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Mini Review

The Current Scenario of the Use of Polyetheretherketone (PEEK) in Guid-ed Bone Regeneration Techniques

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Abstract

Objective: Alveolar resorption following tooth extraction is often a significant challenge in implant rehabilitation, frequently requiring prior reconstructive procedures. The literature reports various techniques for guided bone regen-eration; however, recent applications of PEEK (polyetheretherketone) in these procedures have gained attention due to its bio-compatibility and also its chemical and mechanical properties. The aim of this work is to review the literature on the recent use of PEEK in reconstructive techniques.

Materials and Methods: A search was conducted on PubMed and Google Scholar using the keywords "PEEK bone graft," "PEEK bone reconstruction," "PEEK tissue reconstruc-tion," and "guided tissue regeneration," including publications from the last 5 years.

Results: Eight articles from re-cent years were found, divided between two techniques employing PEEK for guided bone regeneration. One technique utilized PEEK mesh devices (5 articles), while the other used PEEK as a supporting matrix to achieve a tent effect (3 articles). Despite the limited data available due to the novelty of these techniques, the results reported are promising.

Conclusion: It is concluded that further studies on PEEK are necessary, with larger sample sizes and extended fol-low-up, to validate these techniques and confirm the observed results.

Keywords: Biocompatible materials; Bone regeneration; Guided tissue regeneration; Tissue Engineering; Tooth loss

Introduction

Dental implant rehabilitation is a routine practice in dentistry to overcome the problem of missing teeth. There are various reasons why patients experience bone loss, which initially complicates such rehabilitation, being necessary a prior bone reconstruction [1].

In the 1980s, the concept of guided tissue regeneration was introduced, in which tissue regeneration is achieved when cells capable of forming specific tissues fill the defect during the healing process [2]. This way, the biology of the guided bone regeneration (GBR excludes mechanically the unwanted soft tissues, favoring the growth of osteogenic cells in the bone defect [3-5].

The GBR protocol consists on placing a membrane in contact with the bone surface in order to physically protect the area that needs regeneration [3]. The membrane also keeps the isolated space, creating an environment for recruiting osteoprogenitor cells, osteoblastic differentiation, and the unobstructed expression of osteogenic properties [6].

Based on this concept, several can be used, both as barriers and graft materials, primarily autogenous and xenogeneic [5,7]. More recently, techniques of GBR have been modified aimed at improving the predictability of the results and diminishing the morbidity of the procedures [8]. One of these alterations is the use of polymers such as PEEK in the fabrication of membranes, screens, meshes, and tent-shaped screw

Table 1: Characteristics of the included studies, based on the main characteristics searched for in the articles.

Reference	Type of article	Technique used	No of evaluated individuals	Comparison with other biomaterial	Associated graft	Described complications	Bone gain	Post-implants follow-up period
Mounir et al., 2019 [1]	Randomized clinical study – series of cases	Individualized mesh	8 patients	Titanium	Xenogeneic + autogenous	1 patient with exposition of the mesh with 2 weeks of post-op	31.80% Vertical and horizontal are not separated	Not shown
El Morsy et al., 2020 [9]	Series of cases	Individualized mesh	14 patients	No	Xenogeneic + autogenous	1 patient with exposition of the mesh; 1 patient with the need of a new GBR procedure prior to the implant installation.	Vertical 3,47mm Horizontal 3,42mm	Not shown
Pelegrine et al., 2020 [13]	Series of cases	Support matrix	4 patients	No	2 casos – xenogeneic 2 cases – xenogeneic + autogenous	No complications	Horizontal 6,81±1,33mm	Not shown
Li et al., 2022 [12]	Finite element analysis and in vivo study (dogs)	Individualized mesh	3 dogs	Titanium and pericardium membrane o	Xenogeneic + autogenous	No complications	42.11±2.94%	Not shown
Gouda et al., 2023 [11]	Series of cases Splitmouth	Individualized mesh	8 patients	Titanium	Autogenous	1 patient with exposition of the mesh - 30 days post-op	Horizontal 28,53%	Not shown
Macedo et al., 2023 [14]	Series of cases	Support matrix	10 patients	No	5 cases – xenogeneic 5 casos – Xenogeneic + autogenous	No complications	Horizontal HAC 4 – 6,65 ± 1,09mm HAC 3 – 4,45 ± 0,75mm	Not shown
Nunes et al., 2023 [5]	Case report	Support matrix	1 patient	No	Xenogeneic + autogenous	No complications	It was not measured	18 months
Shi et al., 2022 [10]	Review of the literature	Individualized meh	-	Titanium PLLA	-	-	-	-

capsules. PEEK is a material with good mechanical properties and biocompatibility with both bone and soft tissue, and it also allows for customization and manufacturing through milling, 3D printing, or injection molding [8-9]. This way, the purpose of this review of the literature is to investigate and analyze the recent applications of PEEK on alveolar bone reconstructions.

Materials and Methods

A search in the literature was performed for articles in which a relation between the use of PEEK with bone or tissue reconstructions in guided bone regeneration was established. One researcher performed the search in the data plat-forms PubMed and Google Schoolar, with the keywords “peek bone graft”, on April 6, 2024 and “peek bone recon-struction” and “peek tissue reconstruction” on April 5, 2024. It was also performed a search for “guided tissue regen-eration”, on April 16, 2024, with the filters “full text”, “clinical trial”, “meta-analysis”, “systematic review” and “last 5 years”.

As inclusion criteria, articles that related guided bone regeneration and PEEK were selected, if they were available as full text for reading and written in the English language. Articles that neither present PEEK in the guided bone regen-eration, nor were available as full text or were written in a different language rather than in English were excluded.

Evaluation of the articles concerning the type of study, technique used, number of subjects assessed, comparison with other biomaterials, type of graft associated, reported complications, bone gain, and follow-up time.

After selecting the articles, the abstracts of each article were read, followed by a full reading. The references of the included articles were also reviewed to identify additional studies meeting the inclusion criteria.

Results

In total, 8 articles were selected, 5 of which involved the use of PEEK meshes [1,9-12] and other 3 with the use of PEEK as support matrix [5,13-14]. The included studies may be observed in Table 1.

BGR techniques using PEEK

The technique proposed by Mounir and colleagues in 2019 [1] involves virtual planning for the fabrication of PEEK meshes. This technique arose from the need for a substitute material for titanium due to the associated complication rate, including dehiscence, loss and fracture of screws, and infection, attributed to the difference in elasticity modulus compared to bone tissue. The elasticity modulus of PEEK is similar to that of bone tissue, justifying its choice. In this study, using patients' computed tomography scans, DICOM files were generated and PEEK meshes were planned and milled. The meshes were designed to fit the ridge, allowing for graft placement inside in contact with the ridge requiring guided bone regeneration (GBR). Autogenous bone graft was combined with xenogeneic bone and the mesh was fixed. The study compared PEEK meshes with titanium meshes and evaluated 32 implants in 16 patients, equally divided between the two groups. In regions where titanium meshes were installed, pre-modeling of the plates was performed. Results showed one case in each group of mesh exposure, which was conservatively managed with saline irrigation. Implant rehabilitation was successfully achieved in all patients. No statistically significant difference in bone gain was found between the two techniques.

El Morsy et al., 2020 [9], conducted a study with 14 patients treated with PEEK meshes. One patient experienced mesh exposure one week postoperatively, which was managed conservatively with saline irrigation until healing. Another patient had poor-quality bone and the presence of fibrous tissue, necessitating a new GBR procedure and delaying implant rehabilitation.

Pelegrine et al., 2020, designed the Barbell technique [13], which involves the installation of a vertical or transalveo-lar screw into the receptor site, followed by the insertion of a PEEK capsule at the ends. The capsule serves to protect the soft tissues, preventing damage from the screws and avoiding collapse of the tissue over the graft. Additionally, the capsule is inserted after the screw, allowing placement from either the buccal or palatal/lingual side, addressing issues encountered with other techniques where the conventional screw is inserted from the buccal side [13]. Nearly 30% of alveolar bone loss post-extraction occurs on the lingual/palatal aspect. Therefore, such defects cannot be over-looked [15]. The authors conducted a study where two patients were classified as HAC 3, receiving only xenogeneic grafts, and two others as HAC 4 (according to the HAC classification by Pelegrine et al., 2018 [16]), where xenogene-ic biomaterial was combined with bone. As a result, bone gain was 6.81 ± 1.33 mm, allowing for implant placement [13].

Li et al. in 2022 [12], conducted a comparative study between titanium and PEEK meshes customized with pericardi-um membranes, with 6 samples in each group. Finite element analysis and in vivo studies were performed in dogs. Both types of meshes were installed in the same animals. Results showed that the titanium mesh had higher stress resistance and lower deformation compared to PEEK. In the in vivo studies, the results for framework maintenance and osteogenic capacity were similar between the two groups, with both showing superior outcomes compared to per-icardium membranes.

Gouda et al., 2023, conducted a split-mouth study [11] with the objective of comparing titanium and PEEK meshes. Both autogenous and xenogeneic grafts were used. One patient in each group experienced mesh exposure. Both cases were managed conservatively, without affecting the placement of implants. Histologically, the titanium mesh group showed mature, organized lamellar bone, while the PEEK group exhibited less mature bone tissue with interspersed xenogeneic particles. Additionally, there was a significantly greater amount of newly formed bone in the titanium group. The authors suggest that the macroporosity of titanium may have contributed to this result by allowing extra-cellular nutrient diffusion through the membrane.

Macedo et al., 2023 [14], performed the Barbell technique in 10 patients, with five classified as HAC 3, receiving only xenogeneic grafts, and the other five classified as HAC 4, receiving autogenous grafts combined with xenogeneic grafts. After 6 months, they observed bone gains of 6.65 ± 1.09 mm and 4.45 ± 0.75 mm for HAC 3 and HAC 4, re-spectively. Implant placement and subsequent prosthetic rehabilitation were successfully completed in all cases. No complications were reported.

Nunes et al., 2023 [5], describe the clinical case of a 59-year-old female patient who had previously undergone implant placement in the maxilla with unsatisfactory aesthetics. Reconstruction was performed using the Barbell technique, involving the installation of 2 vertical and 1 horizontal screws. The graft used was a combination of xenogeneic and autogenous materials. After 9 months, the device was removed, and the authors report that the outcome was satisfactory, with successful implant placement. No complications were reported by the authors.

Discussion

The ideal material should have biomechanical and biochemical characteristics similar to the tissue being repaired, such as conforming to the defect, ease of sterilization, selective permeability, space maintenance, ease of manipula-tion, resistance to heat and mechanical damage, biocompatibility, chemical inertness, and should not alter imaging results [9,10]. The need for these characteristics justifies the use of PEEK in guided bone regeneration (GBR), as it is a chemically inert material, resistant to fatigue and masticatory forces [11-12,17-20], with a hydrophobic surface that may limit its ability to promote protein absorption, cellular adhesion, and consequently enhance osseointegration [17-18]. However, other authors note that the capsule may not withstand the compressive forces of complete dentures [5].

Although the use of titanium has been widespread for years [9-11], the difference in elasticity modulus compared to cortical bone is significant. As a result, various complications are reported, such as dehiscence and migration of the mesh, screw loss and fracture, which may necessitate a revision of the procedure [17]. PEEK devices are rigid enough to prevent subsidence but without causing damage to the tissue, with a reduced incidence of graft material exposure [5,10,12,17]. However, a disadvantage compared to titanium is the lack of osteogenic potential and integration with bone tissue [9].

The PEEK mesh presents limitations compared to its use as a support matrix, as it requires the use of autogenous grafts in all cases, whereas the latter allows, depending on the ridge profile of the patient, the exclusive use of the biomaterial. This is due to the fact that tissue nourishment occurs only through the receptor bed and is limited by the soft tissue. In three of the studies, mesh exposure was reported [1,9,11], one of which involved poor-quality bone and the presence of fibrous tissue, necessitating a new GBR procedure prior to implant rehabilitation [9]. In contrast, in the studies where PEEK was used as a support matrix, no patient experienced complications [5,13-14].

Regarding bone gain with the use of meshes, the reported gains were 28.53% [11], and 3.47 mm and 3.42 mm horizontally and vertically, respectively [9]. In contrast, other studies reported gains of 42.11 ± 2.94% [12] and 31.8% [1], without differentiation between vertical and horizontal. For the technique where PEEK was used as a support matrix, the gains were 6.65 ± 1.09 mm and 4.45 ± 0.75 mm [14], varying according to HAC classification, and 6.81 ± 1.33 mm [13]. One clinical study did not measure bone gain [5].

Both techniques require tomography for planning. However, in addition to planning, the mesh technique involves the fabrication and printing of meshes, which increases the cost of the procedure and extends the preoperative time.

This present review presents as limitation the fact that it has few studies on the matter. Only five studies in the litera-ture were found regarding PEEK meshes, meanwhile regarding the use as support matrix, three studies were found. This is due to the fact that these are new technique and are still not widely adopted among surgeons. Further studies with postoperative follow-up of installed and functional prostheses are needed for better evaluation.

Conclusion

In summary, the use of PEEK for Guied Bone Regeneration (GBR) follows the same trends in the medical field, with an increasing tendency. Few studies in the literature establish this relationship, with limited sample sizes and short-term follow-up. Therefore, further research with a larger number of patients is needed for a better evaluation of the techniques and validation of the results.

Author's Contributions

FCC: Data collection, data analysis and interpretation, drafted manuscript, critically revised manuscript. MBM: data analysis and interpretation, drafted manuscript, critically revised manuscript. FVR: data analysis and interpretation, drafted manuscript, critically revised manuscript. TCP: Data analysis and interpretation, critically revised manuscript, translation to English. RDN: Data analysis and interpretation, critically revised manuscript.

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