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ORIGINAL ARTICLE

Evaluation of free vascularized medial femoral condyle bone grafts in the treatment of avascular scaphoid waist nonunion

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ABSTRACT

Objectives: The aim of this study was to evaluate the medial femoral condyle (MFC) bone graft procedure for scaphoid waist nonunion with avascular necrosis on magnetic resonance imaging or prior surgery failure.

Patients and methods: Between June 2015 and December 2018, a total of 17 patients (16 males, 1 female; mean age: 29±8.2 years; range, 16 to 40 years) with scaphoid waist nonunion who were treated with vascularized MFC bone grafting were retrospectively analyzed. Pre- and postoperative carpal indices, grip strengths for both hands, range of motion, Visual Analog Scale (VAS) pain score, Quick Disabilities of the Arm, Shoulder, and Hand (QDASH) score, and Mayo Wrist Score (MWS) were evaluated.

Results: After vascularized MFC bone graft surgery, 15 patients healed and returned to work without any limitations. Ten patients of left scaphoid nonunion and seven cases of right scaphoid nonunion were treated; for eight of these patients, the operation was on the dominant side. Eight of these patients were smokers. The mean follow-up was 22.4±5.8 months. The mean hand grip strength was increased from 74.5 to 84% on the contralateral side ($p<0.05$). The average revised carpal height ratio improved from 1.57 to 1.59 ($p<0.05$) and the scapholunate angle changed from 56.9° to 51.6° ($p<0.05$).

Conclusion: The MFC bone grafting is one of the best surgical procedures for small defects such as scaphoid waist nonunion with high union rates, good functional outcomes, and minimal donor site morbidity.

Keywords: Medial femoral condyle, scaphoid waist nonunion, vascularized bone graft.

Scaphoid nonunion is diagnosed with a high frequency of up to 12%.[1] Epidemiological studies indicate that 10% of operated scaphoid fractures require a minimum of one additional surgery for nonunion.[2] Risk factors of scaphoid nonunion are stated in the literature as fracture displacement, poor vascularity, fracture location, smoking, carpal instability, and heavy manual labor.[3-5] Scaphoid nonunion causes wrist pain, stiffness, and dysfunction of the wrist. In the long term, scaphoid nonunion advanced collapse (SNAC) occurs secondary to post-traumatic scapholunate joint injury.[6]

There are different surgical treatment strategies for scaphoid nonunion. The most commonly used strategies are percutaneous screw fixation without bone grafts, non-vascularized bone grafts, pedicled vascularized grafts, and free vascularized medial femoral condyle (MFC) bone grafts.[7] The main goals of these strategies are to correct carpal deformities, restore scaphoid length, achieve bony union, and prevent carpal instability and arthritis.[8] If the patient experiences prior failed surgery, the revision surgery would be a more complex procedure.

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Vascularized or non-vascularized bone grafts or both, if necessary, can be used. In general, vascularized bone grafts are preferred for avascular revision cases and difficult cases. Sometimes, in the treatment of prior failed surgery with avascular necrosis, the use of both vascular bone graft and corticospongiotic bone graft to correct the hump deformity may be required.

The vascularized MFC bone graft was described by Sakai and Kawai[9] in 1991. Vascularized MFC bone grafts have been used in different locations such as the radius, ulna, metacarpal, femur, clavicle, tibia, humerus, carpals, tarsals, and mandible. There are studies in the literature reporting up to 100% scaphoid nonunion treated with vascularized MFC bone grafts.[10] This surgery is used for patients who have poor prognostic factors, such as proximal pole fractures, avascular necrosis, long-standing nonunion, and previous failed surgery.[11] The advantages of vascularized MFC bone grafts are better bone quality than the distal radius, large amounts of corticocancellous bone, the large diameter of the artery and less risk pedicle damage.[7]

In the literature, there are several studies using vascularized MFC bone grafts for the management of scaphoid nonunion. The difference between our study and previous studies is that most of the studies evaluated the treatment of all scaphoid nonunion types with vascularized MFC bone grafts, whereas in our study, only the treatment of scaphoid waist nonunions with vascularized MFC bone graft was evaluated. In the present study, we aimed to evaluate the results of the vascularized MFC bone graft procedure for scaphoid waist nonunion.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Ankara Bilkent City Hospital, Department of Orthopedics and Traumatology between June 2015 and December 2018. Scaphoid waist nonunion cases which treated with the vascularized MFC bone graft procedure in our clinic were reviewed. Only patients aged between 16 and 40 years with avascular scaphoid waist nonunion or prior failed surgery due to scaphoid waist fracture or nonunion were included. Patients with bilateral scaphoid fracture, SNAC, rheumatoid arthritis, osteomyelitis, neurological deficit, multiple carpal bone fracture, and scaphoid fracture with distal radius fracture were excluded from the study. Finally, 17 patients (16 males, 1 female; mean age: 29±8.2 years; range, 16 to 40 years) were included in the study. All patients had avascular scaphoid waist nonunion (Figure 1). Five of them had prior failed surgery.

Patients who had no union for more than six months were accepted as having nonunion and all patients were operated by the authors. Before surgery, demographic data for sex, education, age, occupation, smoking history and hand dominance were evaluated. Duration of nonunion, range of motion (ROM), scapholunate angle, revised carpal height ratio (RCHR), grip strength of both hands, previous surgeries, Quick Disabilities of the Arm, Shoulder, and Hand (QDASH), Mayo Wrist Score (MWS), and Visual Analog Scale (VAS) pain score were evaluated.

In addition, radiological assessment included pre- and postoperative radiographs of the hand in three views (anterior-posterior, lateral, and scaphoid views) (Figure 2), computed tomography (CT), and magnetic resonance imaging (MRI) scans. Pre- and postoperative scapholunate angles were measured on radiographs and union was evaluated with CT. The MRI was performed in all cases to evaluate whether there was avascular necrosis or not, which was confirmed intraoperatively. The free vascularized MFC bone graft procedure was used for patients with avascular scaphoid waist nonunion according to MRI evaluation.

Surgical technique

All patients were operated in the supine position and under general anesthesia. The contralateral lower extremity was preferred for the free vascularized MFC bone graft. Pneumatic tourniquets were used. In necessary cases, surgeons worked simultaneously on the upper and lower extremities.

A volar Russe-type approach was used. The scaphoid was prepared for grafting by removing the fibrous and necrotic tissue. In all cases, avascular necrosis was detected consistently with the MRI findings. In the revision cases, we detected nonunion and avascular necrosis intraoperatively. A high-speed burr was used for preparing the scaphoid (Figure 3), and the osseous defect was measured for the free vascularized MFC bone graft size. The radial artery and its accompanying veins were dissected and prepared for anastomosis.

Harvesting a MFC vascularized bone graft have been described previously.[10] A medial incision is made proximally from the knee joint line. Then, the descending genicular vessels are identified, when the vastus medialis muscle is retracted anteriorly

FIGURE 1. Magnetic resonance image of scaphoid avascular necrosis.

(Figure 4). The longitudinal branch of descending genicular artery is commonly used for bone flaps. We used the longitudinal branch for our patients. Only two patients had anatomical variation. Mostly, the longitudinal branch was the larger one. A sufficiently sized rectangular graft was harvested with a sagittal saw or small osteotome (Figure 5).

The graft was prepared for scaphoid cavity. Rongeurs and rasps were used to shape the graft. Restoring of the normal scaphoid length and correction of the humpback deformity were confirmed under fluoroscopy. An Acutrak® screw was used to fix the bone graft and both fracture fragments together. Intraoperatively, if we thought that the fixation

FIGURE 2. Pre- and postoperative radiographs of the scaphoid waist nonunion in three planes.

FIGURE 3. Preparation of scaphoid for grafting with high-speed burr.

was not good enough, we used Kirschner wires (K-wires). The use of K-wires was required for two patients. Positioning was confirmed with fluoroscopic evaluation. Afterwards, under a microscope, artery repair was performed end-to-side into the radial artery and venous repair was performed end-to-end into the accompanying veins. Perfusion of the graft was visually confirmed by releasing the tourniquet before closure (Figure 6).

Postoperative follow-up

Postoperative short arm cast was used for eight weeks and after that a removable splint used for four weeks. Full weight-bearing was allowed for donor site, and an adjustable-angle knee brace was used for three weeks. All patients were assessed at one, two, three, six, and 12 months after surgery for grip strength, scapholunate angle, MWS, VAS, QDASH, ROM, and any morbidity at the harvesting site. Union was evaluated with CT at the first year (Figure 7).

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. Due to the sample size being below 30, non-parametric test procedures were used. In this context, the Mann-Whitney U test, which is a non-parametric alternative to the independent samples t-test, was used to determine the relationships between parameters. The chi-square test was used for the analysis of categorical data. A p value of <0.05 was considered statistically significant with 95% confidence interval (CI).

RESULTS

Seventeen patients were operated with the vascularized MFC bone graft procedure. However, one patient was excluded from the study due to missing follow-up data. Only one patient had comorbidity (solitary kidney). Ten left and seven right scaphoid nonunions were operated. Five of the patients had previous surgery. Eight of the patients

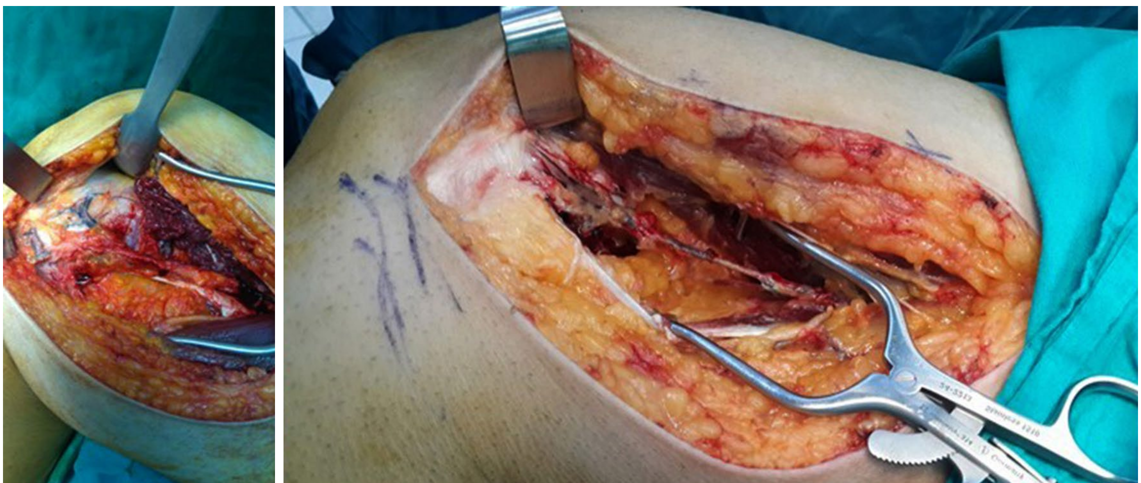

FIGURE 4. Descending geniculate artery pedicle.

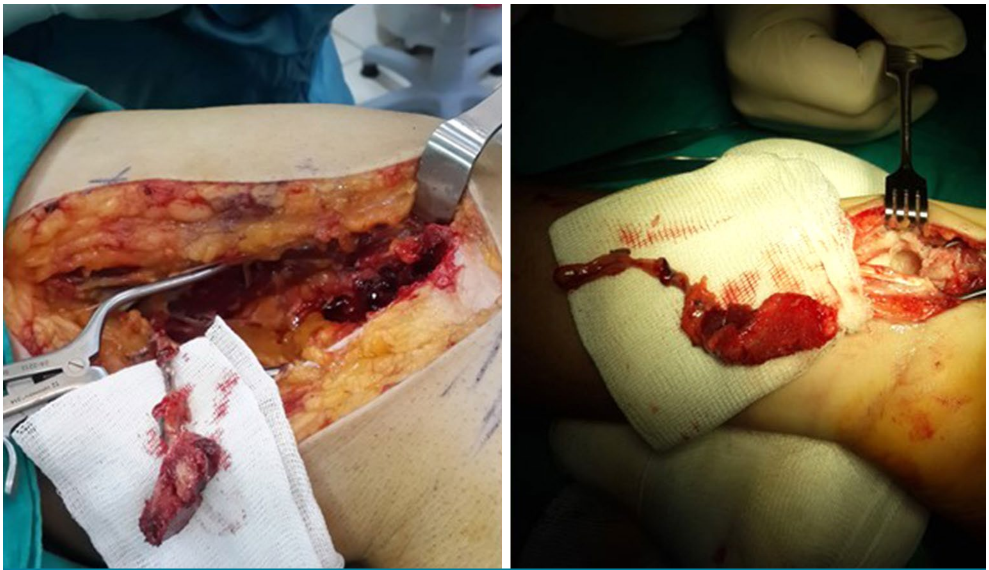

FIGURE 5. Harvesting of the free vascularized medial femoral condyle bone graft.

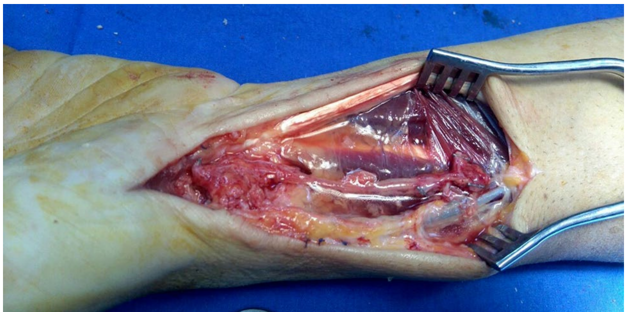

FIGURE 6. Microvascular anastomosis of the genicular artery end-to-side into the radial artery and anastomosis of a concomitant vein end-to-end with a radial vena comitans.

were smoker. The mean nonunion duration was 38.5±59.5 (range, 6 to 204) months and the mean follow-up was 22.4±5.8 (range, 14 to 33) months.

The mean preoperative VAS score was 3.4±0.93 (range, 1 to 4). One year after surgery, average pain score decreased from 3.4 to 1 (Table I). A significant difference was observed between pre- and postoperative VAS scores ($p<0.05$). The average preoperative ROM values were 49.4° flexion, 38.4° extension, 19.3° radial deviation, and 30.7° ulnar deviation. At the first-year follow-up, ROM values were 49.9° flexion, 40.4° extension, 21.6° radial

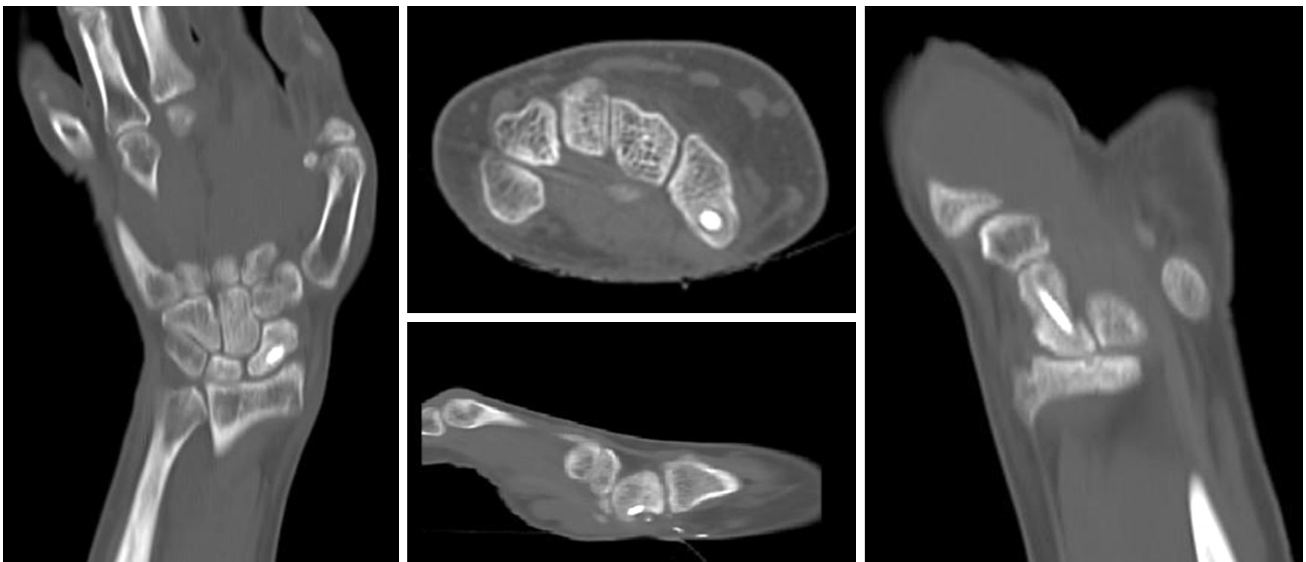

FIGURE 7. Union on computed tomography scans.

TABLE I
Preoperative and postoperative clinical scores and radiological parameters

	Preoperative			Postoperative			
	n	%	Mean±SD	n	%	Mean±SD	*p*
VAS			3.4±0.93			1±0.49*	0.005
QDASH			28.2±18.5			8.2±1.15*	<0.05
MWS	Poor 4			Satisfactory 5			
	Satisfactory 13			Good 10			
				Excellent 2			
Handgrip strength							0.001
Contralateral side		74.5			84*		
Scapholunat angle			56.9±3.08			51.6±3.65*	<0.05
RCHR			1.57±0.05			1.59±0.05*	0.325

SD: Standard deviation; VAS: Visual Analog Scale; QDASH: Quick Disabilities of the Arm, Shoulder, and Hand score; MWS: Mayo Wrist Score; RCHR: Revised carpal height ratio; * p<0.05.

deviation, and 31.8° ulnar deviation. There was no statistically significant difference between pre- and postoperative ROM measurements.

The average preoperative handgrip strength was 34 kg, and contralateral side was affected in 74.5% of the cases. At the first-year follow-up, the average handgrip strength was 39.3 kg with 84% of the contralateral side. There was a significant difference between pre- and postoperative grip strength ($p<0.05$).

With the vascularized MFC bone graft procedure, carpal alignment and scaphoid length were corrected. The RCHR improved from 1.57 to 1.59 ($p<0.05$), while the scapholunate angle changed from 56.9° to 51.6° ($p<0.05$) (Table I).

The pre- and postoperative QDASH and MWS values were also evaluated (Table I). The average QDASH score improved from 28.2 to 8.2 ($p<0.05$). Preoperative MWS values were poor in four patients and satisfactory in 13 patients. One year after surgery, MWS values were satisfactory in five, good in 10, and excellent in two patients. A significant difference was observed between pre- and postoperative MWS and QDASH scores ($p<0.05$).

The surgical treatment of two patients failed. One of them had avascular scaphoid nonunion and the other one who had two prior surgeries was a smoker. Proximal row carpectomy was performed for these patients. There was only one donor site complication (hypoesthesia). Fifteen of the 17 patients returned to their previous work without any limitations.

Three of the patients had no change in pain and function, while the remaining patients experienced decreased pain and increased function.

DISCUSSION

The usage of free vascularized MFC bone grafts is increasing steadily for different nonunions, such as carpal, metacarpal, phalangeal, orbital, maxillary, and mandibular.[12] The MFC bone graft is elastic and can be shaped easily.[13] Therefore, this graft is also appropriate for scaphoid nonunion. In the current study, we used vascularized MFC bone grafts for cases of scaphoid waist nonunion with satisfactory outcomes.

Vascularized and non-vascularized grafts can be used for scaphoid nonunion surgery. Vascularized bone grafts, which have the advantage of higher healing potential compared to non-vascularized bone grafts, are often preferred for small and medium bone defects.[14] Collapse is more common in patients treated with non-vascularized grafts, which is another advantage for vascularized bone grafts.[15] Zaidemberg et al.[16] described the pedicled vascular distal radius graft for the first time in the literature. Successful results of scaphoid nonunion surgery with 1,2-intercompartmental supraretinacular artery pedicled vascularized bone graft (1,2-ICSRA) were reported.[17,18] However, there are limitations for pedicled vascularized grafts, such as limited manipulation and inability to correct the humpback deformity. Chang et al.[18] reported 71% union rate in patients with scaphoid nonunion and 50% union in the presence of avascular necrosis with 1,2-ICSRA. In our study, the union rate was 88%.

Vascularized MFC bone graft, which is not the first choice in scaphoid fracture surgery, is one of the most optimal options for scaphoid nonunion with loss of carpal alignment, humpback deformity, failed surgery, and need of large bone graft.[19] Correction of the humpback deformity restores blood flow, and it is one of the most important parts of surgery.[15] In the current study, there was a significant difference between pre- and postoperative RCHR and scaphoid length. Humpback deformity and scaphoid length were corrected. However, we could not evaluate graft collapse in our study.

In the literature, descending genicular vessels have been preferred in cases in which the MFC flap is used due to its long nature and wide caliber.[20] The MFC has a thin cortex and abundant cancellous bone. Therefore, the flap is flexible and easily shaped. In radiological studies, the curvature of the MFC is compatible with the proximal carpal row.[21] This indicates that vascularized MFC bone graft is appropriate for scaphoid nonunion. Therefore, we preferred descending genicular vessels for vascularized MFC bone graft for cases of scaphoid waist nonunion with satisfactory outcomes.[22]

Harvesting the MFC graft, preparation of the scaphoid, and anastomosis would lead to longer surgery time. Therefore, two surgeons working simultaneously will shorten surgery time. In the current study, two surgeons worked simultaneously.

One of the most important disadvantages of the vascularized MFC bone graft procedure is the usage of the uninjured femoral condyle. Donor site pain has been noted in almost all studies. Although donor site complications are not common, they can affect the patient's quality of life. Therefore, surgeons should not be in a hurry and should be careful during the graft harvesting step. In the current study, there was only one donor site complication (hypoesthesia).

In the literature, there are studies with excellent results for the different scaphoid nonunions treated with the vascularized MFC bone grafts.[10,13,19] A systematic review revealed that vascularized MFC bone grafts had higher union rates compared to iliac grafts.[20] Elgammal and Lukas[23] treated difficult cases of scaphoid nonunion using vascularized MFC bone grafts and their union rate was 80%. In our study, the union rate was 88% and, unlike other studies in the literature, only cases of scaphoid waist nonunion were treated. Only one patient had wrist pain similar to the preoperative pain. All other patients experienced pain relief.

In the literature, there are studies comparing the vascularized and non-vascularized bone grafts for scaphoid nonunion. Ross et al.[24] indicated that vascularized and non-vascularized bone grafts had similar low failure rates and they suggested that surgeons usually chose vascularized bone grafts for more challenging cases.

There are different vascularized bone grafts. Iliac crest vascularized bone graft is one of them. Arora et al.[25] used iliac crest vascularized bone graft for scaphoid nonunions and their union rate was 87.7%. The aforementioned study had a similar union rate to our study. However, the complication rate was significantly higher compared to the vascularized MFC bone graft with 61.37% donor site bone deformation and a 31.7% lateral cutaneous nerve injury.[25] The donor site complication rate of vascularized MFC bone graft is lower than iliac crest vascularized bone graft.

Furthermore, Maraslı et al.[26] recommended the use of non-vascularized grafts due to similar union rates, better functional results, shorter surgical time, and easier technique. Revision surgeries are among the challenging ones. In the current study, we performed five revision surgeries and one of them failed. We performed proximal row carpectomy for failed one. According to the findings of our study, the vascularized MFC bone graft procedure is an effective technique for revision surgeries and cases of avascular scaphoid waist nonunion.

Nonetheless, there are some limitations to the current study. First, our study has a single-center, retrospective design. Second, the sample size is small which prevented us to identify risk factors. Third, the follow-up time is relatively short. Long-term complications can be observed with longer follow-up. Unlike other studies, however, only cases of scaphoid waist nonunion were included in this study, which makes our study valuable.

In conclusion, our study results demonstrate that vascularized MFC bone grafts are among the most optimal surgical procedures for small defects such as scaphoid waist nonunion with high union rates, good functional outcomes, and minimal donor site morbidity.

Ethics Committee Approval: The study protocol was approved by the Ankara City Hospital Clinical Research Ethics Committee (date: 30.09.2020, no: E1-20-1105). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from the patients and/or parents of the patients.

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

Author Contributions: Idea/concept: E.K., M.A.; Design: E.K., G.O., O.B.; Control/supervision: G.O., M.A.; Data collection and/or processing: O.H.K., K.O.U; Analysis and/or interpretation: E.K., K.O.U.; Literature review: O.H.K., K.O.U.; Writing the article: E.K., O.B.; Critical review: G.O., M.A.

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