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The efficiency of two different synthetic bone graft materials on alveolar ridge preservation after tooth extraction: a split-mouth study

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Abstract

Background Alveolar Bone loss occurs frequently during the first six months after tooth extraction. Various studies have proposed different methods to reduce as much as possible the atrophy of the alveolar ridge after tooth extraction. Filling the socket with biomaterials after extraction can reduce the resorption of the alveolar ridge. We compared the height of the alveolar process at the mesial and distal aspects of the extraction site and the resorption rate was calculated after the application of HA/β-TCP or synthetic co-polymer polyglycolic - polylactic acid PLGA mixed with blood to prevent socket resorption immediately and after tooth extraction.

Methods The study was conducted on 24 extraction sockets of impacted mandibular third molars bilaterally, vertically, and completely covered, with a thin bony layer. HA/β-TCP was inserted into 12 of the dental sockets immediately after extraction, and the synthetic polymer PLGA was inserted into 12 of the dental sockets. All sockets were covered completely with a full-thickness envelope flap. Follow-up was performed for one year after extraction, using radiographs and stents for the vertical alveolar ridge measurements.

Results The mean resorption rate in the HA/β-TCP and PLGA groups was ± 1.23 mm and ± 0.1 mm, respectively. A minimal alveolar bone height reduction of HA/β-TCP was observed after 9 months, the reduction showed a slight decrease to 0.93 mm, while this rate was 0.04 mm after 9 months in the PLGA group. Moreover, the bone height was maintained after three months, indicating a good HA/β-TCP graft performance in preserving alveolar bone (1.04 mm) while this rate was (0.04 mm) for PLGA.

Conclusion The PLGA graft demonstrated adequate safety and efficacy in dental socket preservation following tooth extraction. However, HA/β-TCP causes greater resorption at augmented sites than PLGA, which clinicians should consider during treatment planning.

Keywords HA/β-TCP, PLGA, Periodontal bone loss, Dental socket preservation, Teeth removal

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Background

Over the past decades, dental implants have begun to be a widespread treatment; however, tooth extraction associated with bone loss in both height and width over time is still a problem when planning dental implants. The height of the alveolar process at the mesial and distal aspects of the extraction site is a reliable indicator to assess the level of bone volumetric changes. Schropp et al. have reported that linear measurements on radiographs at the mesial and distal sites of the extraction socket almost corresponded to the level of the bone generated into the socket. They demonstrated that the loss of the height of the alveolar bone crest mainly occurred within the first 3-month period after tooth extraction, while reorganization of lamina dura occurs during the entire healing period [1]. It is expected that the height and width of the alveolar ridge shrinkage by 40-60% after tooth extraction and continue within the first 2–3 years of extraction [2]. This negatively affects the size of the bone that is necessary for dental implants and prosthetics. Appropriate continuous mechanical stimulation of the periodontal ligament is a fundamental factor in keeping the height of the alveolar bone in natural teeth [3]. Mechanical stimulation directed to the bone is stopped immediately after tooth extraction, thus, it is necessary to support the walls of the alveolus to avoid destruction and to minimize the atrophy of the alveolar ridge [4]. Multiple studies have evaluated the reduction of the alveolar ridge after tooth extraction. These studies have shown that the resorption rate of the alveolar ridges is faster during the first six months after the extraction [2]. The resorption of the alveolar ridge seems to be greater in the molar region [5]. Tan WL et al. have reported a lesser vertical reduction (11–22%; 1.24 mm on the buccal, 0.84 mm on mesial, and 0.80 on distal sites) than horizontal (29–63%; 3.79 mm) at 6 months [6]. Moreover, the bony resorption of the posterior region of the mandible occurs in the labial direction, leading to a lingual orientation of the alveolar ridge [7]. The rate of regression of the alveolar ridge is bigger in the mandible, at a rate of 0.4 mm per year, while the rate of regression of the alveolar ridge in the maxilla is 0.1 mm annually [8]. Periodontal defects at the distal aspect of the mandibular second molar are confirmed after removal of the overlying alveolar crestal bone of the third molar, thus may cause a deep bone defect distal to the second molar extending down to the base of the extraction socket [9]. Various studies showed that 43.3% of the cases result in probing depths of 7 mm or greater 2 years after removal of the third molar [10]. Studies have proposed different methods to reduce as much as possible the atrophy of the alveolar ridge after tooth extraction [11, 12]. Autografts are considered the standard for large bone defects, but donor site morbidity makes them limited to use [13]. On the other hand, allografts can be used for small defects, but this implies a bone bank with a potential risk of transmission of infections and immune adverse reactions [14]. Bone substitutes are synthetic combination biomaterials that can be used as a scaffold to preserve the height of the alveolar bone after tooth extraction. Currently, hydroxyapatite (HA), β-tricalcium phosphate, and calcium phosphate are widely used, but the challenge is to form a scaffold with biologically active molecules, and living cells and promote bone regeneration [15]. Generally, bone grafts are used to bridge the bone between the edges of the graft and the edges of native bone segments. Gradually the new bone replaces the graft [16]. The application of HA with tricalcium phosphate mixed with blood is a perfect osteoconductive scaffold and becomes strongly anchored by fibrous tissue into the alveolar cavity after tooth extraction [17]. Hydroxyapatite generally is considered non-bioresorbable, and also offers strength and stability, while Tricalcium phosphate is ultimately partially bioresorbable and does not elicit any inflammatory or foreign body responses [18]. The biomechanical rationale for their use is that bone growth within the pores will give these materials strength. The most important phenomenon for calcium phosphate is its ability to bond strongly to living bone and can show directed growth characteristics, making bone growth extend to areas that it would not otherwise [19]. The combination of 75% hydroxyapatite and 25% tricalcium phosphate can provide a good balance of mechanical properties [20]. Synthetic polymers such as polyglycolic acid, polylactic acid, and polycaprolactone are comparable to autograft, but it was found that they have bad incorporation and implement poorly on radiographic estimation with elevated rates of graft breakdown, nonunion, and displacement [21, 22]. However, the use of PLGA copolymers in grafting into defects is advantageous due to their biocompatibility, biodegradability, tunable degradation rate, and mechanical properties [23]. Both HA/β-TCP and PLGA are widely used in clinical practices (Alveolar ridge augmentation, Alveolar bone protection after tooth extraction, Restoration of periodontal bone lesions) [24]. Intraoral radiographs could be adequate to measure bone resorption in sites. Luangchana et al. reported no difference between CBCT and panoramic radiography in the mean measurement difference of vertical alveolar bone, particularly in the mandible [25]. These findings are supported by Eachempati et al., who found a high correlation between the height of alveolar ridge measurement in CBCT and panoramic radiography utilizing metallic ball markers as fiducial markers [26]. However, many in vivo clinical studies reported submillimeter differences between CBCT and conventional radiographic measurements without a statistically significant difference [27]. Radiographic assessment of alveolar crest height levels

allows for the accurate evaluation of vertical or horizontal bone defects. However, more homogeneous research protocols with standardized outcome variables and follow-up times are needed to assess and compare the application of different graft materials in alveolar ridge preservation procedures [28]. Our study aimed to compare the ability of two bone substitutes to preserve alveolar ridge anatomy following tooth removal.

Methods

Study design and sample selection

Fifteen participants were included in this study, ranging in age from 18 to 31 years (mean 23.8). The study was conducted on twelve patients (33.3% males, and 66.7% females). The participants were recruited from Outpatient clinics at Wadi International University & Arab University for science and technology and followed up through one year. The inclusion criteria include patients referred by the orthodontists with mandibular impacted third molars bilaterally, vertical, or slightly sloping to the medial and completely covered, either by a layer of periosteal mucosa only or with a thin bony layer. Completed medical and dental history was taken from all patients, the alveolar bone was evaluated and the panoramic image was considered as a diagnostic guide for the impaction. Exclusion criteria include smoking, patients with systemic diseases, and pathology in the involved area. Also, three patients were excluded because we could not follow up on them. Patients were fully informed about the treatment applied and the complications of surgical procedures. The study was conducted under the Helsinki Declaration for medical studies and was approved by the ethical committee (approval protocol number: 480.2/116). Written informed consent was obtained from all patients.

Surgical methods

All Patients were subjected to a standardized surgical protocol by the same surgeon and another operator carried out the postoperative measurements. Before surgery, the mouths were rinsed with a chlorhexidine digluconate solution of 0.2% for 2 min. With local anesthesia 2% lidocaine with epinephrine 80,000/1, full-thickness envelope flap were reflected to expose the alveolar crest, using a horizontal incision on the top of the lateral alveolar process of the second molar extending over the vestibule lateral to the first molar. Bone removal is started in the lateral cortex 2 to 3 mm below the bony crest using an electric surgical handpiece and a round surgical bur. The anterior part of the buccal crest was 1 to 2 mm away from the distal root of the second molar, then; a straight elevator was placed to elevate the impacted molar with minimum damage to the bone around the tooth. For the same patient, at the one halve, 75% hydroxyapatite+25% β-tricalcium phosphate (powder) was used, while at the other halve, a co-polymer of polyglycolic-polylactic acid (powder) (PLGA) was used. The graft was mixed with a little blood (growth factors) taken from the alveolar cavity after extraction and then tamponades within the alveolar cavity to the level of the remaining alveolar margin borders, taking great care to press it within the cavity with a gauze pad moistened with saline, excluding the surgical suction from the area of application. A mattress suturing on the top of the alveolar process was performed. The patients received detailed verbal and written postoperative instructions. Antibiotic therapy consisting of Augmentin 1000 mg twice daily for five days and mouth rinsing with 0.2% chlorhexidine mouthwash, analgesics every 8 h for 10 days were prescribed. The suture was removed one week postoperatively.

Clinical assessment

The patient was clinically monitored every week until the first three months of surgery. No complications, complaints, or dehiscence of the wound occurred during the follow-up for one year.

Radiographic assessment

There is currently insufficient evidence to compare the effectiveness of autogenic graft materials in alveolar ridge preservation techniques based on CBCT scan assessments [28]. Conventional radiographic methods do not involve irradiation to the patient, it is low cost and gives immediate evaluation of the height of the alveolar ridge. The ideal radiograph should include the complete area of interest and allow assessment of alveolar crest levels. Over the past several years, digital radiographs have been used frequently in dental practice. Nevertheless, digital detectors are not flexible in the mouth like traditional X-ray films. Radiographic analysis requires a standardized geometry to minimize angulation differences that introduce errors in the measurements. In our study, the radiographic evaluation was carried out immediately after tooth extraction, directly after application of the graft, 3 months, 6 months, 9 months, and 1 year postoperatively using a parallel projection technique with standardized geometry. To minimize the geometric distortion, a stent with a length of 10 mm was fixed on the film to be used as a guide in calculating the magnification ratio. Moreover, a piece of silicone was applied to the film holder from the upper and lower occlusal aspect, so the film is placed laterally as much as possible to cover all borders of the area at the same position (Fig. 1). The radiographic images taken were transferred to the AutoCAD program for the measurements. On each radiograph a horizontal line connecting the lateral cusps of the first and second molars was created and extended laterally, then a vertical line was created perpendicular

Fig. 1 The film holder is from the upper and lower occlusal aspect, so the film is placed laterally as much as possible to cover all borders of the area at the same position

to the horizontal line and passed from the furthest point on the lateral surface of the second mandibular molar, thereafter, 5 parallel lines were created parallel to the first vertical line, with a distance of 2 mm between them covering all area of bone augmentation. A stent was used as a scaling reference. Subsequently, the alveolar height was determined so five points were fixed to measure the height of the alveolar ridge, and the average of 5 distances was calculated in each of the studied observation periods (Figs. 2 and 3). Linear measurements were taken by the same calibrated examiner. The alveolar height was determined by calculating the arithmetic mean of the heights at the five measured points on each radiograph. To find the real alveolar height in each radiograph, this mean value was multiplied by the length of the stent measured in the radiograph (in mm) and then divided by 10. The amount of resorption was then determined as the difference between the initial and subsequent real alveolar heights for each studied case.

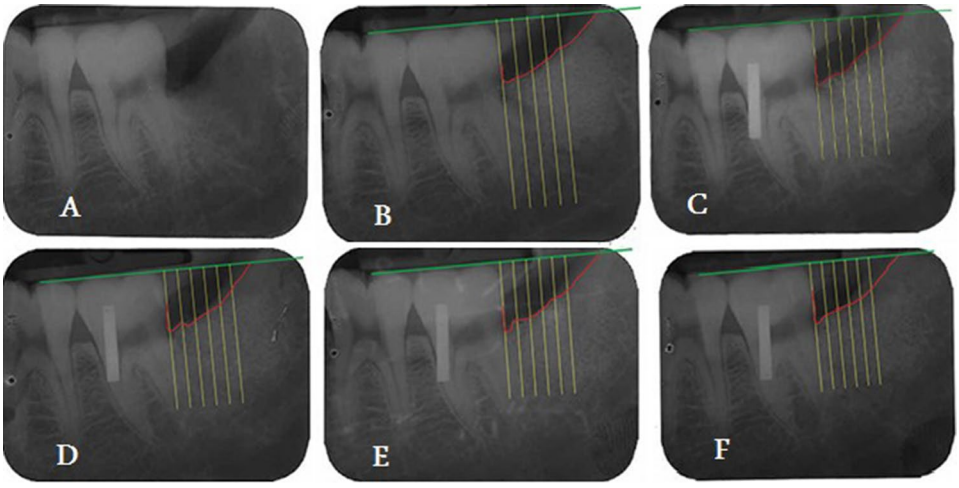

Fig. 2 Radiographs of (HA+ β-tricalcium phosphate) graft before and after the implantation. (**A**) Before, (**B**) Immediately, (**C**) 3 months, (**D**) 6 months, (**E**) 9 months, (**F**) 1 year

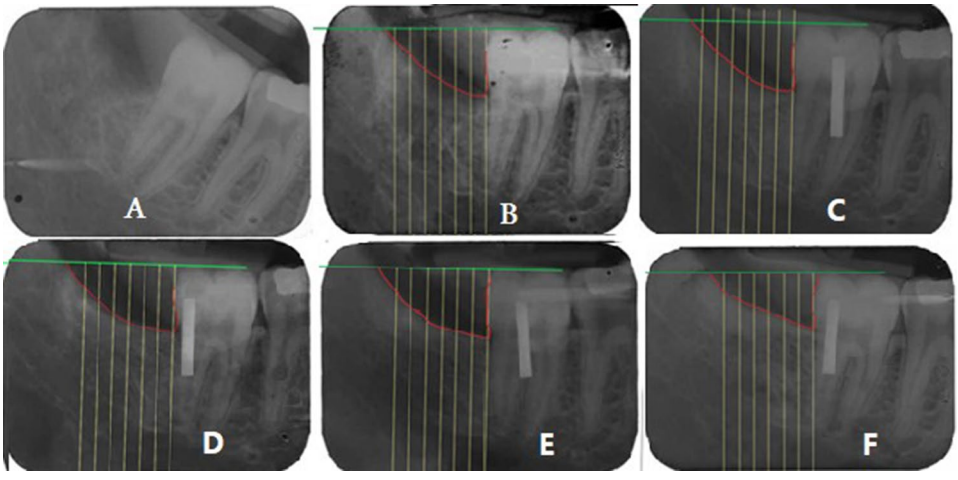

Fig. 3 Radiographs of PLGA graft before and after the implantation. (**A**) Before, (**B**) Immediately, (**C**) 3 months, (**D**) 6 months, (**E**) 9 months, (**F**) 1 year

Table 1 The arithmetic mean, standard deviation, and standard error of the amount of bone resorption (in mm) in each of the studied periods and the type of graft used

Periods	Graft	*N*	M	SD	SE
3 months	HA + β-TCP	12	1.04	1.48	0.43
	PLGA	12	0.04	1.13	0.33
6 months	HA + β-TCP	12	1.02	1.4	0.4
	PLGA	12	0.13	1.18	0.35
9 months	HA + β-TCP	12	0.93	1.66	0.48
	PLGA	12	0.04	1.15	0.33
12 months	HA + β-TCP	12	1.23	1.45	0.42
	PLGA	12	0.01	1.12	0.32

Table 2 The results of the independent Student's T-test for the significance of the differences in the amount of bone resorption (in mm) between the HA + β-TCP group and PLGA group in the research sample, according to the measurement period. * A P value below 0.05 ($P < 0.05$) was deemed significant

Periods	Ave. difference	St. error	*P*-Val	T-Val
3 months	1.01	0.54	0.075	1.871
6 months	0.9	0.54	0.112	1.659
9 months	0.89	0.58	0.141	1.529
1 year	1.22	0.53	0.031*	2.307

Statistical analysis

To evaluate the significance of the differences in the average amount of bone resorption (measured in mm) between the two groups (HA + β-TCP and PLGA) at various observation periods (3 months, 6 months, 9 months, and 1 year), a Student's T-test for independent samples was conducted. Before the analysis, the assumption of normal distribution of resorption rates was assumed. Differences were considered statistically significant when the P value was below 0.05. This analysis allowed for the comparison of bone resorption rates between the groups at each specific time interval (see Table 1 for detailed results).

Results

The study was conducted on twelve patients (33.3% males, and 66.7% females), the average age was 23.8 (18–31) years. Our results reveal that there was no effect of the patient's gender on the amount of bone resorption regardless of the time of measurement. It is noted in Table 2 that the value of the significance level is smaller than the value of 0.05 after one year, that is, at the 95% confidence level, there are statistically significant differences in the average amount of bone resorption (in mm) after one year of implantation between the two groups. We conclude that the amount of bone resorption after one year in the HA+β-TCP group graft was greater than in the PLGA group in the research sample. As for the rest of the periods studied (after 3 months, after 6 months, after 9 months), it is noted that the value of the significance level is greater than the value of 0.05, meaning at the 95% confidence level, there are no statistically significant differences in the average amount of bone resorption after 3 months, after 6 months and after 9 months between the group of cases with HA+β-TCP graft and PLGA graft, there was no effect of the type of graft on the amount of bone resorption after 3 months, after 6 months and after 9 months in the research sample (Fig. 4).

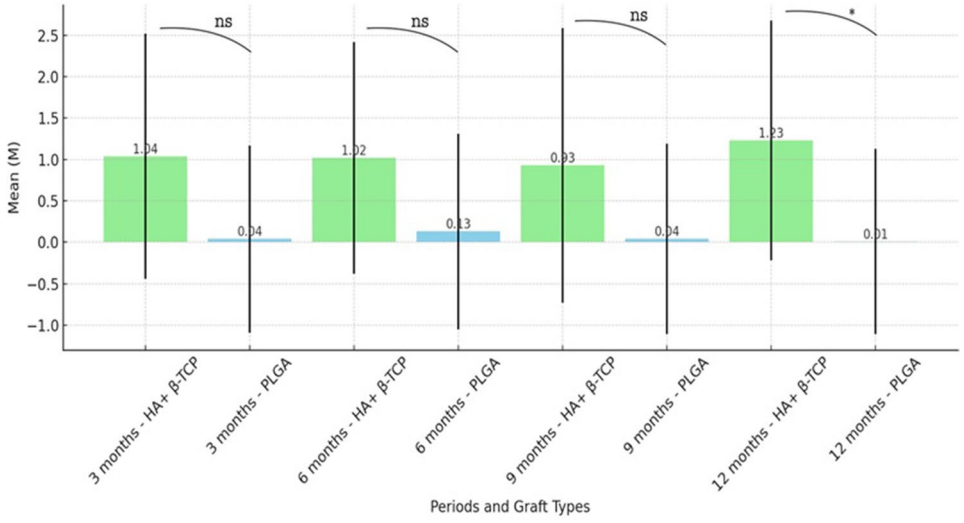

Fig. 4 Differences in average bone resorption between patient groups depending on the period and graft status, including average, standard deviation, and statistical significance in the difference of mean resorption based on intra-periodic Student's T-test analysis comparing the two graft statuses (ns - not significant; * - $P<0.05$)

Discussion

Alveolar bone is gradually absorbed and converted into woven bone after tooth extraction [29] leading to a prominent reduction in bone height particularly in the buccal side of the alveolus [4]. Many methods can be offered to maintain the height and width of the alveolar ridge after tooth extraction. Clinical and radiological investigations proved that none of the grafts had dehiscence, whether in HA+β-TCP graft or PLGA graft, for this reason, many types of grafts were used. Healing occurs with or without grafting, when the alveolus is not grafted the blood clots fill up the alveolus then woven bones are remodeled causing the horizontal and vertical ridge reduction. However, resorption is reduced when the alveolus is grafted [30]. Both HA+β-TCP and PLGA are biocompatible materials and tend to occlude tissue ingrowth [31]. Regardless of the type of bone graft, combined with blood or not they might accelerate bone ingrowth and result in bone creation [32]. However, to date, there have been few histological examinations of implanted H+β-TCP or PLGA combined with growth factors concerning bone resorption. Histological observation of β-TCP graft suggests that osteogenesis and resorption occurred simultaneously [33], also, continue over time, while the PLGA graft is more effective in stimulating bone formation and the resorption process is weaker over time [34]. The resorption rate of the alveolar ridges is quick during the first six months after the extraction and proceeds at an average of 0.5–1.0% per year [6]. Biomaterials HA+β-TCP or PLGA are exceedingly used to increase the rate of bone formation, which is required to conduct advanced procedures for dental implants. The healing process takes approximately 12 to 16 weeks [35]. Schropp et al. deduced that two-thirds of the affected bone succumb to a few degrees of resorption through the first three months post-extraction [1]. Almost 50% of the alveolar bone width is missed within 12 months after tooth extraction, and 30% (a 3.8-mm change) appears within the first 12 weeks [36]. Clinical and radiological studies demonstrate that none of these grafts outperforms the other, for this reason, different types of membranes were used either alone or with these grafts to support bone formation especially when the initial closure of the soft tissues surrounding the alveolar cavity is not achieved [37]. Our study reveals that the arithmetic mean of bone resorption for the areas grafted with HA+β-TCP is greater than that of the areas of PLGA during most of the imaging periods. Moreover, it is concluded that the rate of 75% hydroxyapatite+25% β-tricalcium may help slow resorption, but hinder the processes of bone formation, which leads to rapid resorption of the alveolar ridge. This rate, one year after applying the graft, indicates that the modeling phase of this graft has not ended. Our study revealed that there was a difference between the two grafts in resorption of PLGA because the P value after one year of applying the graft is less than 0.05, i.e. $P<0.05$ at a 95% confidence level. However, regardless of the patient's gender and whatever the time of measurement, we have noted that there are no statistically significant differences in the average bone resorption of HA+β-TCP graft and PLGA, that is, there is no difference in the use of any of the two grafts, whether in males or females. We believe that this lack of influence is because the female group was not subject to additional physiological changes, such as pregnancy and lactation, which may affect bone metabolism. Finally, our study is limited to radiographic evaluation. We believe that the healing process evaluation at the alveolar bone surface after bone grafting should be evaluated via histological methods.

Conclusion

It seems that mixing the blood with a combined biomaterial (hydroxyapatite and calcium-phosphate) is a good osteoconductive scaffold and becomes strongly anchored by fibrous tissue into the alveolar cavity after tooth extraction. Moreover, this study improved success for both grafts (HA+β-TCP, PLGA). PLGA graft material was resorbed and replaced by a normal-looking bony network after a year, while still cassock granules within the alveolar cavity on HA+β-TCP graft radiograph. The largest bone resorption in the HA+β-TCP graft was 1.23 mm, while the bone resorption in the PLGA graft did not exceed 0.01 mm so the PLGA graft is the most conservative of the alveolar height, one year after its application.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-024-04803-8.

Supplementary Material 1

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Author contributions

S. O.: Conceptualization, Methodology, Investigation. M. K.: Methodology, Writing original draft, Visualization, Investigation, Writing- Reviewing and Editing.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval

The study was approved by the local ethics committee of the Arab University for Science and Technology (EC Ref No. : 1/1/2021).

Consent for publication
Not applicable.

Informed consent
The study was conducted in compliance with the recognized international standards, including the principles of the Declaration of Helsinki. Data and samples were collected under the patient's informed written consent following the ethics committee.

Competing interests
The authors declare no competing interests.

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