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Partial nasal bone reconstruction with acrylic bone cement: experimental study

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Abstract

Background: The aim of this study was to evaluate the effectiveness of acrylic bone cement in partial nasal bone reconstruction.

Methods: This study was conducted using nine New Zealand rabbits. The left nasal bones of the rabbits were included in the experimental group, and the right nasal bones were evaluated as the control group. The partial bone segments on the bilateral nasal bones were marked and removed symmetrically. A synthetic graft material made of acrylic bone cement was placed in experimental group, and the partial bone segment removed from the right side was placed in control group as an autograft. All rabbits were sacrificed at the end of the 28th day. Samples were taken from the grafts and from the surrounding soft tissues for histopathological examination. Acute inflammation, chronic inflammation, vascularization, fibrosis, foreign body reaction, bone proliferation, and the presence of empty lacunae were evaluated under a light microscope for both groups.

Results: Surrounding soft tissue on synthetic and autograft were the same in terms of chronic inflammation. There was no statistically significant difference for vascularization, fibrosis, and foreign body reaction. Synthetic graft and autograft were the same in terms of chronic inflammation, fibrosis, and bone proliferation. There was no statistically significant difference for vascularization, foreign body reaction, and presence of empty lacunae ($p > 0.05$).

Conclusion: This study showed no significant differences between the use of acrylic bone and the use of an autograft for partial nasal bone reconstruction in terms of graft or tissue healing. Acrylic bone cement may therefore serve as a good alternative for nasal bone reconstruction.

Keywords: Acrylic bone cement, Septorhinoplasty, Graft, Rhinoplasty

Background

The nasal bone is an important component of the nasal root as well as the bone roof of the nose [1]. Grafts play an important role in nose surgeries performed for medical or aesthetic purposes [2, 3]. Autografts or allografts can generally be classified as rigid and soft, and those with a hard structure can usually be used to support the structure or support the nasal bone [4]. Autografts have some disadvantages, such as donor area morbidity, increased surgical time, and risk of bending or resorption, despite their advantages, such as low risk of rejection and biocompatibility. Allografts also have several advantages, such as durability and reduced surgical time; their main disadvantages are higher cost and risk of rejection or infection [3, 5].

Polymethyl methacrylate (PMMA) is commonly known as bone cement. Bone cement has been used in orthopedic surgeries for approximately 60 years [6]. Bone cement is first used in the form of a fluid and then hardens immediately after use. Common procedures in which bone cement is used include arthroplasty, joint reconstruction, detection of pathological fractures, filling of bone defects, vertebroplasty, kyphoplasty, and cranioplasty [6]. Because bone cement is a formable material, it can be

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used as an allograft in open rhinoplasty. The aim of the present study was to compare the results of a synthetic nasal bone graft made from acrylic bone cement with the results of a nasal bone autograft in rabbits.

Methods

The Experimental Animals Ethical Committee approved the study protocol (24.04.2018, 18/14). All applicable institutional and national guidelines for the care and use of animals were followed.

In this study, a total of nine young adult male albino New Zealand rabbits were used, including one for the preliminary study and eight for the main study. The ages of the rabbits ranged between 14 and 16 weeks, and their weights ranged between 2.5 and 3.5 kg. The rabbits were housed at 22 ± 2 °C, at 60–70% humidity, and in standard laboratory conditions with 12-h light and 12-h dark periods and were fed with standard rabbit feed and water. Upper-anterior, right-side, left-side, and oblique photographs were taken of all animals prior to the surgical procedure.

Surgical procedure

The operation was performed under general anesthesia using 50 mg/kg ketamine hydrochloride (Ketalar, Eczacibasi, Turkey) and 5 mg/kg xylazine (Rompun, Bayer, Germany) intramuscularly. The intercantal distance was measured and recorded in all rabbits before surgery was started. After the surgical area was cleaned, 2 ml of 20 mg/ml lidocaine hydrochloride and 2 ml of 0.0125 mg/ml epinephrine hydrochloride (Jetokain, Adeka 32 İlaç ve Kimyasal Ürünler San., Turkey) were applied as infiltration anesthesia.

After a vertical incision was made on the nasal dorsum, the skin and subcutaneous tissue were dissected and the nasal bones became visible. On both sides, the rectangular bone segment with a short axis of 5 mm and a long axis of 20 mm was measured and marked on the nasal bones and then cut and removed with a saw. For all the rabbits, the left nasal bones were included in the experimental group and the right nasal bones were evaluated as the control group.

In the experimental group, negative molds of the removed bone segments were obtained using a silicone mold (Otoform® AK Dreve Otoplastic GmhH, Unnah/Germany). Afterward acrylic bone cement (ORTHOCEM 3, Teknimed S.A.S., Bigorre/France) was poured into each negative mold and left to harden for 10 min (Fig. 1). The new graft made from acrylic bone cement was placed into the defect area on the left nasal bone. In the control group, the removed bone segment was repositioned as an autograft in the same position on the right nasal bone. The skin and the periosteum were sutured and closed. External fixation was applied with a splint on the nasal dorsum, and the splint was removed 1 week later. A spray containing oxytetracycline (5 g) was applied to the postoperative incision sites. No complications were observed during the surgical procedure and post-operative period.

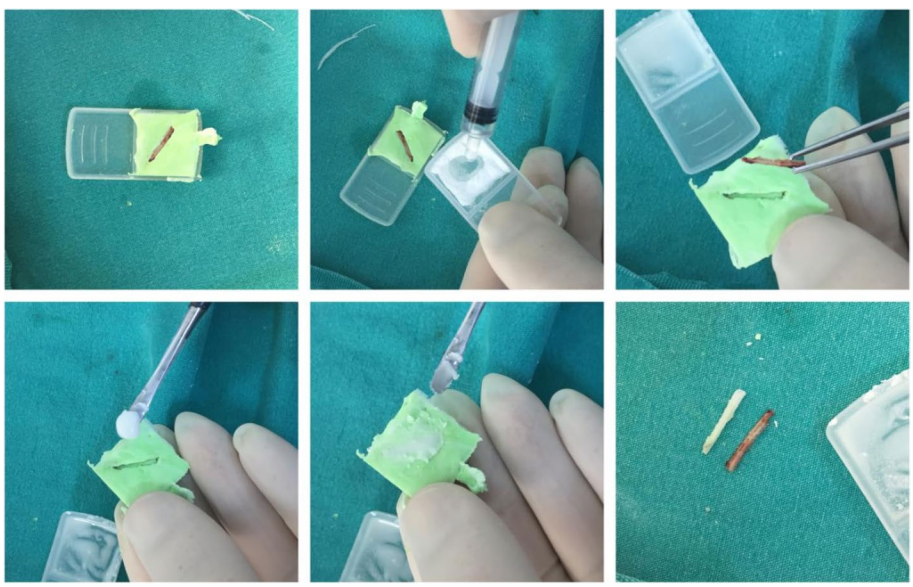

Fig. 1 Molding of the synthetic graft and production steps (left to right, top to bottom)

Sacrifice

After 28 days, the intercantal distances were measured and upper-anterior, right-side, left-side, and oblique photographs were taken again. Then, all the animals were sacrificed using pentobartital sodium® (150 mg/kg). The extracted specimens were stored in a 10% formaldehyde solution.

Histological examination

External fixation was done with a 5 × 5-cm patch. The fixation period is 1 week. The tissue samples were fixed in 10% neutral buffered formaldehyde at room temperature for 72 h. Then, they were decalcified in 10% formic acid. Increasing concentrations of alcohol (70%, 80%, 90%, 96%, and 100%) were used to ensure dehydration. After the samples were passed through xylol for transparency, they were embedded in paraffin. Five-micron tissue sections were taken, stained with hematoxylin-eosin, and examined under a light microscope (Nikon Eclipse 80, Tokyo, Japan). The images were transferred to a computer with a digital camera. Samples from both groups were evaluated under light microscopy by the same pathologist in a blinded fashion in terms of acute inflammation, chronic inflammation, vascularization, fibrosis, foreign body reaction, bone proliferation, and the presence of empty lacunae. Empty lacunae is a feature of osteocyte apoptosis/death.

Statistical analysis

The data were analyzed using the SPSS version 22.0 (IBM Corporation, Armonk, New York, USA) package program. A comparison of pathological changes between the experimental and control groups was conducted using the McNemar test. Variables were analyzed at a 95% confidence level, and a p value of less than 0.05 was considered significant.

Results

Macroscopic findings

Before the animals were sacrificed, their intercantal distances were measured again. There was no difference between the preoperative and postoperative intercantal distances. There were no complications, such as removal of the graft or displacement at the acrylic bone cement side. There was also no crepitation during palpation in either group, and no problems were observed in terms of wound healing. In the macroscopic evaluation following sacrifice, no significant differences were observed between the two groups in terms of vascularization, fibrosis, protrusions, or color changes. In both the experimental and control groups, the grafts were found to be fully compatible with the recipient bone tissue and to establish a tight connection with the surrounding tissues (Fig. 2).

Microscopic findings

The grafts and surrounding tissues were evaluated both in the experimental and control groups in terms of acute inflammation, chronic inflammation, vascularization, fibrosis, and foreign body reaction, under light microscopy after staining with hematoxylin and eosin. There was no evidence of acute inflammation on the graft or its soft tissue in either groups. Chronic inflammation and fibrosis were detected in the all grafts of both groups. Except one sample in each group, chronic inflammation was detected in all surrounding tissue samples in either groups. Although there are some different results in other parameters for graft and surrounding tissues, there was no statistically significant difference between the experimental group and the control group ($p > 0.05$). The microscopic findings of the graft surrounding tissue samples and the statistical comparisons between the two groups are shown in Table 1, the microscopic findings of the graft samples and the statistical comparisons between

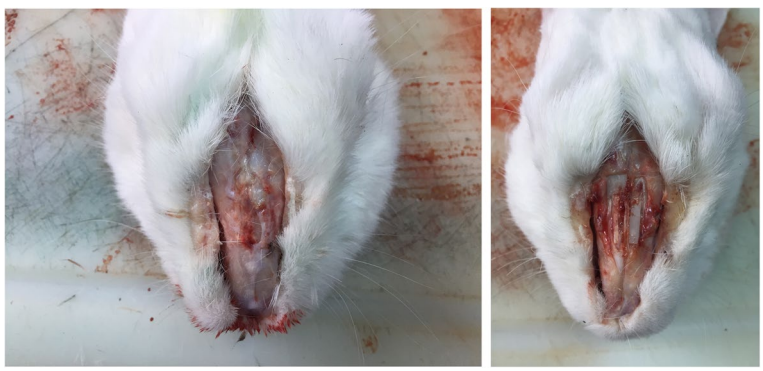

Fig. 2 Postoperative macroscopic examination (red arrow autograft, blue arrow synthetic graft)

the two groups are shown in Table 2.The histopathological samples of the experimental and control groups are shown in Figs. 3 and 4.

Discussion

Alloplastic materials are the subject of research with the goal of reducing donor morbidity. An ideal graft material should be stable, non-toxic, non-antigenic, cheap, and natural and show high biocompatibility. Many alloplastic materials are used today, but an ideal graft material having all these features is not yet available [7, 8]. In revision of rhinoplasty cases, the importance of allografts increases in patients who do not want scar tissue. Also, autografts such as bone and cartilage are not perfect. There are disadvantages such as malposition, resorption, limited resource, donor site morbidity [4, 9]. In the present study, bone segments were removed from the nasal bones of rabbits. Then, a new graft of the same size and shape as each bone segment was created with acrylic bone cement, and the outcomes of this new synthetic graft were compared with those of a nasal bone autograft. The results showed no statistically significant difference between the two groups in terms of recovery.

Frequently used alloplastic materials include polydioxanone (PDS), silicone, expanded polytetrafluoroethylene (ePTFE, GORE-TEX®), porous high-density polyethylene (Medpor®), and bioactive glasses. Silicone does not have a porous structure, does not fuse with tissue, acts more like a foreign body, and may produce an immune response for fibrous encapsulation formation [10]. Complications associated with silicone include protrusion (2.9%), infection (3.8%), capsule formation, graft displacement (9.8%), and graft drift (76.5%) [8]. Silicone bends easily and is therefore insufficient to support the nasal dorsum. Moreover, silicone cannot form enough volume for augmentation in cases of saddle nose deformity [10]. For these reasons, silicone is not considered an ideal implant material for the reconstruction of the nasal bone roof.

Polytetrafluoroethylene (PTFE, GORE-TEX®) is used for the reconstruction of the nasal skeleton. However, several studies have shown that PTFE usually causes a giant cell foreign body reaction and must be removed due to infection [11]. PTFE is also a soft material and is not preferred due to increased risks of graft infection, extrusion, and rejection [12]. Polidiaksanon (PDS) and polylactic foil have been found to be weak in terms of maintaining skin elasticity and nasal valve patency in cases of reconstruction. In addition, these materials have been reported to lose their mechanical stability within 2 months and have proven inadequate to support the septal skeleton [13]. Although hydroxyapatite

Table 1 The microscopic findings of the graft soft tissue samples and comparison of the pathological findings of the graft soft tissue samples between the experimental and control groups

	Soft tissue on synthetic graft (experimental)	Soft tissue on autograft (control)	*P* value
Acute ınflammation			
Positive	0	0	$p > 0.05$
Negative	9	9	
Chronic ınflammation			
Positive	8	8	$p > 0.05$
Negative	1	1	
Vascularization			
Positive	1	2	$p > 0.05$
Negative	8	7	
Fibrosis			
Positive	8	7	$p > 0.05$
Negative	1	2	
Foreign body reaction			
Positive	3	2	$p > 0.05$
Negative	6	7	

[a] McNemar test

Table 2 The microscopic findings of the grafts and comparison of the pathological findings of the graft samples between the experimental and control groups

	Synthetic graft area (experiment)	Autograft area (control)	*P* value
Acute ınflammation			
Positive	0	0	$p > 0.05$
Negative	9	9	
Chronic ınflammation			
Positive	9	9	$p > 0.05$
Negative	0	0	
Vascularization			
Positive	6	5	$p > 0.05$
Negative	3	4	
Fibrosis			
Positive	9	9	$p > 0.05$
Negative	0	0	
Foreign body reaction			
Positive	8	6	$p > 0.05$
Negative	1	3	
Bone proliferation			
Positive	4	4	$p > 0.05$
Negative	5	5	
Presence of empty lacunae			
Positive	7	6	$p > 0.05$
Negative	2	3	

[a] McNemar test

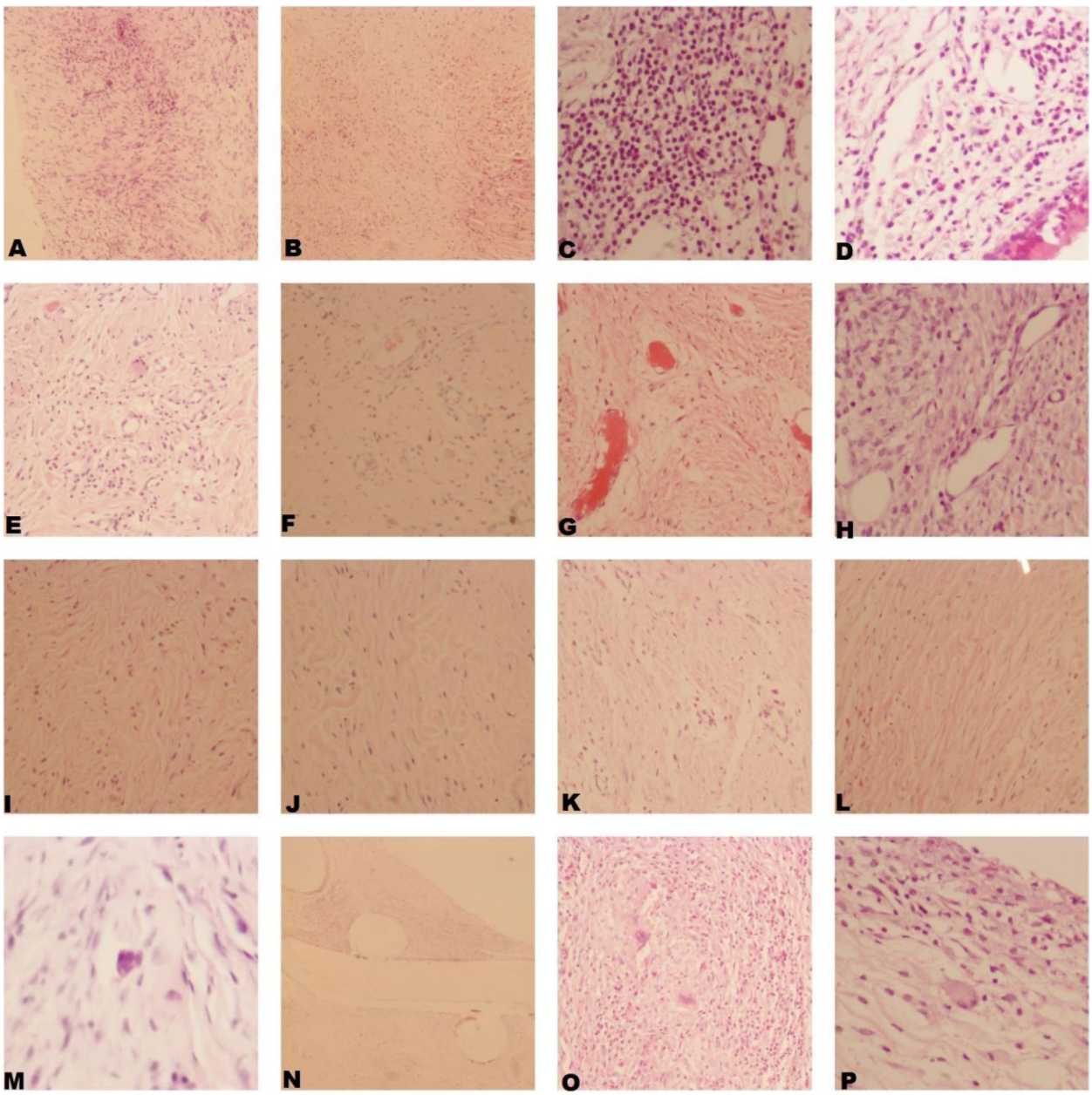

Fig. 3 Histopathological samples of the control and the experimental groups. **A**, control group, graft soft tissue, chronic inflammation (H&E, × 100). **B** Experimental group, graft soft tissue, chronic inflammation (H&E, × 100). **C** Control group, graft, chronic inflammation (H&E, × 400). **D** Experimental group, graft, chronic inflammation (H&E, × 400). **E** Control group, graft soft tissue, vascular proliferation (H&E, × 200). **F** Experimental group, graft soft tissue, vascular proliferation (H&E **G**: Control group, graft, vascular proliferation (H&E, × 200). **H** Experimental group, graft, vascular proliferation (H&E, × 400). **I** Control group, graft soft tissue, fibrosis (H&E, × 200). **J** Experimental group, graft soft tissue, fibrosis (H&E, × 200). **K** Control group, graft, fibrosis (H&E, × 200). **L** Experimental group, graft, fibrosis (H&E, × 200). **M** Control group, graft soft tissue, foreign body reaction (H&E, × 400). **N** Experimental group, graft soft tissue, foreign body reaction (H&E, × 100). **O** Control group, graft, foreign body reaction (H&E, × 200). **P** Experimental group, graft, foreign body reaction (H&E, × 400)

has demonstrated high biocompatibility, previous studies have found some complications associated with this material, such as foreign body reaction, separation of the implant, and late postoperative inflammatory reaction [14–17].

Acrylic cement is a form of polymethylmethacrylate (PMMA) and has been used in the field of orthopedics

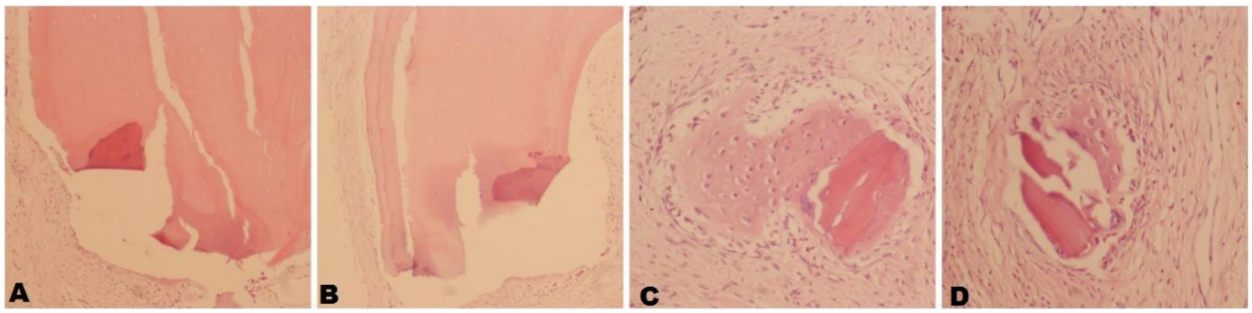

Fig. 4 Histopathological samples showing bone proliferation and presence of empty lacunae. **A** Control group, graft, presence of empty lacunae (H&E, × 100). **B** Experimental group, graft, presence of empty lacunae (H&E, × 100). **C** Control group, graft, bone proliferation (H&E, × 200). **D** Experimental group, graft, boneproliferation (H&E, × 200)

for fixation of prosthetic implants, for hip endoprosthesis, and for plaster replacement in the 1950s [18]. It has also been used to remodel osteoporotic or metastatic cancer areas and to repair cranial defects (cranioplasty) and vertebral fractures (vertebroplasty and kyphoplasty) [19, 20]. PMMA with three-dimensional printing technology is useable option to patients undergoing cranioplasty [21]. Polymethylmethacrylate (PMMA) is a cross-linked chained polymer that is hardened by synergetic heat, created by Röhm in 1901 and revised by Kulzer and Degussa in 1943 [22, 23]. Depending on the thickness of the cement cover, the environmental temperature, and the monomer/polymer ratio, the temperature of PMMA has been proven to increase in vitro but mostly varies between 70 and 120 °C. However, temperatures of this substance recorded in vivo range between 40 and 56 °C. Furthermore, in vivo threshold values may cause protein denaturation and damage for osteonecrosis [24]. However, it can be said that it has more advantageous than other alloplastic materials in terms of infection risk [25, 26].

In a study of the early results of PMMA injection, six subjects developed necrosis in the vertebral bone after injection; this result was mostly attributed to an exothermic reaction [27]. In the present study, necrosis was not observed at all, and the presence of empty lacunae was observed in seven samples in the experimental group and six samples in the control group. There was no statistically significant difference for presence of empty lacunae between the two groups. In another study investigating the effects of PMMA on auricular cartilage, foreign body reaction was detected in all subjects. In addition, mononuclear cell formation and fibrosis were observed in 95% of the subjects [28]. Similarly, chronic inflammation, fibrosis, and foreign body reaction were observed in the experimental and control group samples of the present study. However, no statistical differences were observed between the groups in terms of these pathological findings. In a case-control study conducted by Huang et al., peripheral necrosis, fibrous tissue formation, and giant cell reaction were detected in patients undergoing vertebroplasty with PMMA; in the group without PMMA use, neovascularization was observed and no foreign body reaction was detected [29]. In the present study, neovascularization was observed in both the experimental and control groups despite the lack of statistically significant differences between the groups. In addition, the presence of empty lacunae and bone proliferation were detected in both groups. In a study by Krebs et al., in which bone and intervertebral disc augmentation were performed with PMMA in 12 sheep, the authors reportedly observed a thin fibrous capsule and foreign body reaction [30]. In the present study, foreign body reaction was observed in both groups, but the difference for foreign body reaction was not statistically significant.

PMMA does not affect imaging methods like titanium-based implants, it has a more reasonable price advantage than hydroxyapatite-based ceramics. For these reasons, we thought it was worth working on nasal bone reconstruction. We concluded that PMMA can be used as an alternative material to allografts in nasal bone reconstruction. Since our study was a histopathological study, postoperative swelling and bruises were not evaluated. The main disadvantage of this study was that the number of rabbits was kept low, since ethical committee approval was required. Although the low number of subjects increases the risk of type 2 error, we can conclude that the results we obtained are compatible with the literature, but more research is needed on this subject. In addition, the long-term effects of acrylic bone cement on nasal bone reconstruction are not evaluated.

To our knowledge, this study was the first to show that acrylic bone cement can be used as bone graft material for the nasal bone and the nasal root area. In the present study, partial reconstruction of the nasal bone was carried out by creating an acrylic bone cement graft of the same size and shape of the required nasal bone segment during operation. This use of bone cement differs from previous usages, as it is generally used as an injection. Moreover, depending on the generalizability of this study's outcomes, acrylic bone cement can be prepared by a three-dimensional printer in the future for bone repair, grafting, or prosthetics.

Conclusion

In our study, histological results of allograft material made with acrylic bone cement and bone autograft material in nasal bone reconstruction were compared. There was no statistically significant difference between the two materials. Acrylic bone cement has the potential to be a graft material that can be used in rhinoplasty. However, since the long-term results and aesthetic effects of nasal reconstruction with acrylic bone cement are beyond the scope of this study, more research are needed on this subject.

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Authors' contributions
Conceptualization: Karakoc O. Data curation: Karatas HA, Akınocal FC, Kılınc M. Writing—original draft: Karatas HA, Bınar M, Akınocal FC. Writing—review and editing: Karatas HA, Karakoc O. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets during and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The Experimental Animals Ethical Committee of Gülhane Training and Research Hospital approved the study protocol (24.04.2018, 18/14).

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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