Reliability of an infrared auditory thermometer in the measurement of oral temperature

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Abstract

Aim: To evaluate the reliability of the measurements obtained from different parts of the oral cavity using an infrared auditory thermometer, and to contrast these results with those obtained from the axilla and auditory canal.
Study design: A comparative descriptive design was used to establish differences between the temperature recordings made in 66 healthy volunteers with an infrared auditory thermometer applied to different parts of the body (oral cavity and left ear) versus the recordings obtained with a glass mercury thermometer in the axillary zone. The study sample was balanced with respect to gender, and the mean age was 21.15 (± 1.61) years.
Results: The largest standard deviation of all the locations corresponded to the left ear. This variable did not present a normal distribution. However, there were no statistically significant differences among the consecutive measurements made in the different anatomical (oral or axillary) regions.
Conclusions: The thermal device used in this study seems to fulfill most of the requirements of an ideal clinical thermometer for yielding objective information on body temperature. It is easy to use, noninvasive, inexpensive and rapid. The temperature in the oral cavity is very representative of body temperature.

Key words: *Body temperature, temperature, fever, thermometers, thermography.*

Introduction

According to the American Medical Association, the normal core body temperature varies from 97.8º to 99ºF (equivalent to 36.5-37.2ºC) (1). An abnormal temperature might indicate infection, inflammation or any deterioration in patient health. Furthermore, the core body temperature can be modified by different factors such as age, the time of day, gender, physical exercise, stress, drug treatments, environmental temperature, clothing, and the recent intake of hot or cold food or drinks (2). For this reason, all these situations must be taken into account when measuring body temperature.
The standard device to measure core body temperature has been the mercury thermometer. However, this thermometer is now rapidly being replaced by faster and simpler electronic devices based on infrared thermometry, which moreover pose no threat to the environment.
Temperature recordings vary depending on their location. One of the problems found in determining core body temperature with these infrared devices is deciding the body location for recording. The axilla, oral cavity and rectum have been the classical locations for measuring core body temperature. On the other hand, it must be taken into account that the rectal temperature is 0.5ºC higher than the oral temperature, and that the latter in turn is 0.5ºC higher than the axillary temperature (1).
Infrared tympanic thermometry measures core body

temperature from the intensity of infrared radiation detected in the tympanic membrane (3). Shinozaki et al. (4) reported that this would be an ideal place to measure core body temperature, because the blood vessels which supply the tympanic membrane share carotid artery central vascularization, which perfuses the regulatory center in the hypothalamus. On the other hand, Fritz et al. (5) found that the readings obtained with their infrared auditory thermometers did not reflect the temperature of the tympanic membrane but rather of the auditory canal.

The ideal device for temperature recording should be rapid, painless and reproducible, reflecting core body temperature. In addition, it should offer other qualities such as safety, comfort, easy handling characteristics, and cost effectiveness.

The present study explores the reliability of the measurements obtained from different parts of the oral cavity using an infrared auditory thermometer, and compares these results with those obtained from the axilla and auditory canal.

Material and Methods

- *Patients*

The present study was carried out in the University Dental Clinic of the University of Murcia (Spain). Sixty-six volunteers (dental students) were recruited. The study sample was balanced with respect to gender (46.7% men and 53.3% women), and the mean age was 21.15 (± 1.61) years. Written consent was obtained in all cases, and the study was conducted in abidance with the Declaration of Helsinki II.

The inclusion criteria comprised the following:

• Healthy individuals without systemic, oral or ear disease.
• Non-smokers.
• The absence of medication in the form of antiinflammatory, antihypertensive, or corticoid drugs during the week prior to the study.
• In the case of women, the absence of hormonal alterations such as pregnancy, menstruation or contraception.
• No food or drink consumption, or oral washing, in the 30 minutes before the exploration.
• No application of deodorant or of anything else to the measurement surface.

- *Materials*

A glass mercury thermometer (Grado®, Quirumed S.L., Valencia, Spain) and an infrared thermometer (ThermoScan®, BRAUN, Inc., San Diego, CA, USA) were used.

Temperature recordings from the axilla and left tympanic membrane, as well as from the oral cavity, were made in all subjects. Furthermore, the intraoral temperature was measured from different surfaces: lip vermilion (LV), lip mucosa (LM), cheek mucosa (CM), left alveolar mucosa (LAM), gum (G), hard palate (HP), faucial mucosa (FM), lingual dorsum (LD), lingual belly (LB), floor of the mouth (FoM) and skin of the lip (SL).

The glass mercury thermometer was used to measure axillary temperature. This thermometer was placed for five minutes under the left axilla (A), while the intraoral and tympanic recordings were made with the infrared thermometer.

The same person collected all data in order to avoid differences between different explorers. The temperature recordings were repeated three consecutive times, and the mean of the three readings was registered. These measurements were always performed under the same conditions and at the same time of day (10:00 a.m.). Each student stayed sitting in a room where the temperature was 21ºC, listening to relaxing music for five minutes. Once the subject was calm and relaxed, the temperature exploration was carried out. The first temperature measurement was recorded from the left tympanic membrane, followed by the left axilla and finally the intraoral zones. The disposable tips of the thermometer were changed with every anatomic region (ear or mouth).

Temperature was recorded with the infrared thermometer following the instructions of the manufacturer.

- *Statistical analysis*

Data were processed using the SPSS version 13 (Chicago, IL, USA) statistical package for Windows. The variables recorded for each subject were analyzed using descriptive statistics, determining the mean, standard deviation and maximum and minimum values from the different anatomical locations. In addition, these variables were examined using the Student t-test for the comparison of means of independent samples, analysis of variance (ANOVA) and the Kolmogorov-Smirnov test.

Results

1. Descriptive statistics

The highest average temperature was recorded from the FM in both the total sample [mean temperature 37.46ºC; 95% confidence interval (95%CI): (36.49; 38.42)] and by gender - the mean temperature in men [37.41ºC; 95%CI: (37.27; 37.54)] being similar to that recorded in women [37.49ºC; 95%CI: (37.37; 37.60)].

In contrast, the lowest average temperature was recorded from the LV, with 35.01ºC for the global sample [95%CI: (34.85; 35.16)]. By gender, the average temperature was 34.88ºC in men [95%CI: (34.70; 35.05)] and 35.14ºC in women [95%CI: (34.99; 35.28)].

The highest standard deviation of all the temperature recordings and for the global study sample corresponded to the left ear (LE).

2. Inferential statistics

2.1. Analysis of variance (ANOVA): Reliability of the measurements

No statistically significant differences were found among the temperature recordings obtained consecutively from each anatomical surface for both the global population and in the two gender groups.

2.2. Kolmogorov-Smirnov test (Table 1)

All the studied variables, with the exception of tympanic membrane temperature, showed a normal distribution, as these are direct biological measurements. This allowed the use of parametric tests for analysis of the results.

2.3. Student t-test for independent samples by gender

No statistically significant differences were observed between men and women with respect to mean temperature.

Table 1. Kolmogorov-Smirnov test.

LOCATIONS	N	NORMAL PARAMETERS	
		Mean temperature (ºC)	Standard deviation
LV	54	35.00	0.65
LM	66	36.56	0.78
CM	66	37.10	0.68
LAM	66	37.00	0.67
G	64	35.86	0.66
HP	58	35.54	0.82
FM	65	37.45	0.49
LD	59	35.74	0.78
LB	66	36.91	0.59
FoM	66	36.94	0.67
SL	53	35.44	0.59
LE	66	36.18*	0.83
A	66	36.85	0.37

Discussion

Core body temperature is a vital sign regulated by the hypothalamus. This temperature moreover varies according to the location involved - pulmonary artery temperature being considered the gold standard for the measurement of core temperature. However, pulmonary artery temperature monitoring is impractical in the daily clinical setting, due to its invasive nature, handling difficulties and high cost. For this reason, other more accessible anatomical regions are used, such as the axilla, rectum, ear or oral cavity.

Axillary temperature is the most comfortable and safest place to record body temperature, though it is the least accurate location, because it is affected by environmental conditions (1). Furthermore, Mayfield et al. (6) noted that brown fat located in the axillary area could rapidly increase cellular metabolic rates and oxygen consumption, thereby generating heat. Accordingly, Singh et al. (7) indicated that a reliable temperature measurement from the axilla should reflect the mean between the two axillas.

While rectal temperature is the most accurate of the three recording modalities, it is also the most uncomfortable. The side effects include pain or infection. It is recommended in children under 6 years of age and in unconscious or confused sick people. On the other hand, the contraindications to rectal temperature recording include patients with rectal surgery or rectal dysfunction (1).

With respect to ear temperature, Korta et al. (8) reported that core body temperature is not affected by the presence of cerumen, otitis media or tympanic alterations. According to the manufacturer in the infrared thermometer, otitis has little effect upon temperature recording. However, we considered that since infections produce a local response, they could raise the temperature in the infected ear. Further studies are needed in this respect. In our study, the Kolmogorov-Smirnov test showed tympanic membrane temperature to be the only variable lacking a normal distribution ($p= 0.017$), and thus requiring a nonparametric test for analysis. Furthermore, and in coincidence with other studies (9,10), the data obtained were analyzed on the basis of the standard deviation of repeated measurements - the highest standard deviations being seen to correspond to the tympanic membrane (0.84ºC) (Table 1). This could be due to inadequate temperature readings from the tympanic membrane (5), the presence of cerumen (11), an excessively curved auditory canal, or poor positioning of the thermometer during the temperature reading. Accordingly, Stavem et al. (10) reported the greatest accuracy of tympanic thermometers to be obtained when calculating the mean temperature of both tympanic membranes (right and left).

Concerning oral temperature, this location offers several advantages, including simplicity, convenience and considerable reliability. However, it also has some disadvantages: it cannot be used in patients subjected to oral surgery or with oral pathology; patients with breathing difficulties; or patients receiving oxygen therapy (1).

On the other hand, several studies (2,12) indicate that many factors influence intraoral temperature, such as the consumption of cold or hot food and fluids, smoking (13), heart rate, etc. Accordingly, we controlled as many such factors as possible in our study, based on the inclusion criteria and the measurement method used.

Moore et al. (14) reported that intraoral temperature varies during the day. Consequently, in this study, the temperature recordings were always performed at the same time (10:00 a.m.) and under the same environmental conditions (21ºC). Moreover, the subjects were required to be relaxed, since stressful situations activate the autonomic nervous system - producing changes in core body temperature (15).

Furthermore, we observed that the temperature readings were also affected by the presence of keratin in the epithelium, which hindered the transmission of infrared radiation to the recording device. For this reason, the highest temperature recordings were detected from mucosal surfaces with little keratin - CM, LAM, FM, LB, LM and FoM - while the lowest temperature recordings corresponded to SL, LV, G, HP and LD (Table 1).

Another important factor to be taken into account is the place where the temperature recording is made, since an anatomical temperature gradient exists within the oral cavity (16). In the present study, the lowest intraoral temperatures were recorded from HP (mean temperature: 35.54ºC), while the highest intraoral temperatures corresponded to FM (mean temperature: 37.46ºC). This could be due to the presence of environmental factors. Zehner and Terndrup (17) reported that environmental temperature affects the oral and tympanic temperatures, but not rectal temperature. The penetration of air within the oral cavity at the time of temperature measurement, or oral breathing on the part of the subject, can influence the recordings (18). In this study, the LV and SL temperatures (35.00ºC and 35.44ºC, respectively) were similar to those recorded at HP. These low temperatures could be due to the fact that these are the oral regions more exposed to the environment.

In contrast, sublingual temperature (LB) is the temperature least affected by the environment and by the intraoral anatomical temperature gradient. It is therefore routinely used as the anatomical reference for recording intraoral temperature. The value is close to 37ºC for most individuals, when measured under specific conditions (19). Volchansky and Cleaton-Jones (20) reported that the sublingual temperature stays constant relatively when the mouth is closed; consequently it should be measured at the moment in which the mouth is opened.

Considering the different classical anatomical regions for temperature recording (axilla, rectum, ear and mouth), several authors (21) have found the highest temperature recordings to be those obtained in the rectum, while the lowest temperature recordings correspond to under the tongue, and are similar to the axillary temperature values. In our study, and despite the fact that rectal temperature was not measured, we confirmed the similarity between axillary temperature and LB temperature, with values similar to those reported by these authors (6) (36.85ºC and 36.91ºC, respectively).

In our study, the lowest standard deviations of all repeated measurements were recorded from the axilla (0.37), and intraorally from FM (0.49), followed by LB (0.59). Consequently, in the same way as other authors (20, 12), we found this sublingual site to be adequate for measuring core body temperature, in view of its easy access. In contrast, FM is not considered appropriate, since access is complicated, and nausea can be induced. Access to the axilla is simple, though its readings can be influenced by factors such as environmental temperature, clothing, body hair or adipose tissue.

Regarding temperature recording devices, classically the thermometer most widely used for measuring core body temperature has been the glass mercury thermometer. However, this instrument poses the inconvenience of mercury toxicity. In accordance to the Environmental Protection Agency, mercury is a toxic substance that constitutes a threat to health and the environment. Since such thermometers can be broken and thus become a hazard, their use should be abandoned, in abidance with applicable legislation (22). In order to avoid such environmental toxicity, other thermal devices have been developed, including infrared thermometers.

Korta et al. (8) obtained temperature recordings from 248 children with a glass mercury thermometer and using the same infrared thermometer as in our study (ThermoScan®, BRAUN, Inc., San Diego, CA, USA). These authors found that the younger the child, the greater the difference in temperature between the two thermometers. Also, the infrared thermometer recordings of oral temperature coincided with those obtained with the glass mercury thermometer, though no such coincidence was observed in the case of the rectal or axillary temperatures.

We can conclude that the auditory infrared thermometer used in our study is inexpensive, simple, rapid and reliable in application to core body temperature measurement, regardless of gender, and provided the temperature readings are made from the oral cavity or axilla. The underside of the tongue or lingual belly would be an ideal site for measuring core body temperature, because it offers easy access and constitutes non-keratinized mucosa. High mean temperature recordings are obtained, with a low standard deviation. Further studies should be carried out to confirm the accuracy of the temperature recordings obtained, comparing them with the values obtained with the gold standard for measuring core body temperature, i.e., pulmonary artery temperature.

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