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Comparison of the Effects of Superficial and Deep Heat Agents on Hamstring Muscle Flexibility in Healthy Individuals

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ABSTRACT

Objective: Stretching and warm-up exercises are commonly used to increase hamstring flexibility in sports rehabilitation. The aim of the study was to compare immediate and short-term effects of hot packs, infrared, and ultrasound on hamstring flexibility when applied before stretching exercises in healthy individuals.

Materials and Methods: A total of 60 participants were randomly divided into four groups. All participants performed hamstring stretching exercise three times a week for six weeks. Each stretching session consisted of three repetitions of 15 seconds duration. Before the stretching exercises, hot packs were applied to Group I, infrared to Group II, and ultrasound to Group III. Group IV (control group) performed self-stretching exercises alone. Hamstring flexibility was assessed with the Active Knee Extension (AKE) test in all sessions before and after the interventions.

Results: AKE significantly increased after all sessions ($p<0.05$) and in the short term ($p<0.05$) in all groups. The short-term effect did not differ between the groups ($p>0.05$). Among the different agents, infrared has the highest effect size.

Conclusion: The results of the study showed that both superficial and deep heat agents had an increasing effect on hamstring flexibility. However, the application of superficial or deep heat agents before stretching exercises did not provide an additional increase in hamstring flexibility.

Keywords: Flexibility, hamstring, heating, infrared, muscle stretching exercise.

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INTRODUCTION

Flexibility refers to the ability of muscles to extend and plays a crucial role in facilitating normal joint movement. Decreased flexibility causes decreased muscle function, pain, an increased risk of injury, and decreased athletic performance. The hamstring muscles are a biarticular muscle group and have a tonic postural character.[1] Therefore, the hamstring muscles have a great tendency to shorten.[2] Decreased hamstring muscle flexibility or muscle shortness is a condition that increases the risk of injury in both sedentary individuals and athletes. In addition, hamstring muscle shortness is associated with biomechanical problems in the knee joint and low back pain.[3]

Stretching exercises are the most commonly used exercises to increase hamstring flexibility in rehabilitation and sports. Other techniques used to increase flexibility include warm-up exercises, the use of heat agents, and cold applications.[4] Before exercising, warming up through exercise or the application of heat therapy is commonly used because heat therapy prepares the muscle for the metabolic challenge of exercise by increasing tissue metabolism.[5] Heat application has been reported to increase flexibility, reduce the risk of injury, and reduce the energy required for muscle contraction.[6]

The reduction of muscle elongation is the most permanent clinical sign after a hamstring injury. Therefore, stretching is especially useful in treating the primary lesion and preventing relapse.[7–9] When the literature is examined, the short-term effects of active and passive stretching exercises are generally examined.[4,10–14] Some of these studies reported that stretching exercises alone are sufficient to improve hamstring flexibility,[10,12,13] but others suggested that heat applications are beneficial in increasing muscle flexibility.[5,11,14]

Heat therapy can be divided into two groups: deep heat therapy and superficial heat therapy. It can also be classified as moist or dry. Dry superficial heat therapy includes the use of infrared lamps and electric heat pads,[15] while moist superficial heat therapy involves the use of hot pack. Deep heat agents include ultrasound therapy, shortwave diathermy, and microwave diathermy.[16]

Determining the most effective hamstring flexibility training will reduce the risk of injury in athletes and prevent knee and low back pathologies by increasing the functionality of sedentary individuals. Previous studies have presented contradictory findings regarding the effect of hot pack application as a moist superficial agent[5,11,14] and ultrasound as a deep heat agent[12,13,17] on flexibility. Therefore, it is not clear which type of heat therapy, superficial or deep, has a greater effect on hamstring flexibility when used before stretching exercises. Furthermore, to the best of our knowledge, no study has investigated the effect of infrared application as a superficial heat agent on hamstring flexibility. Therefore, the aim of this study was to compare the immediate and short-term effects of hot pack, infrared, and ultrasound therapies before stretching exercises in hamstring muscle flexibility training in healthy individuals.

MATERIALS AND METHODS

This randomized clinical study was conducted between January 2019 and January 2021 at Sarayköy Vocational School.

Participants

The study included 60 healthy participants aged between 18 and 25 years, with a mean age of 19.46±1.57 years. The participants were randomized into four groups using a computer system. The inclusion criterion was having active knee extension of less than 60 degrees when the hip was flexed to 90 degrees. The measurement was performed bilaterally, and the side with the shortest extension was included. Participants who had undergone knee surgery, had systemic or inflammatory pathologies in the lower extremities, had knee pathologies, were pregnant, had malignancy, or had an exercise habit were excluded. One hundred participants were invited to participate in the study. Twenty-eight participants were excluded from the study because they did not meet the inclusion criteria (n=20) or did not wish to participate (n=8). Finally, 72 participants were randomly assigned to four groups, with each group consisting of 18 participants (Fig. 1).

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Pamukkale University Clinical Research and Ethics Committee (26.06.2018/13). It was also registered with the clinicaltrials.gov identifier NCT04328155. Written informed consent was obtained from all participants.

Sample Size

The sample size was estimated based on the primary endpoints, which were defined as flexibility with ultrasound therapy. The overall effect size in a reference study was found to be large (f=3.07).[13] Therefore, we conducted a four-group comparison with a large effect size (f=0.5). According to this calculation, including at least 56 participants (at least 14 for each group) would provide 80% power with a 95% confidence level. The sample size of the current study was larger than the calculated minimum sample size.

Assessment

Hamstring flexibility was assessed using the Active Knee Extension (AKE) test. The knee angle was measured using a double-armed transparent plastic universal goniometer.[13,18] Participants were positioned supine with 90° hip-knee flexion and were asked to extend the knee as much as they could. All measurements were repeated three times, and the average score was recorded.

The pre- and post-intervention measurements for all sessions represented immediate effects. The short-term effect was recorded from the baseline measurement to the end of the 18th session.

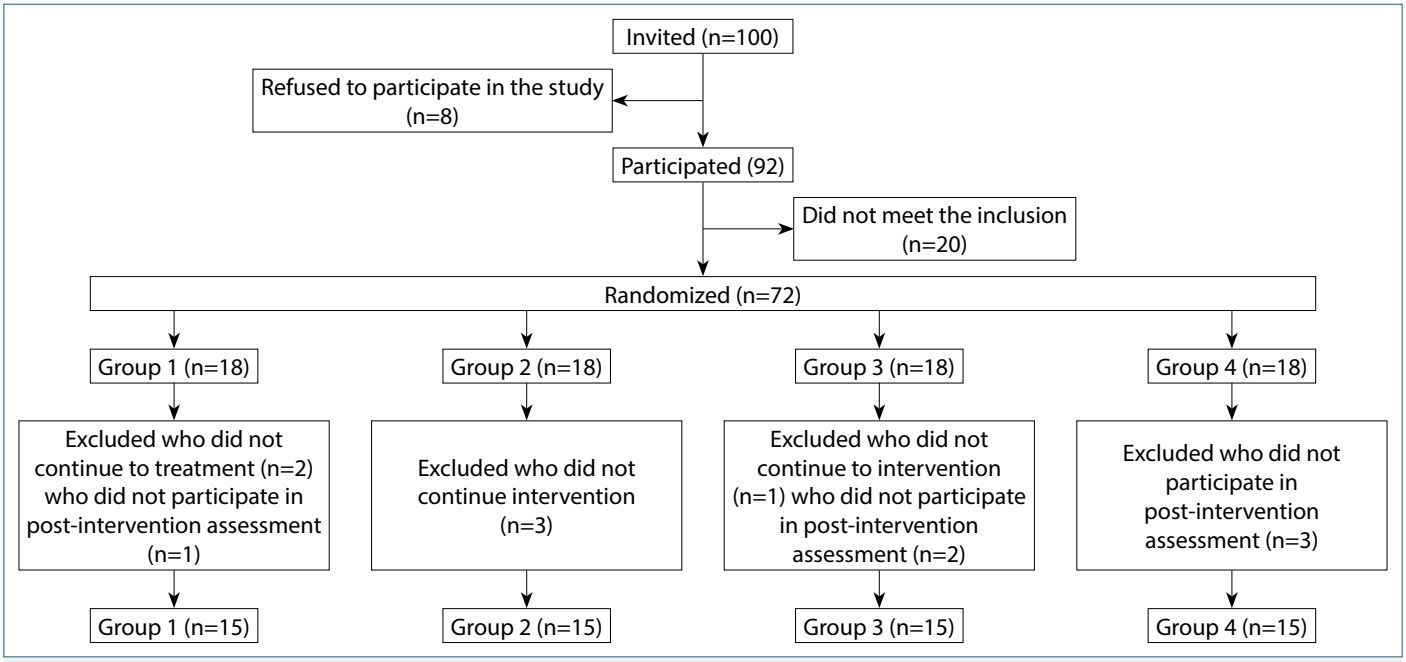

Figure 1. Flowchart of the study.

Intervention

All interventions were administered three times a week at the same time each day for six weeks. In each session, participants in all groups performed a 15-second hamstring stretching exercise with three repetitions. Participants performed self-stretching exercises using tape while in the supine position. The starting position for the exercise was the hip and knee fully extended. Participants pulled on the ends of the band to bring the hip into full flexion while keeping the knee in full extension. Participants were instructed to stop when they felt a slight stretch in the back of the leg. A 15-second rest period was provided between stretches. The stretching sessions were supervised by a physiotherapist (Fig. 2).

Group I received 20 minutes of hot pack application on the hamstring muscle in the prone position before the hamstring stretching exercise.[13,19] A constant-temperature water tank (M2-Chattanooga Hydrocollator) was used to heat the hotpacks. The water temperature in the tank was set to 70°C, and the hotpacks were covered with towels after being removed form the tank.

Group II received 20 minutes of infrared therapy (Orthocare Rehab R7111-Infrared 1 Lamp) on the hamstring muscle in the prone position from a distance of 50 cm before the hamstring stretching exercise.[16]

Group III received 5 minutes 1MHz of continuous circular mode ultrasound therapy (Chattanooga 2776 Intelect Mobil Us with 5 cm^2 applicator) at an intensity of 1.5 W/cm^2 using water-based ultrasound gel on the hamstring muscle in the prone position before the hamstring stretching exercise.[13,14]

Figure 2. Stretching intervention.

Group IV only performed hamstring self-stretching exercises.

Statistical Analysis

The data were analyzed using the IBM Statistical Package for the Social Sciences (SPSS) Statistics 25 package program. Continuous variables were presented as median, mean±-

Table 1. Demographic data of the groups

	Group 1 (n=15)		Group 2 (n=15)		Group 3 (n=15)		Group 4 (n=15)		p[a]
	Min–Max		Min–Max		Min–Max		Min–Max		
Age (yr)	17–21 (19.00)		18–24 (19.00)		17–26 (19.00)		18–24 (19.00)		0.727
BMI (kg/m^2)	17.07–34.48 (21.51)		15.63–34.48 (19.43)		17.96–28.16 (20.79)		15.04–29.76 (21.25)		0.706
Gender	**Female** n (%)	**Male** n (%)	**Female** n (%)	**Male** n (%)	**Female** n (%)	**Male** n (%)	**Female** n (%)	**Male** n (%)	
	13 (86.6)	2 (13.3)	11 (73.3)	4 (26.6)	12 (80)	3 (20)	10 (66.6)	5 (33.3)	0.608

a: Kruskal-Wallis analysis of variance; BMI: Body mass index; Min: Minimum; Max: Maximum.

Table 2. Comparison of pre- and post-intervention ake test values in the groups

AKE test (degree)	Pre-intervention	Post-intervention	p[b]	ES
Group I	35.33–55.00 (44.00)	40.00–80.00 (60.00)	0.001	0.63
Group II	35.67–50.67 (41.00)	41.67–73.00 (63.00)	0.001	0.80
Group III	40.00–60.00 (45.00)	50.00–90.00 (60.00)	0.001	0.67
Group IV	40.00–55.00 (50.00)	49.00–75.33 (60.00)	0.001	0.74
P[a]	0.085	0.762		

a: Kruskal-Wallis analysis of variance; b: Wilcoxon paired two-sample test; ES: Effect size; AKE: Active knee extension test.

standard deviation, and categorical variables as numbers and percentages. The normal distribution of continuous variables was evaluated using the Shapiro-Wilk test. The Wilcoxon paired two-sample test was used for non-parametric pairwise comparisons of within-group change scores. The Kruskal Wallis Analysis of Variance was used to compare AKE test values between the groups for non-parametric test assumptions. The level of statistical significance was set at $p<0.05$. The effect size (Cohen's d value) was calculated based on the pre-treatment and post-treatment values of the groups. Effect size values were classified as small (0.20–0.49), medium (0.50–0.79), and large (0.8 and higher).[20]

RESULTS

A total of 60 participants, with a mean age of 19.46±1.57, completed the assessment and interventions. In Group I, 86.6% (n=13) were female and 13.3% (n=2) were male. In Group II, 73.3% (n=11) were female and 26.6% (n=4) were male. In Group III, 80% (n=12) were female and 20% (n=3) were male. In Group IV, 66.6% (n=10) were female and 33.3% (n=5) were male.

Demographic characteristics, including age (p=0.727), BMI (p=0.706), and gender (p=0.608), did not differ significantly between groups (Table 1).

Immediate Effect

A statistically significant improvement was observed in AKE Test values after each session and after the treatment compared to the pre-intervention and pre-session period in all groups (p=0.001). Throughout the 18 sessions administered to the groups, the AKE Test value measured after each session was higher than the value measured before the session in all groups. Weekly averages of AKE test values are presented graphically (Fig. 3).

Short Term Effect

A statistically significant improvement in AKE test values was found at the end of the study compared to baseline test values in all groups (p=0.001) (Table 2). However, there was no significant difference between the groups (p=0.762) (Table 2). The effect size of the AKE test in Group II was large, while the effect sizes in the other groups were medium (Table 2).

DISCUSSION

This study aimed to compare the immediate and short-term effects of superficial and deep heat agent applications before stretching exercises on hamstring muscle flexibility in healthy individuals. Hot packs were used as superficial wet heat therapy, infrared was used as superficial dry heat therapy, and ultrasound was used as deep heat therapy. Sixty healty

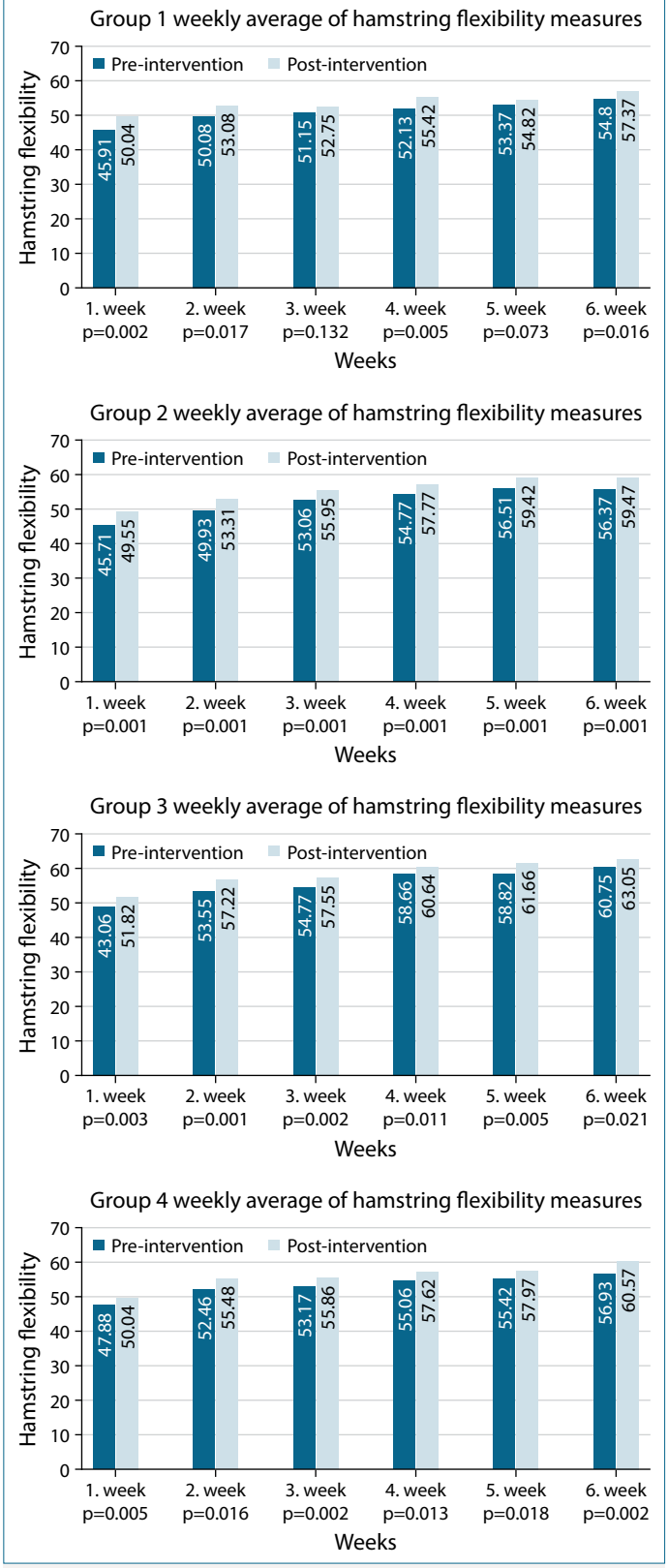

Figure 3. Stretching intervention.

participants with hamstring muscle tightness were randomly divided into four groups. All participants in the groups performed self-strectching exercise for six weeks and 18 sessions. Group I received hot packs, Group II received infrared therapy, and Group III received ultrasound therapy before the stretching exercises. Group IV only performed hamstring stretching exercises. The AKE test was used to measure hamstring flexibility. The results of this study showed improvement in hamstring flexibility both at the end of each session (immediate effect) and at the end of the study (short-term effect) with the use of warm agents before hamstring stretching exercises. However, the addition of superficial and deep heat agents to hamstring muscles before stretching exercise did not provide an additional increase in flexibility. Interestingly, the highest effect size was observed with infrared therapy compared to the other agents.

Static stretching has been considered the gold standard in flexibility training.[10] Various therapies have been employed to improve hamstring muscle flexibility.[18] Hamstring stretching exercises have been widely used as a common intervention by physical therapists, athletic trainers, and sports professionals to enhance mobility at the hip and knee and reduce muscle soreness.[20] Numerous studies have examined the duration of a single stretch and the time required to achieve significant improvements in hamstring flexibility using different muscle stretching techniques, including active, passive, and assisted stretching. However, there is limited consensus in the literature regarding the optimal duration for achieving improvements, with some studies suggesting as little as four weeks and others suggesting up to 12 weeks for optimal changes.[1,21,22] Furthermore, the immediate effects of hamstring stretching exercises on knee range of motion have been observed to last only last three to six minutes.[23,24] Therefore, in this study, we investigated both the immediate and short-term effects of heat agents on hamstring flexibility.

Hot pack application is one of the most extensively studied heat agent for its effect on hamstring flexibility. Işık et.al. conducted a study comparing the immediate effects of stretching alone, massage followed by stretching, and hotpack application followed by stretching exercises on knee joint range of motion in individuals with short hamstring muscles. Sixty participants were randomly divided into three groups. The first group received stretching exercises, the second group received classical massage followed by stretching, and the third group received hotpack application before stretching. Hamstring flexibilites were measured before and immediately after the interventions using the AKE test. The investigators reported statistically significant differences in AKE test values in all groups. When examining the differences between the groups, the authors reported that hotpack application before stretching exercises and massage before stretching

exercises had positive effects on increasing stretching performance. The authors concluded that only static stretching and stretching-induced interventions were effective in increasing hamstring muscle length and range of motion.[11] Moreover, the hot application before stretching exercise group showed the highest change value. In a study by Petrofsky et al.,[5] the immediate effects of heat and cold on the force required for knee flexion were investigated. The study compared the effects of a 4-hour ThermaCare heat wrap as a slow heat modality, a 20-minute hotpack application as a fast heat modality, and a 20-minute ice pack application. The findings suggested that heat application is beneficial for muscle flexibility, while cold treatment may have the opposite effect. Similarly, in another sudy by Brodowichz, the effect of a stretching exercise protocol alone was compared to the effects of a 20-minuted hotpack application and a 20-minuted cold pack application fixed to the hamstring muscle in college baseball players. The authors reported an increase in hamstring flexibility after all interventions. However, stretching with ice was found to be more effective than both stretching with heat and stretching alone.[14] These findings differ from the findings of other previous studies related to cold treatment for flexibility. The reason for the discrepancy in findings may be attributed to seeral factors. In the study by Brodowichz, the sample consisted of college baseball players who did not have short hamstrings, and they continued their regular baseball training and resistance training three days a week. On the other hand, Petrofsky et al. conducted their study on non-athletes.[5,14] Derbachew[25] also compared the effect of stretching exercises on flexibility using the sit and reach test. Three experimental groups, consisting of football players, participated in stretching exercises three days a week for six weeks. The control group did not engage in any interventions. The heat therapy groups received 20 minutes of heat packs or cold packs before stretching exercises, while the exercise group performed stertching exercises only. At the end of the study, no significant differences were found in the control group but significant improvements were observed in all three experimental groups. The investigator reported that the most effective method was the combination of heat and stretching, while cold treatment may have an opposite effect.

In the literature review, no study specifically examining the effect of dry heat on hamstring flexibility was found. However, there is a study by Demura et al.[26] investigating the effect of infrared therapy on shoulder and ankle range of motion. The authors reported improvements in shoulder and ankle range of motion after infrared application and suggested that infrared is an effective heat agent for enhancing range of motion. Altough no superior effect of heat agents over each other was found in the present study, infrared application before stretching exercises showed a higher effect size. Therefore, infrared therapy may be chosen for its ease of operation.

There are conflict findings regarding the effect of ultrasound application as a heat modality on flexibility. Some previous studies have shown that ultrasound therapy does not provide additional benefits when used before stretching exercises to improve hamstring muscle flexibility.[12,13] For example, one study investigated the effects of self-myofascial stretching on hamstring flexibility and found that it had a significant effect, but the addition of ultrasound therapy did not provide and additional benefits.[12] Similarly, another study compared Proprioceptive Neuromuscular Facilitation (PNF) stretching with cryotherapy or ultrasound as thermotherapy and found that while significant improvements were achieved with both interventions, there were no significant differences when compared to PNF stretching alone.[13] On the other hand, the findings of the study by Knight et al.[18] contrast with the findings of the present study and previous studies.[12,13] In Knight et al.'s[18] study, they compared the static stretching protocol with the use of hotpacks as a superficial heat modality, ultrasound as a deep heat modality, and warm-up exercises before static stretching exercises to improve the extensibility of the plantar flexors. Ultrasound was found to be the most effective modality for improving dorsiflexion range of motion.

In a systemic review by Nakano et al.[27] they aimed to answer the question of whether the application of heat enhances the effect of stretching on range of motion (ROM) compared to stretching alone. The investigators indicated that different heat applications can improve the effect of stretching exercises on ROM immediately, and they suggested that future studies should determine the most efficient application method. The current study aimed to examine the most effective heat agent for improving hamstring flexibility.

In the literature, there are studies that investigate flexibility in both genders,[4,5,21] while others focus on either male or female participants.[15,16,19,28] The particpicants in the current study included both males and females to generalize the results.[29] It is important to note that gender is considered a significnat predictor of joint flexibility.[30]

Whatever there are similar studies in the literature, we did not exclude the gender factor from out study. Although there was no significant difference in the distribution of male and female participants among the groups, it is important to note that three-quarters of the participants were female. The gender factor represents a limitation of our study. Additionally, we utilized the AKE[19,30] test as a daily practice method, but using ultrasound-based or optoelectronic assessments[5,29] may provide more accurate and individualized results. Therefore, this can be considered as another limitation of our study.

CONCLUSION

Our results suggest that the application of superficial and deep heat agents before stretching exercises is beneficial for hamstring flexibility in both immediate and short term. While no superior effect of one heat agent over the others or stretching exercise alone was found, infrared application showed a higher effect size. Thus, future studies investigating the effect of infrared therapy on hamstring flexibility in both healthy individuals and athletes are warranted.

Peer-review: Externally peer-reviewed.

Ethics Committee Approval: The Pamukkale University Clinical Research Ethics Committee granted approval for this study (date: 26.06.2018, number: 13).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Author Contributions: Concept – ANOS, ŞŞ, AKÖ, MBK, UBA; Design – ANOS, ŞŞ, AKÖ, MBK, UBA; Supervision – ANOS, ŞŞ, AKÖ, MBK, UBA; Resource – ANOS, ŞŞ, AKÖ; Materials – ANOS, ŞŞ, AKÖ, MBK; Data Collection and/or Processing – ANOS, ŞŞ, AKÖ; Analysis and/or Interpretation – ANOS, ŞŞ, AKÖ, UBA; Literature Search – ANOS, AKÖ, UBA; Writing – ANOS, ŞŞ, UBA; Critical Reviews – ANOS, ŞŞ, AKÖ, MBK, UBA.

Conflict of Interest: The authors have no conflict of interest to declare.

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