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Research article

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What is the role and importance of temperature measuring devices in finger replantation surgery?

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Abstract

Background/Aim: Post-operative circulation monitoring is very important in replantation surgery. Vascular pathologies that occur can be detected and undergo intervention as a result of strict follow-up protocols, thus increasing success rates. Although many alternative methods for circulation monitoring are available, no gold standard for such monitoring exists. This study aimed to find a more reliable and easier method by comparing different temperature measurement methods to facilitate the follow-up of patients who underwent finger replantation after the operation.
Methods: This study was designed as a retrospective case series study. It was conducted between January 2017 and December 2019. Eighteen patients who presented with flexor zone 2 finger amputations and who had undergone replantation surgery were included in the study. The cases were randomly divided into two equal groups. While the finger temperature of the patients in the first group was measured with an indoor/outdoor temperature device, the measurement was obtained using a non-contact infrared thermometer in the second group.
Results: In our study, the mean age of group 1 was 44.33 years, and the mean age of group 2 was 45. Eleven fingers from nine patients in the group 1 and 10 fingers in 9 patients in the group 2 were replanted. All amputated finger replantation were performed. The patients stayed in the hospital for five days, were followed, and treated. The success rate based on living fingers was 54.54% in group 1 and 60% in group 2. The mean measured finger temperatures were 34.12 and 35.76 °C in groups 1 and 2, respectively. In group 1, the mean time of measurement was calculated as 4 min 31 s. In the group 2, the mean time of measurement was calculated as 1 s. In the study, two measurement tools were used to determine fingertip temperatures in the two similar groups.
Conclusion: In our study, we found that infrared non-contact temperature measuring devices are both reliable and useful as a heat meter in the follow-up of finger after the replantation operation.

Keywords: Finger replantation, Temperature measuring devices, Follow-up

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Introduction

Today, with the developments in microsurgery and the increase in number of trained surgeons, microsurgery and finger replantation operations can be performed in all major hospitals. Postoperative care is as important and essential as surgical success in replantation surgeries. Unfortunately, physicians working outside of big cities do not have the chance to establish a microsurgery team, and usually only one or two surgeons can work on a provincial basis. The viability and circulatory status of the replanted fingers are generally followed by capillary filling, finger color, turgor, arterial Doppler, measurements of the filling pressure of the pulp, or simply puncturing the fingertip with a needle and measuring bleeding levels [1]. It is obvious that surgeons cannot be at a patient's side continuously. A nurse with good experience in microsurgery case follow-up procedures monitors capillary filling, finger skin temperature, skin color, turgor, and tissue fullness, which are indicators of finger circulation after replantation surgery, and warns the surgeon when necessary. In cases in which frequent nursing rotations occur in the ward, the need to simplify these findings, learn to evaluate the condition of the finger, and facilitate decision-making is present. Capillary filling, finger color and temperature are easily measurable findings, but they are subjective. Measuring finger temperature during follow-ups yields the most accurate information about circulation in the finger [2]. It is not possible to follow up without understanding the use of different temperature measuring devices and correct measurement methods. This study aimed to find a more reliable and easier method to monitor finger temperature by comparing different temperature measurement methods to facilitate the follow-up of patients who underwent finger replantation after the operation [3]. It was seen that no current literature concerning this topic is available, and it is thought that our study with current temperature measuring instruments will contribute to the replantation-related literature.

Materials and methods

This study was conducted retrospectively between January 2017 and December 2019 after approval from the local ethics committee was received. The study was dated 22.06.2022 and numbered 2022.06.192. The data were collected by the researcher. Between January 2017 and December 2019, 18 patients who had presented with flexor zone 2 finger amputation and undergone replantation surgery were included in the study. The cases were randomly divided into two equal groups. While the finger temperature of the patients in the first group was measured with an indoor/outdoor temperature device (Figure 1), the measurement was made with the non-contact infrared thermometer used routinely in the hospital in the second group (Figure 2). Informed consent was obtained from all individual participants included in the study and complied with the 1964 Helsinki Declaration and comparable ethical standards.

Figure 1: Measurement of finger replantation temperatures with contact probe in group 1

Figure 2: Measurement of finger replantation temperatures with infrared thermometer in group 2

Technical information of devices

1. The indoor/outdoor humidity and temperature measuring device has dimensions of 100 mm × 100 mm × 20 mm with a weight of 98 g. The object measures the temperature of the surfaces between −50~70 °C and measures the body temperature and the temperature of the contact surface with the outdoor temperature measuring probe. It measures the ambient humidity in the range of 10% to 99%. Temperature accuracy s ±1°C, humidity accuracy ±5% relative humidity (rh), temperature resolution 0.1 °C, and humidity resolution 1% rh. The measurement time is not specified.

2. The non-contact infrared thermometer has dimensions of 110 mm × 53 mm × 162 mm (L*W*H) and weight of 147g (battery excluded). It measures the temperature of the object surfaces between 0 and 118°C and measures the body temperature in the area in which it is marked. Measurement time is ≤ 0.8 seconds. Sensitivity is 0.1 °C.

Other circulatory findings, primarily the temperature of our patients, to whom we gave the same treatment and care, were also evaluated during this process. The patients were routinely hospitalized for five days during which time finger temperature, color, and capillary filling were checked every hour. For the two groups with similar characteristics, temperature measurements were obtained from the same body area every hour, the circulation of the patients was monitored, and notes were taken. the patients' temperature measurements always came above 32 °C. It was also considered that the air temperature in the city, including summer, is below 30 ºC, and the temperature of the hospital is around 22 ºC. The mean finger temperature of the patients was calculated by taking the average of all measurements. The duration of the measurements was made by placing the finger pulp sideways in the first group, the largest possible contact surface was created, and the measurement was then obtained. In the second group, the measurement was made with the finger pulp in the middle of the thermometer measurement window.

Statistical analysis

Data were analyzed using SPSS Version 20.0. For categorical variables, data were summarized as frequencies and percentages. No assumptions were made for missing data. Those variables that showed a statistically significant difference in the univariate analysis were included in the multivariate analysis at $P < 0.05$. The results are presented as odds ratios (ORs), 95% confidence intervals (CIs), and corresponding *P*-values.

Results

In our study, injury characteristics and individual characteristics were similar and homogeneous in the two groups. In our study, the mean age of group 1 was 44.33 years (20.2), and the mean age of the group 2 was 45 (21.5). One female patient was in group 1 and two female patients were included in group 2. Seven right and two left hand injuries were reported in group 1, and six right and three left hand injuries in group 2. Eleven fingers from nine patients in group 1 and 10 fingers in 9 patients in group 2 were replanted. The number of amputations included five index fingers, three ring fingers, one thumb, one middle finger, and one little finger in the group 1, and three middle fingers, three little fingers, two ring fingers, one thumb, and one index finger in the group 2. All amputated fingers underwent replantation surgery. The patients stayed in the hospital for five days and were followed and treated. Circulation was monitored and detected in the replanted fingers of the patients and was followed until the day of discharge. At the first follow-up session, stump revision was performed on necrotic fingers, which were found to have no circulation in the finger. The success rate was 54.54% in group 1 and 60% in the group 2 based on the number of living fingers. The mean measured finger temperature was 34.12 (0.2) °C in group 1 and 35.76 (0.9) °C in group 2. In group 1, the mean time of measurement was calculated as 4 min 31 s. In group 2, the mean time of measurement was calculated as 1 s (Tables 1, 2). Contact measurement temperature was controlled by non-contact measurement in four randomly selected patients in group 1. Accordingly, it was observed that the contact measurement was between 0.9 and 2.1 °C and showed an average of 1.64 °C underestimation. This finding was interpreted as an effect of the cylindrical metal probe because one surface of the metal probe touches the finger, while the larger surface does not; it is also affected by low ambient temperatures.

Table 1: Group 1 measurements with external contact measuring device

Age	Gender	Finger	Temperature	Measurement time	Success Status
24	Male	Ring	34.3	4 min	Unsuccessful
26	Female	Index middle Ring	34.0	4 min 10 s	Unsuccessful Successful
44	Male	Little	34.3	4 min 30 s	Successful
45	Male	Index	34.7	5 min	Unsuccessful
18	Male	Index	34.6	4 min 15 s	Successful
60	Male	Index	32.0	5 min 5 s	Successful
68	Male	Ring	34.2	5 min 40 s	Successful
74	Male	Index	34.8	4 min	Successful
40	Male	Thumb	34.2	4 min 25 s	Successful

Table 2: Group 2 measurements obtained with an infrared non-contact measuring device

Age	Gender	Finger	Temperature	Measurement time	Success Status
65	Male	Little	35.2	0.8 s	Unsuccessful
51	Male	Ring	35.3	0.8 s	Unsuccessful
19	Male	Middle	35.9	0.8 s	Unsuccessful
51	Male	Thumb	36.2	0.8 s	Successful
23	Male	Index middle	35.8	0.8 s	Unsuccessful
55	Female	Ring	35.9	0.8 s	Successful
44	Male	Little	35.2	0.8 s	Successful
62	Female	Little	36.1	0.8 s	Successful
35	Male	Middle	36.3	0.8 s	Successful

Discussion

The first replantation surgery was performed by the team of Ronald Malt in 1962 with brachial artery repair on a 12-year-old who needed arm replantation at the proximal humerus level. Following this case, Kleinert revascularized the partial finger amputation in 1963, and Zhong Wei Chen replanted an amputation at the distal forearm level of a machinist patient under loop magnification. The first finger replantation was performed by Komatsu and Tamai in 1965. After these successful surgeries, the subject of monitoring these limbs and revision in case of arterial or venous insufficiency began to be discussed [1, 2].

The first thermometer dates to Ancient Greek history and works according to the principle of expansion of air from heat. They discovered the “air thermoscope”, a temperature measuring device that traps air. The medical thermometer was also invented by Galileo Galilei toward the end of the 1500s and called the “water thermoscope”. An Italian physician made a mm gradation on the thermometer of that day and began to accurately measure the temperature of the patients. The ue of infrared temperature measuring devices became widespread after The American Society for Nondestructive Testing accepted it as a standard test in 1992 [2].

The temperature of the replanted finger and the temperature of the adjacent control finger were monitored in a 1977 study, and three poor prognostic criteria were identified: (1) the temperature of the replanted finger between the fingers by more than 2.5 °C lower than the other, (2) the temperature of the replanted finger is below 30 °C for more than 1 h, and (3) the replanted finger was below 30 °C when no apparent problem existed. During the hospitalization period, the finger temperature of our patients was at least 32 °C and the highest was 36.3 °C. Since problems developed after discharge in unsuccessful cases, it is not possible to give a valid reason for such an occurrence [1].

In a 1982 article by Okutsu (in Japanese), it was reported that as a result of temperature measurements and follow-ups starting in 1974, they warmed the limb with an electric blanket to provide peripheral circulation after replantation surgery and free tissue transplants [2]. They found that the critical temperature for circulation is 32 °C, and if the replant temperature is below this temperature, blockage in the vessels occurs. They stated that the temperature was the same as the armpit temperature in 80% of the replantation patients and 90% of the free tissue transplants. Based on these limits, they developed a device consisting of a thermistor and a resistance bridge to be used in microsurgery case follow-ups. The device consisted of the thermistor and the device in contact with the flap or finger. They set the device to 32.1 (0.3) °C so that when the temperature was above this value, the blue light would light up, and when the temperature dropped below the set degree, both the red light would light up, and it would make a buzzing sound. According to Okutsu, clinical examination findings, such as skin color of the finger and capillary filling are subjective [2]. Hence, he stated that these parameters are not always reliable. In our cases, the patients were followed up with an interval of 1 h between evaluations, and the temperature did not fall below 32 °C during the hospitalization period in any of the patients.

In the study of Lu et al. in 1984, 153 of 154 replantation surgeries that were above 32 °C survived [3]. Necrosis occurred in 22 of 26 cases at 32 °C and below. To investigate the critical temperature for successful surgeries, the best temperature for finger survival between 31 and 33 °C was investigated at 0.1 °C intervals. They reported that a skin temperature of 32 °C and above after the finger replantation operation was the best prognostic finding. This study revealed that finger temperature monitoring is effective in replant survival and is the best indicator of circulation.

Aihara et al. [4] described the use of an adherent skin surface temperature indicator by evaluating it in their study in 1993. This method, in which the circulation is understood based on a color indicator, is not available in every country and has an extra cost. The biggest shortcoming is that the adjusted color change scale does not give clear temperature information.

Along with technological developments, the use of more sophisticated devices, such as laser Doppler flowmeter and implantable Doppler also in use. In the review by Karina et al. [5], the methods preferred by surgeons in developed countries were investigated: "It showed that in the United States, 151 surgeons interested in microsurgery preferred the monitoring technique, while 56.1% used hand Doppler, 22% implantable Doppler, and 16.6% tissue oximetry. Similarly, it showed that less than 20% of 148 microsurgery surgeons in the UK routinely used such devices in clinical evaluation. However, the implantable Doppler system, Laser Doppler flowmetry (LDF) and Near-infrared spectroscopy (NIRS) are methods that are reported to detect flap failure earlier than conventional methods. Therefore, these appear to be the best monitoring techniques for most flaps at this time. Moreover, implantable Doppler and microdialysis showed a successful usage in embedded flaps. However, head-to-head comparisons of different monitoring techniques are required to better and more thoroughly evaluate which technique or combination of techniques is most appropriate for each flap type." As can be understood from the quote, these methods are more expensive and more complex.

In our study, we sought an easy-to-teach and safe method for surgeons who cannot follow patient follow-up with a hand Doppler or other methods due to other duties in the hospital and due to the low number of surgeons in developing countries.

In a study by Smith et al., measured temperature and oxygen saturation in the dorsal middle phalanx in replanted fingers in the middle and both ends of the alternating flap in free flap surgery using a Copenhagen radiometer and Clark-type electrode equipment by adhering the electrodes with adhesive tape [6]. No information about this method in patients with advanced age finger replantation and free flap, chronic obstructive pulmonary disease (COPD), or similar patients with low oxygen saturation in the blood is available. However, it would be very difficult to obtain these measurements in Ishikawa subzones and flexor zone 2, since the electrodes cannot be adhered to such a small area. Difficulties in applying this method in replants that are constantly bleeding exist. In our study, contact and non-contact temperature measurements may vary according to a patient's condition, and these devices can be inexpensive and easy to use. Uncomplicated follow-up methods can be performed and measured by the nurse without the need for a physician to be present.

Working with a wireless thermometer on intact fingers, Ruopsa et al. [7] stated that this type of thermometer may be useful, but no study has been done regarding its use in replantation surgeries or injured tissue. It does not give any information and experience about clinical applications. In this study, we revealed the difference between fever measurement methods and emphasized which parameters should be considered when using one method in cases in which the other method is not available, not as a way to emphasize the use of one method over the other.

We saw that the infrared non-contact temperature meter, which we used in the follow-up of the patients, showed lower temperature when it was not used in the correct area. Therefore, during surgery, the skin on the arterial anastomosis trace was marked, and the temperature was measured from that area. It was understood that the measurements with the contact probe measuring the outdoor temperature can differentiate temperatures by 1.63 °C on average. Furthermore, the average time to measure temperature with this method was 4 min 31 s. It was necessary to wait an extra 20–30 s to make sure the thermometer showed the final temperature. Since capillary filling and finger color are subjective findings, they are not always reliable as Okutsu [2] stated. Measuring temperature is the best objective finding. In our study, hourly measurements were not below 32 °C, and revision surgery was not required. In the literature, no current article on our research topic could be found. The discussion was made with the publications that are available and whose data are still considered up-to-date.

Limitations

The limitation of this study was the small sample size.

Conclusion

In our study, we found that infrared non-contact temperature measuring devices are both reliable and useful. The usage of non-contact infrared thermometers guided by red light will show more accurate temperature in marked replant follow-up. Contact temperature measuring instruments can be used as an alternative and can be kept in mind as a device that measures less than 1.63 °C temperature. As a result of this study, it was understood that it can be easily learned to measure the skin-marked replant temperature with a non-contact thermometer.

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