biological safety, low patient morbidity, high volumetric stability, easy availability, long shelf life and reasonable production cost. [4]

- Osteoconduction designs the capacity of a material to serve as a scaffold for neighboring vascular and bone cells. They will be able to migrate there, colonize it, vascularize it to synthesize a new bone matrix.
- Osteoinduction is the ability of a material to recruit and differentiate mesenchymal cells in a site lacking them, due to the presence of chemical agents. The material must therefore contain proteins and growth factors that stimulate this neo-formation.

- A material is called osteogenic when it has the ability of a material to form bone from living osteogenic cells within it. Only autogenous bone is osteogenic, by the presence of living bone cells. [4]

The current biomaterials used for these grafts are allografts, xenografts, and alloplastic materials, but the gold standard is autogenous bone graft, because of his osteogenicity. This "ideal" graft material shows some disadvantages like his limited availability, donor site defect, and morbidity, patient discomfort in cases of distant extraoral grafts. [4] To overcome those drawback, novel autologous dentin graft matrix has been developed. Our study reviews the results of mineralized autologous dentin particulate (AMDM) for immediate socket grafting, as an ARP.

2. OBJECTIVES

Main objective: Evaluate the efficacity of an ARP technique using chair-side processed AMDM as an immediate grafting material

Secondary objective: Review the dimensional changes and histological qualities of the preserved alveolar ridge.

3. MATERIALS AND METHODS

3.1. PICO search strategy

The formulation of the PICO question is : In the case of a surgical extraction, is there evidence that AMDM immediate socket graft preserves the alveolar ridge, compared to spontaneous healing ?

The criteria applied are exposed in the following table (Table 1).

Table 1. Criteria applied to the PICO question.

P	Population	Patients requiring surgical extraction
I	Intervention	Immediate socket graft with AMDM
C	Comparators	Spontaneous healing
O	Outcomes	- Preservation of the alveolar ridge in volume - Histological qualities of the newly formed bone

3.2. Literature search

A literature search was conducted in 2 databases. In PUBMED, the keywords were conjugated in the Boolean search formula: (("bone substitute"[All Fields]) AND ("dentin"[All Fields])) OR ("dentin grinder"[All Fields]) OR ("ATG autogenous tooth graft"[All Fields]) OR ("Autogenous dentin graft"[All Fields]) OR ("dentin graft"[All Fields]). In Google Scholar, the keywords were combined as following: ((autogenous dentin graft) OR (socket preservation)) AND (dentin)

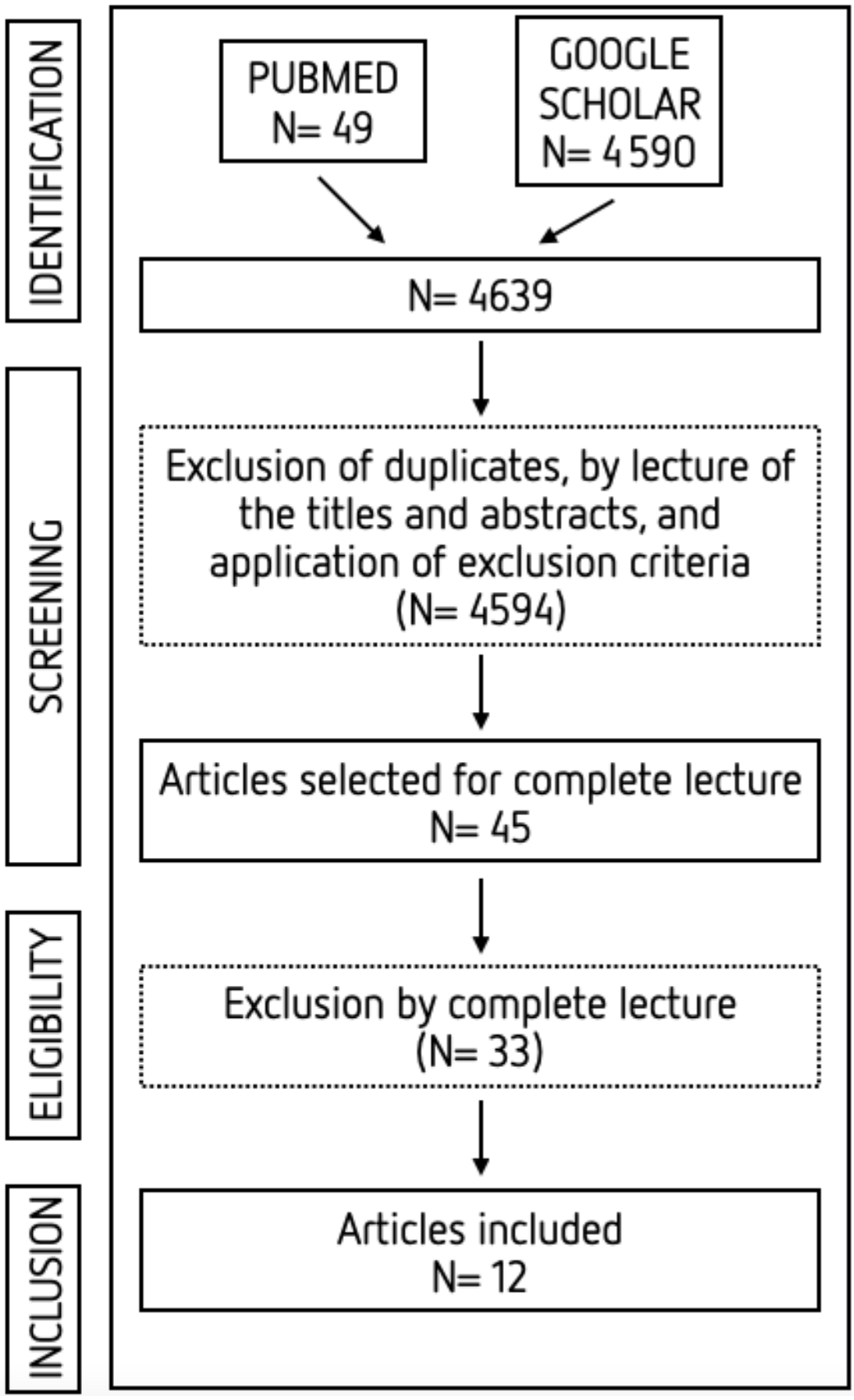
Inclusion criteria involved articles published in the English language and those articles with access for full reading, from 2014 to 2022, related to the theme of dentin graft socket preservation. The eligibility inclusion criteria used in the article searches involved: Pilot clinical study, Case Series, Randomized Controlled Trial, Comparative Study, Clinical Trial.

The exclusions criteria were as follows: literature reviews, articles dated more than 10 years, article where the full text was not available, studies on animals, in vitro studies and articles that did not present information allusive to the theme of the submitted work.

A preliminary validation was done by simple lecture of the title and abstracts, to determine if the articles met the objectives of the study. After that, a secondary evaluation was performed by lecture of the totality of the text, with the same objectives. The selected articles were read and assessed individually. Thus, 12 articles considered relevant to the study of the theme were selected, as shown in Figure 1. Full text lecture of all the articles retrieved and review was done. By pooling the extracted data from selected papers, the reviewed data was synthesized. This search strategy is illustrated in the following flowchart (Figure.1).

Additional research was conducted manually, pairing each keyword with the word "dentin graft" to identify relevant literature reviews, systematic reviews related to the subject, or other studies indirectly related to the topic, to allow comparisons or enrich the introduction and discussion sections.

Figure 1. Flowchart of the search strategy used in this review.



4. RESULTS

In PubMed, the literature search identified a total of 67 articles. After application of the 10 years filter, 18 were excluded. The preliminary evaluation, by lecture of the 49 articles titles and abstracts, but also with application of the others exclusion criteria, excluded 27 articles. The remaining 22 articles were fully read. The secondary evaluation led to the exclusion of 14 articles, and the remaining 8 articles were included.

In Google Scholar, the literature search identified 4 590 articles, with already the application of the 10 years filter. By the preliminary lecture of the abstracts and titles, with the other exclusion criteria in mind, a selection of 23 articles was made. After complete lecture of those articles, only 4 of them were relevant for our review.

The following information was recorded for this review: authors' names, year of publication, objectives of the study, type of study, methods, results, and conclusion. These information are presented in the following table. (Table 2).

By manual search, 3 studies, 2 reviews and 1 in vitro study were added in our discussion, as well as a book and a journal article, to support and improve understanding of the subject.

Table 2. Relevant data from the included studies

Authors /Year	Article Type	Objectives	Material and methods	Results	Conclusion
(Binderman et al., 2014) [6]	Case Series	First Presentation of novel procedure, ARP with AMDM socket graft.	Processing the teeth in the 'Smart Dentin Grinder' and Grafting the ADMD immediately in extraction sites or into bone defect sites.	Implant insertion was possible as soon as 2-3 month after grafting of autogenous dentin. On x-rays and biopsy of grafting sites a dense dentin-bone composite was found. No wound healing complications were observed	AMDM grafted immediately after extractions should be considered as the gold standard for socket preservation, bone augmentation in sinuses and bone defects.
(Valdec et al., 2017) [12]	Case Series	To introduces ARP technique in which the extraction socket is augmented with AMDM.	Processing the teeth in bone mill and performing an immediate socket graft. Bone biopsy and CBCT evaluated histological qualities and dimensional changes respectively.	After an observation period of 4 months, an implant was placed in the augmented area, which osseointegrated successfully and could be restored prosthodontically in the following. The results of this method showed a functional and aesthetic success.	The pre-implantological ARP with AMDM could be performed successfully.
(Fathy et al., 2019) [7]	Randomized controlled trial	This study was designed to evaluate the effect of using AMDM grafted for socket preservation	Immediate socket graft with AMDM was tested against spontaneous healing. Panoramic x-ray and CBCT evaluated dimensional changes and bone density.	There was statistically significant decrease in horizontal and vertical ridge dimensions in both groups after 6 months, but the decrease of vertical and horizontal ridge dimensions in control group was statistically significantly higher than that in graft group, also bone density of graft group was statistically significantly higher than that of the control group after 6 months	AMDM can be used as a good autogenous graft material for socket preservation giving promising results in reducing vertical and horizontal bone loss, and favourable bone density values after 6 months
(Dwivedi et al., 2020) [13]	Case Series	Evaluate on the potential for osteoconduction, osteoinduction, and osteogenesis by growth factors in AMDM.	CBCT evaluation for alveolar bone height changes were assessed. Bone biopsies were made to place implant and permitted histological analyses.	The mean alveolar dimension, pre- and post-operative, were statistically different. The histological semi-quantitative analysis revealed 34–66%of new bone formation in 40% of cases, while 67–100% of bone formation in 60% of cases. 80% of patients had collagen fibers in parallel and well-organized form and only interwoven and loosely arranged collagen fibers were present in 20% of patients. 70% of patients showed an osteocyte presence, while only 30% showed osteocyte absence. 60% of patient showed no rimming, only 40% showed osteocyte rimming. Twenty percent of patients had nest formation and 80% had no nidus formation	The outcome of this study suggests that chair side AMDM graft can be used for socket survival, sinus, and ridge augmentation as it is less time consuming, easy to prepare, with lower bone resorption speed, osteoinduction, osteoconduction, osteogenetic properties, and excellent primary implant stability
(Pohl et al., 2020) [14]	Case series	Evaluate ARP with immediate socket grafting with AMDM mixed with PRF.	The dimensional changes of the ridge were assessed by CBCT	The reduction in the buccal bone plate thickness 1 mm, 3 mm, and 5 mm below the buccal crest was -0.87 ± 0.84 mm, -0.60 ± 0.70 mm, and -0.41 ± 0.55 mm, respectively. The mean ridge width changes 1 mm, 3 mm, and 5 mm below the crest were -1.38 ± 1.24 mm, -0.82 ± 1.13 mm, and -0.43 ± 0.89 mm, respectively. The average midbuccal bone height gain was +1.1%, while the midlingual height gain was 5.6%.	A AMDM with PRF is effective in preserving postextraction alveolar ridge dimensions

(Andrade et al., 2020) [15]	Case series	Evaluate ARP with immediate socket grafting with AMDM mixed with PRF.	Dimensional changes evaluation by CBCT and Histological Analysis were made	The vertical and horizontal dimensions were preserved or even increased after 4, 5, or 6 months and remained stable after 6 months of implantation. The histological examination revealed a median relative percentage of bone, dentin, and connective tissue of 57.0, 0.9, and 39.3%, respectively. A comparison of samples at different time points (4, 5, and 6 months) showed a progressive increase in the proportion of bone with a decrease in the proportion of dentin. The bone was compact with normal osteocytes and moderate osteoblastic activity. In 4 out of 10 samples, no dentin was observed in the other samples, it represented 1–5% (with geometric fragments).	Dentin block showed to be a suitable bone substitute in an alveolar ridge preservation model. promising results of dentin block as a bone substitute in ARP could have an important clinical impact considering this biomaterial brings together the regenerative potential of three autologous products with excellent biological and clinical behaviour, low risk of adverse effects, and feasible acquisition.
(Sánchez-Labrador et al., 2020) [10]	Randomized controlled trial	Evaluate the efficacy of AMDM for the regeneration of periodontal defects caused by bone loss associated with impacted lower third molar extraction	Probing depth of the adjacent teeth at 3 and 6 months assessed the evolution of the defects. Bone density and alveolar bone crest maintenance were evaluated by CBCT at 6 months. Pain, inflammation, mouth opening capacity were evaluated on at 2 and 7 days.	Probing depth, radiographic bone density, and alveolar bone crest maintenance showed significant differences between the test and control sides.	AMDM was found to be an effective biomaterial for bone regeneration after impacted lower third molar extraction
(Esquivel-Chirino et al., 2021) [8]	Case Report	The aim of the case report was to evaluate and compare clinical and histological outcomes using an AMDM graft versus DFDBA as ARP	A split mouth design, opposing DFDBA bone graft (right quadrants) to AMDM (left quadrants). Tooth were processed with SDG. Six months later, (CBCT) was obtained, to evaluate bone mineral density, and bone biopsy were collected for histological evaluations	DFDBA showed a more consistent bone formation without evidence of bone graft particles. AMDM sample demonstrated a more disperse distribution, and dentin particles were observed. In the maxillary area, DFDBA and the AMDM showed a bone density of 585 HU and 304 HU, respectively. For the mandibular zone, the bone density was 583 HU for the DFDBA and 712 HU for the AMDM. In the AMDM sample, dentin particles were identified as well as associated new bone matrix production within the particles. Vascularized connective tissue was identified between bone spaces and dentin particles with a fusion zone and bone matrix production between two particles of mineralized dentin.	AMDM can be considered an alternative for bone fill. It promotes new bone formation and is non-immunogenic. Histological characteristics that were similar to bone tissue were observed, bone density was appropriate. The clinical, histological, and tomography imaging outcomes following tooth extraction were great.

(Elfana et al., 2021) [11]	Randomized controlled trial	Compare radiographic changes and histologic healing following ARP using AMDM (test), versus ADDM (control group)	20 were randomized to grafting with AMDM or ADDM. Grafts were covered with CM. Ridge dimensional changes and Histological analysis were conducted with CBCT and Bone biopsy respectively.	All sites healed uneventfully. Reduction was 0.85 ± 0.38 mm and 1.02 ± 0.45 mm in ridge width, 0.61 ± 0.20 mm and 0.72 ± 0.27 mm in buccal and 0.66 ± 0.31 mm and 0.56 ± 0.24 mm in lingual ridge height for the AMDM and ADDM group, respectively (p> .05). Histologically, no inflammatory reactions were noticeable, and all samples showed new bone formation. Qualitatively, graft- bone amalgamations were more pronounced in ADDM samples. Histomorphometrically, new bone, graft remnants and soft tissue occupied 37.55% ± 8.94%, 17.05%± 5.58% and 45.4% ± 4.06% of the areas in the AMDM group and 48.4%± 11.56%, 11.45% ± 4.13% and 40.15% ± 7.73% in the ADDM group of the examined areas, respectively (p> .05).	AMDM and ADDM are similarly effective in ARP. Yet histologically ADDM seems to demonstrate better graft remodelling, integration and osteoinductive properties
(Xhaferi et al., 2021) [17]	Case series	Present a novel procedure in for ARP employing AMDM for immediate socket or bony defect	Dimensional changes of the ridge were assessed with calipers. PD was assessed. Bone density was evaluated. Patient related outcome were evaluated by questionary.	During the follow up period of six months, clinical measurements of post-extraction dimensional changes of the alveolar ridges showed minimal horizontal and vertical bone resorption with preserved alveolar ridge volume, with an accelerated bone regenerative process without special postoperative complications.	Dentin particulate grafted immediately after extractions should be considered as gold standard due to its osteogenetic, osteoinductive and osteoconductive effects on bone tissue regeneration with the use of mineralized dentin matrix we get maximum utilization of our own biological potential without the use of other artificial graft materials
(Santos et al., 2021) [9]	Randomized controlled trial	To compare test primary stability of implant placed in ridge preserved with AMDM or Xenograft.	Visual analogue scale and analgesic consumption were measured for a week. Bone biopsies were made to assess histomorphometry. Implant stability, Marginal bone loss, and presence of mucositis/peri-implantitis were registered.	Fifty-two patients (66 implants) completed the study. MDM and xenograft groups presented similar primary (77.1 ± 6.9 vs. 77.0 vs. 5.9) and secondary (81.8 ± 5.1 vs. 80.1 ± 3.8) implant stabilities. The percentage of newly formed bone in MDM (47.3%) was significantly higher than xenograft (34.9%) (p<0.001), and the proportion of residual graft was significantly lower (12.2% in MDM and 22.1% in xenograft) (p<0.001). No significant differences were found as far as clinical, radiographic, and patient-related outcomes.	Implants placed in sites preserved with MDM had similar primary stability in comparison to xenograft granules. MDM showed a significantly higher quantity of newly formed bone and lower amount of residual graft in histomorphometry results and equal clinical and patient-related outcomes.
(Van Orten et al., 2022) [16]	Case Series	Assess the efficacity of ARP socket grafting with AMDM mixed with PRF. "sticky tooth"	8 sites were grafted with AMDM mixed with PRF and covered with CM. Radiographical evaluations were made with OPG and CBCT, histological evaluations were made with bone biopsies.	No further horizontal GBR intervention was required in any cases, and the histological findings were unremarkable. The new bone was mostly spongy and in direct contact with the remaining dentin granules.	Within the limits, it may be concluded that this method is valuable for socket preservation and obtaining vital and good quality bone structure. The sticky tooth technique seems to be very efficient despite the more complex equipment.

The literature search in PubMed and Google Scholar identified 12 articles selected according to the inclusion and exclusion criteria. All those studies are clinical trial, 7 are case series, 1 is a case report and 4 were randomized controlled trial. In the total included studies, 4 were prospective clinical trial of the immediate socket graft with AMDM. Two of our studies compared AMDM graft with spontaneous healing, one was in a split mouth design, the other was a randomized controlled trial with 2 different groups. Three of our studies compared the results of AMDM with other grafting materials, one with xenograft, one with allograft and one with demineralized dentin. Three of our studies explored the use of biological additives, 2 added PRF and one PRF and fibrinogen.

The Scientific Journal Ranking (SJR) score was also used to evaluate the scientific influence of academic journals by publication date for each selected study. Their respective rankings are showed in the following table (Table 3).

Table 3. SJR quality rating of academic journals

Study	Journal	Rank
(Binderman et al., 2014) [6]	Journal of Interdisciplinary Medicine and Dental Science	Not registered
(Valdec et al., 2017) [12]	International Journal of Implant Dentistry	Not registered
(Fathy et al., 2019) [7]	Al-Azhar Journal of Dental Science	Not registered
(Dwivedi et al., 2020) [13]	Journal of Oral Biology and Craniofacial Research	Q2
(Pohl et al., 2020) [14]	Materials	Q2
(Andrade et al., 2020) [15]	Clinical Oral Investigations	Q1
(Sánchez-Labrador et al., 2020) [10]	Materials	Q2
(Esquivel-Chirino et al., 2021) [8]	European Journal of Dental and Oral Health	Not registered
(Elfana et al., 2021) [11]	Clinical Oral Implants Research	Q1
(Xhaferi et al., 2021) [17]	Serbian Dental Journal	Not registered
(Santos et al., 2021) [9]	Clinical Oral Implants Research	Q1
(Van Orten et al., 2022) [16]	Journal of Dentistry	Not registered

Of the 10 different journals used as sources, only 4 were identified in the SJR database. In our total of 12 studies, 25% had a very good ranking of Q1, 25% a good ranking of Q2 and a major part of 50% were not ranked. The Journal of Dentistry article was too recent (2022) to have its ranking, the other 5 journals, were not identified in the database.

5. DISCUSSION

5.1. Spontaneous Healing

An extraction, an invasive procedure, creates an inevitable bone scar, this regeneration results in a contraction of the bone tissue. The healing of an extraction socket is a series of inflammatory response starting directly after the extraction, this healing lasts 12 to 16 weeks. The mineralization begins by trabecular bone formation between the 4th and 8th week, and then begins a maturation process that will end at about 12 weeks, when the socket is filled with lamellar bone and bone narrow. [1][2]

Tan et al. did a systematic review in 2012 that showed a horizontal bone loss between 29-63% and a vertical loss of 11-22% in 6 months. [1] Schropp et al. made an evaluation of 12 months, the width of the bone was reduced by half, corresponding to a loss of 5 to 7 mm. The jaw region did not influence the results. [2]

These studies have shown that most of reduction occurs during the first year, with the most significant loss during the first 3 months, [1][2] 2/3 of the loss for, followed by progressive reductions in dimensions thereafter. Usually, resorption is greater in buccal cortical plate compared to the lingual side. [1]

These results are very important for the decision regarding the prosthetic replacement of the tooth. Allowing the bone to heal spontaneously may call into question the future placement of an implant, or even the aesthetics of the overlying soft tissue.

5.2. Dentin and bone composition

Osseous tissue is composed essentially of 3 types of cells. Osteoblasts, bone-forming cells, osteocytes, mature bone cells and osteoclasts, that resorb bone. Their presence or absence can indicate the maturation of the new bone. During the bone formation, dense connective tissue is replaced by deposition of inorganic calcium salts. This deposition is made by the osteoblast, until they become osteocytes. The major inorganic component is apatite crystals. Dentin contains hydroxyapatite, it is calcium phosphate with low crystalline content. AMDM has a similar Ca/P ratio as mandibular ramus autograft and

allograft, those composites release their ions inducing the precipitation of apatite and permitting osseointegration. [5]

The organic part consists of 90% collagen microfibrils, type 1 being the highly predominant one, as well as soluble non-collagenous proteins, interleukin, and growth factors (for example: BMPs, TGFs, PDGFs). Those growth factors have various effect, like migration and proliferation of mesenchymal cell, induction of collagen synthesis or angiogenesis in new tissues. [4] Dentin shares with bone some of these non-collagenous proteins, like dentin matrix protein 1, bone sialoprotein, and osteopontin. [5] Bone Morphogenetic Proteins (BMPs) have a very important stimulating effect on bone formation. [4][5] BMPs influence the mobility, division, and differentiation of mesenchymal and osteoprogenitor cells. BMP2 seems to be the best to induce osteoblast differentiation. [4]

Khanijou et al. demonstrated that AMDM released BMP2 from day 1 until day 10, they also reported that this growth factor release was much higher than the one from allograft material at day 5 and day 10. They also observed a great number of migrated osteoblasts. Human fetal osteoblastic cells were travelling through a membrane to a AMDM covered site. The results were comparable to those of autogenous bone. Those results prove the strong osteoconductive qualities of AMDM. Moreover, an osteoinductive effect is offered by the tubular structure of the dentin, and the healing presence of collagen type 1 in those tubules. [5]

AMDM shares a lot of the inorganic bone composition in terms of calcium ions and organized phosphorus, its organic matrix also contains type I collagen and growth factors, those similarities permit greats osseointegration, osteoinduction and osteoconduction capacities. Three of or studies even used platelets concentrate, created by extracting growth factors, such as PDGF, TGF-β, and VEGF [4], from the blood by centrifugation, to rise the osteoinductive capacities.

5.3. AMDM immediate socket grafting

5.3.1. Graft Preparation

All the studies made a point about the importance of an atraumatic extraction, preserving the bony walls of the socket is a pilar for a minimum bone loss. After careful and meticulous extraction, the recollected tooth must be ground.

In the majority, the graft matrix preparation was achieved with the 'Smart Dentin Grinder'™. Binderman et al. were the first who described the protocol to use this new procedure, in 2014. [6]

First, the teeth with root canal fillings should not be used, the filling could cause contamination. Teeth with other kind of restauration, crowns, and fillings, can be "cleaned" of those materials and the final dentin obtained can be processed.[6]

- Teeth preparation

Immediately after extraction, the remotion of all restoration materials, carious lesions, discolored dentin, remnants of Periodontal ligament and calculus is obtained with the use a high-speed tungsten carbide bur. The roots can be split in this process. The clean "entire" (root and crown) teeth are dried with an air syringe. [6]

- Processing in the 'Smart Dentin Grinder'™

The clean teeth are placed in the sterile grinding chamber. In 3 seconds, the teeth are grinded, then, with a cycle of vibrations for 20 seconds, the device let falls the particles of less than 1200 μm in another chamber, the collecting drawer. This chamber keeps particles between 300-1200 μm. The littlest particles, less than 300 μm are not an efficient grafting size, they are falling into a waist drawer. This size selection has an efficacy of more than 95%. [6]

- Cleansing of the graft matrix (basic alcohol cleanser)

The particulate dentin from the collecting drawer must be immersed in a basic alcohol cleanser for 10 minutes. This solution is made with 0.5M of NaOH and 30% alcohol (v/v), it defats, and dissolves organic debris, bacteria, and toxins. After this treatment the dentin tubules are clean and wide open. After this bath, the cleanser his decanted. [6]

- Washing of the cleanser

The particulate needs to be washed twice, in a sterile phosphate buffered saline. This solution is also decanted, leaving the particles wet and ready to graft. This wet mixture

can be dried with a hot plate (140◦C) for 5 minutes, to have a dry AMDM that could be used for immediate graft or in future grafting procedures. [6]

The volume of graft matrix obtained by this procedure is more than twice the original root volume. Molar teeth gave average of 2 grams of graft material. [6][7] The grinding of a 26 produced enough AMDM to fill the extraction socket and a subjacent sinus defect. [6] This processing technique provides a high-volume graft that is free of bacteria, viruses, and fungi. [6][8]

The mean surgical time was observed from the first incision to the last suture, Santos et al. found it to be 23.2 minutes and Sánchez-Labrador et al. 26.2. In comparison the spontaneous healing was completed in 12.38 minutes. [9][10]

Although most of our result studies used this exact protocol, some made few changes:

- In two articles, searchers choose to perform a cleaning of the pulp chamber with sterile endodontic files. [11][12]
- Valdec et al. removed layers of enamel and cementum with a high-speed diamonds bur. The remaining dentin was cut into smaller piece with a bone rongeur forceps and particulated in a bone mill, achieving sizes between 0.25 and 2 mm. Some autogenous blood was taken in the surgical site and mixed to the AMDM. [12]
- Dwivedi et al. used a conventional grinder to process they're teeth. The motor rating was 1500 W with a speed of 700 rpm. [13]
- Elfana et al. differed in the processing. They used a hand bone mill (Gold Bone Mill, MCT Bio, Korea) to grind the teeth. They dried their AMDM with sterile gauze after double washing the cleanser. [11]
- Some used biological additives, rich in growth factors. Those types of additives are used since nearly 2 decades. [4] Pohl et al., and Orten et al. mixed platelet-rich fibrin (PRF) in their graft matrix, and Andrade et al. mixed PRF and fibrinogen. [14][15][16]

5.3.2. Dimensional changes evaluation

These dimensional changes of the alveolar ridge are a principal parameter to determinate the efficacity of an ARP technique. They permit to compare the mean loss happening during spontaneous ridge healing to the preserved one.

Pohl et al. think the buccal bone height changes, buccal bone resorption, and ridge width changes 1 mm below the crest are the most critical dimension changes after an extraction. The buccal bone height being essential in implant stability and very visible in esthetic areas, it's exacerbated diminution may result in recession around the implant. [14]

In his presented clinical cases, Binderman et al. exposed some qualitative result, no exact measurements were published. His radiographics showed a complete restauration of the alveolar ridge heights. In his cases of an impacted LTM, at 4 months, it was observed a complete restoration conferring a normal a distal bone support of tooth 47. It was noted in his last case, with a bone defect extended to the maxillary sinus (26), that the minimum ridge heights at 3 months was 8,3 mm, and 1 year after implantation there was no crest resorption. [6] Xhaferi et al. measured the ridge width with bone calipers 2mm and 4mm below the crest. At 2mm their 3 cases showed a mean loss of 1mm, and a mean loss of 0,66mm at 4mm below the ridge crest. [17]

In most of our, studies those evaluations were made with CBCT scans, by comparing pre-extraction, post extraction, post grafting and different follow up. This method of subtraction radiography is often used to evaluate small changes in bone's dimensions. [2]

- Valdec et al. made CBCT scans before extraction, 4 months after grafting, to ensure enough bone volume for the prosthetic, and 1 year after the implantation. They observed a loss of 0.76 mm in the vertical dimension and a loss of 1.1 mm in the horizontal dimension. [12]
- Fathy et al., with CBCT immediately after extraction and 6 months after grafting demonstrated a vertical loss of 0,58mm and a horizontal of 1,04 mm. [7]
- To evaluate dimensional changes Sánchez-Labrador et al. measured the distance between IAN to the crestal bone with CBCT at 6 months postoperatively. They observed a 0.54 mm gain vertically. [10]
- Dwivedi et al. made measurement 4 months after grafting, and registered a heights loss of 0,6 mm and a slight width gain of 0.678 mm. More generally, no significant

marginal bone loss nor significant height reduction was observed, radiographically the alveolar socket anatomy had been restored. [13]

- Elfana et al. made the ridge width their primary outcome. They also observed changes in ridge heights buccally and lingually. The follow up was at 6 months. The losses were 0.85 ± 0.38mm (11 ± 5.36%) in width, and the vertical diminutions were 0.61 ± 0.20mm (6.8 ± 2.61%) buccally and 0.66 ± 0.31mm (6.83 ± 2.69%) lingually. [11]

- Andrade et al. made CBCT measurements before extraction, at implantation after 4 months and 6 months after the implant pose. They observed in the first 4 months a vertical augmentation of the ridge dimensions. The ridge gained 1,7 mm buccally and 2,12 mm lingually in heights and 0,57 mm in width. Those gains remained stable at the 6 months after implantation timeline. [15]
- Pohl et al. compared measurements of the ridge and buccal bone thickness prior to extraction and 4 months after. The ridge gained in vertical dimension +0,16 ± 2,34 buccally (+1.1%), and +0,4 ± 1,68 lingually (+5.6%). They registered width loss of 1.38±1.24 mm, –0.82±1.13 mm, and–0.43±0.89 mm, measured 1 mm, 3 mm, and 5 mm below the crest respectively. The reduction in the buccal bone plate thickness 1 mm, 3 mm, and 5 mm below the buccal crest was–0.87±0.84 mm, –0.60±0.70 mm, and–0.41±0.55 mm, respectively. This resorption of the buccal bone 1mm below the crest correspond to the initial measure of the bundle bone. The bundle bone is a tooth-dependent structure, resorbing after tooth extraction, and, until now, no grafting material was able to prevent bundle bone resorption. [14]

Checking the periodontal probing depth, distance from the free gingival margin to the base of the sulcus allows to check the stability of the surrounding periodontium. Sánchez-Labrador et al. discovered that probing depth was significantly reduced when AMDM graft was used in the adjacent socket, versus spontaneous healing control group. The reduction for the DV, DM and DL surfaces were respectively 1.53 mm, 2,8mm, 2,33mm in the test group, control group had a 0.27 mm, 0,07 mm, and 1,4 mm means. This reduction was mainly produced during the first three months after surgery. [10] In the case of and impacted third molar, Xhaferi et al. measured a value of 1 mm after 6 months. The AMDM

graft completely restored the defect created by osteotomy.[17] Those results permit to affirm that AMDM doesn't affect periodontal health of the adjacent teeth, but Schropp et al. didn't observe loss of attachment levels on adjacent teeth at the 12 months follow up, were the extraction socket healed spontaneously.[2]

All the studies concluded that great dimensional preservation of the bone was obtained, preservation of the probing depth was also observed. None of the related case have showed the need of further ridge augmentation for implant placement with the reason being extraction scar.

5.3.3. Histological bone qualities

Some of our studies made radiographical evaluations of the bone qualities. At their follow up, 4 months for Binderman et al. and 3 to 6 months for Xhaferi et al. , observation of early formation of new bone and great osteointegration of the AMDM into the new bone were made.[6][17] During the first 60 days, large amounts of new woven bone were created, and at 90 days small portion of lamellar bone were found, with great stability and density.[17] At 1 year and 2 years after implantation, x-rays showed great bone density, the bone around the implant was very radiopaque, seemingly indicating that the AMDM produced a very solid support for implants.[6]

Hight bone density indicate the efficacity of osteointegration and regeneration of new bone tissue. Augmentation of bone density are explained by formation of new bone matrix but can also be due to the dentin remnant with high density.[7] With CBCT evaluation at 6 months, great variety of bone density were observed: 583 HU[8], 592,9 HU[7], 848.5 HU[9] and 1538.93 HU[10].

In most of the studies, implant placement was the finality of the treatment. At the time of implant placement (between 106 days to 6 months), a bone slot had to be taken out by trephine bur. Those slots were treated has biopsy and stained to obtain histological information and histomorphometric analysis. Orten et al. made their biopsy between 106 and 420 days after ARP, Binderman et al. at 3 months, Valdec et al. and Pohl et al. at 4 months, Elfana et al., Andrade et al. and Esquivel-Chirino et al. at 6 months.[6][8][11][12][14][15][16]

Evidence of new bone formation was found in the totality of the biopsies, without any signs of inflammation, infection nor necrosis. New bone formation was revealed by the presence of osteoblasts, a sign of active bone, osteocytes presence is a sign of mature bone.

Between 3 to 4 months dentin was integrated in the new woven bone. In the Pohl et al. study the dentin particles were in direct contact with the new bone formation. [6][12][14] At 6 months mature new lamellar bone was found. [15][11] Orten et al. even observed it sooner. [16] Andrade et al. collected samples a different time until 6 months and could observe an increase in the bone proportion (26.3% at 4 months,56.5% at 5 months, and 66.5% at 6 months) correlated with a decrease of the dentin remnants (10.4% at 4 months, 4.8% at 5 months, and 0.9% at6 months). [15]

Complete osteoclastic resorption of the AMDM was not obtained in 11 out of 12 studies, dentin particles were found integrated in the bone at all the stages. But Andrade et al., discovered that in 4 of their 10 sites, all dentin seemingly disappeared, in 2 other site the proportion was ≤1%, it must be remembered that PRF biological additive was in the graft matrix. [15] Xhaferi et al. Explained this by the mineralization of the dentin, inducing a very slow resorption of the AMDM. [17]

In general, observations were made about an intimate contact between dentin and bone, resembling ankylosis. Esquivel-Chirino et al. observed it clearly. They observed dentin particles surrounded by bone matrix, connective tissue, and in close contact with new bone formation. They precisely identified production of bone matrix in direct contact between two dentin particles. [8] In contradiction with those results, only 1 out of the 8 biopsies studied by Elfana et al. showed a direct dentin-bone union. All the other dentin remnants were encapsulated by connective tissue. [11]

Deeper investigations were made in some studies, and histomorphometric analysis were conducted to analyze those bone slots . Santos et al. and Elfana et al. studied the same parameters, at the same follow-up time of 6 months. They found similar results. New bone represented 47.3 % (± 14.8) and 37,55% (± 8,94) of their respective biopsies, soft tissue 40.5 % (± 17.6) and 45.4 % (± 4,06) and finally remnants of grated material were 12.2 % (± 7.7) and 17.05 (± 5.58). [11][9]

Dwivedi et al. assessed that new bone formation was present in all their 4 months biopsy. They even observed osteocytes presence in 21 subjects (70%), which indicate a

maturation of the tissue.[13] Andrade et al. found a mean of 0,9% of dentin particles at 6 months. The total bone represented 66,5 % of the biopsy, and connective tissue 32,6 %.[15]

Time frames were not homogeneous. But their evaluations made evident bone formation on the surface of the dentin particles and surrounding them. They could verify a true osteogenesis process, were after woven bone formation it was turning into mature lamellar bone at a physiologic time frame. All the subjects showed sufficient histological bone regeneration.

By observing these peri-particulate osteo-genesis and the release of growth factor, we can observe an osteoconductive effect of the mineralized dentin fragments.

Total degradation of the graft material was only observed when it was used in combination with platelet-rich fibrin and fibrinogen.[15] Further studies, with longer follow-up should be conducted to assess the possible total biodegradation of this grafting material.

6. CONCLUSION

All subjects tested showed great dimensional preservation of the ridge. The biopsy showed maturation of the bone. Even if some graft particles were always present at 6 months, all grafted sites showed enough density and bone qualities.

ARP techniques are a pivotal step in oral rehabilitation. Avoiding further ridge augmentation, only by improving our extraction protocols by a few steps, is now an ethical question. Indeed, reducing the number of surgical procedures reduces the risks for the patient. AMDM is a next level alternative to all the socket graft materials already used. More studies, with much larger samples and follow up need to explore the long-term results of this technique. This material showed great osteoconductive and osteoinductive qualities, by his internal structure and growth factor releasing. This new procedure not only provide great amount sterilized of bone graft materials but can be achieved chair-side, by one practician, in approximatively 25 minutes. The 'Smart Dentin Grinder'™ is very efficient, but the particulation of effective bone graft could be achieved with other techniques, with for example hand bone mill. All the subjects that needed implant in our studies didn't need any other bone augmentation at the time of implantation. Implant placed showed good osteointegration. The transformation of what was considered a surgical waste in this great autogenous bone graft material is a real innovation.

7. REFERENCES

1. Tan WL, Wong TL, Wong MC, Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. Clin Oral Implants Res. 2012 Feb;23 Suppl 5:1-21.
2. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent. 2003 Aug;23(4):313-23.
3. Perrin J. Les conséquences du non-remplacement des dents extraites ou absentes. Information Dentaire. 2021 Sept 22;(32):38-4
4. Pikos MA. Bone augmentation in implant dentistry: A step-by-step guide to predictable alveolar ridge and sinus grafting. Quintessence Publishing; 2019.
5. Khanijou M, Zhang R, Boonsiriseth K, Srisatjaluk RL, Suphangul S, Pairuchvej V, Wongsirichat N, Seriwatanachai D. Physicochemical and osteogenic properties of chairside processed tooth derived bone substitute and bone graft materials. Dent Mater J. 2021 Jan 31;40(1):173-183.
6. Binderman I, Hallel G, Nardy C, Yaffe A, Sapoznikov L. A Novel Procedure to Process Extracted Teeth for Immediate Grafting of Autogenous Dentin. J Interdiscipl Med Dent Sci, 2014; 2: 154.
7. Fathy A, Abd-Elakher M, Elfeky A. Effect of Using Mineralized Dentin Particulate Grafted for Socket Preservation. Al-Azhar Journal of Dental Science, 2019; 22(3): 211-215.
8. Esquivel-Chirino, C., Vargas-Romero, V., Rodríguez-Torres, G., Villatoro-Ugalde, V., Rivas-Fonseca, M. G., Montes-Sánchez, D. G., Carmona Ruiz, D., Valero Princet, Y., & Márquez-Correa, C. Alveolar Ridge Preservation Using Autogenous Dentin Graft versus Demineralized Freeze-dried Bone Allograft (DFDBA): A Case Report. European Journal of Dental and Oral Health, 2021; 2(2), 18–22.
9. Santos A, Botelho J, Machado V, Borrecho G, Proença L, Mendes JJ, Mascarenhas P, Alcoforado G. 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 Aug;32(8):905-915.

10. Sánchez-Labrador L, Martín-Ares M, Ortega-Aranegui R, López-Quiles J, Martínez-González JM. Autogenous dentin graft in bone defects after lower third molar extraction: A split-mouth clinical trial. Materials 2020
11. 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;32:539–48.
12. Valdec S, Pasic P, Soltermann A, Thoma D, Stadlinger B, Rücker M. Alveolar ridge preservation with autologous particulated dentin-a case series. Int J Implant Dent. 2017 Dec;3(1):12.
13. 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 Oct-Dec;10(4):535-541.
14. Pohl S, Binderman I, Tomac J. Maintenance of Alveolar Ridge Dimensions Utilizing an Extracted Tooth Dentin Particulate Autograft and PlateletRich Fibrin: A Retrospective Radiographic ConeBeam Computed Tomography Study. Materials (Basel). 2020 Feb 29;13(5):1083.
15. Andrade C, Camino J, Nally M, Quirynen M, Martínez B, Pinto N. Combining autologous particulate dentin, L-PRF, and fibrinogen to create a matrix for predictable ridge preservation: a pilot clinical study. Clin Oral Investig. 2020 Mar;24(3):1151-1160.
16. Van Orten A, Goetz W, Bilhan H. Tooth-Derived Granules in Combination with Platelet-Rich Fibrin ("Sticky Tooth") in Socket Preservation: A Histological Evaluation. Dent J (Basel). 2022 Feb 16;10(2):29.
17. Xhaferi B, Petreska M, Xheladini A, Papic I. Use of mineralized dentin graft in augmentation of different indication areas in the jaw bones. Stomatol Glas Srb 2021;68:113–21