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Intra-Oral Temperatures in Man with Special Reference to Involvement of the Central Incisors and Premaxillary Alveolar Process in Lepromatous Leprosy[1]

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During the course of treatment for lepromatous leprosy in England, a male Pakistani patient was noted to have red discoloration of the upper central incisor teeth associated with a periapical granuloma. Apicectomy and examination of the connected leproma revealed typically lepromatous histopathology with fragmented bacilli in macrophages ([20]). While making separate observations of the temperature of the face with a thermographic camera ([14]), we observed an area of apparent low temperature in the region of the premaxillary alveolar process. Thermography proved technically unsatisfactory for the further study of this region and we resorted to the use of thermistor probes to record intra-oral temperatures in the region of the upper and lower incisor and molar teeth under a range of defined conditions. The results obtained are correlated with the known clinical pattern of involvement of teeth and supporting structures in lepromatous leprosy and with a large volume of archeological material from victims of this disease in Danish medieval burial grounds ([15-18]). Factors which may account for the peculiar distribution of leprosy in the mouth and teeth are discussed, with particular emphasis on the factor of low temperature in the tissues mainly affected.

MATERIALS AND METHODS

Temperature measurements were made with a tele-thermometer (Yellow Springs Instrument Company, Inc., Ohio, U.S.A., Model 43 TA) and three interchangeable thermistor probes. **Type 1** was a standard "banjo" probe (Ref. No 408), consisting of a 1 cm diameter disc, 0.15 cm thick and mounted on a rigid insulated stem 8 cm in length. The 99% response time of this probe was three seconds. **Type 2** was also standard (Ref. No 524) and consisted of a thermistor mounted just proximal to the tip of a 24 GA. needle, the length of the shaft being 4 cm. The 99% response time of this probe was 0.5 seconds. **Type 3** was the same as Type 2, but with the addition of a small quantity of epoxy resin (Araldite) around the tip.

The tele-thermometer incorporated a mirror beneath the recording needle to minimize error due to parallax; the manufacturer's stated readability was 0.1°C and this was confirmed by us using different observers.

Series 1 consisted of 100 Caucasian patients attending an outpatient clinic for treatment of viral warts of hands or feet; they were otherwise physically well at the time of examination and were not taking any regular medication. The completely edentulous were excluded; those with not more than one edentulous space in each jaw were included. Patients with a history of infective jaundice were excluded and also those who had consumed hot or cold drinks within the 20 minutes prior to measurement. In Series 1, all 100 subjects had been indoors for at least 15 minutes prior to examination and no restriction was placed on talking. The air temperature range was 15-27°C and the humidity 60-75%rF. Recordings in this series were made with the Type 1 ("banjo") probe only, the observer placing it against the vestibular surface above $\underline{|1}$, below $\overline{|1}$, above $\underline{|7}$ and below $\overline{|7}$.

The left side was used because it was most convenient for a right-handed observer. Recordings were made after 20 seconds in each position, although the instrument usually reached a steady state after ten seconds.

Series 2 consisted of 20 subjects attending the same outpatient clinic, five of whom had also been included in Series 1. The Type 3 probe was used and the following experiments performed.

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Mouth closed experiment. The left side recordings as described above were repeated to establish the random state of each subject. A further set of recordings was then made after ten minutes of mouth closure.

Noseclip experiment. After a period of ten minute normal activity, the "random state" recordings on the left side of the mouth were repeated, and this was followed by a period of ten minute compulsory mouth-breathing using a clip to occlude the nose completely. The noseclip was removed at the end of this period and recordings immediately repeated with the subject breathing through the nose, the mouth being closed during manipulation of the probe.

Vertical temperature gradient experiment. The gradient along the vertical axis of the upper and lower left central incisors was determined in each subject, using the Type 2 probe, placing its tip at the incisive edge of each tooth, at the gum margin and in the vestibular sulcus.

During the course of this series, the opportunity was taken to examine ten patients to investigate observer bias, the subject once again manipulating the probe, but this time with two observers, remote from each other. The positions in the mouth were randomized and known to one observer only, while the tele-thermometer readings were made independently by the second observer.

Series 3 consisted of ten subjects who were examined both before and after a period of exercise with the mouth closed, in order to study the effect of forced nasal breathing. They ran at a moderate pace in the open air with the mouth closed, over a distance of approximately 300 meters. Recordings were made before and after this effort, using the Type 1 ("banjo") probe, applied as before to the labial surface of the vestibular fold opposite $\underline{|1}$, and $\overline{|1}$, and also in the midline sublingually. The sequence of recording was randomized and two independent observers employed.

RESULTS

Series 1. This consisted of 100 unselected patients (57 females and 43 males) whose ages ranged from 6 to 69 years. An analysis of the temperatures of the four regions (Table 1) was made:

1. The incisor region was colder than the molar by an average of 1.05°C ($p < 0.001$).
2. The upper incisor region was colder than the lower incisor region by an average of 0.66°C ($p < 0.001$).
3. The upper molars were colder than the lower molars by an average of 0.20°C ($p < 0.01$).

TABLE 1. *Mean temperature (°C) by tooth region based on 100 unselected subjects.*

Tooth region	Upper	Lower	Difference
Central incisor region	34.73	35.39	0.66[a]
Rear molar region	36.01	36.21	0.20[b]
Difference	1.28[a]	0.82	

[a] Denotes probability is less than 0.001.
[b] Denotes probability is less than 0.01.

The statistical technic used to investigate the temperature differences between the teeth was an analysis of variance with individuals categorized into age/sex blocks (Table 2). As well as the large variation in temperature between regions it was also found that males had a slightly higher mean temperature than females, and that particularly in males and to a lesser extent in females, there was a tendency for the temperature to be lower with increasing age (Table 3). However, neither trend is statistically significant. After eliminating variation in temperature due to age and sex, the differences in the readings from subject to subject were still large ($p < 0.001$), revealing the heterogeneity of the sample (Table 2).

Series 2. Observer error studies were carried out on 20 unselected patients. It was found that the observed difference between upper and lower posterior molar regions could possibly be due to sampling error ($p = 0.08$), but the other two differences under investigation are beyond doubt, since it would have required an incredibly large systematic bias of 0.58°C to have taken place to invalidate them.

The first experiment in this series was to ascertain the effect of breathing with the mouth closed for ten minutes (Table 4). The initial set of readings showed that the upper tooth region was colder than the lower in 19 of the 20 subjects (one subject had identical readings), giving a mean difference of 0.47°C ($p < 0.001$). After the mouth had been closed for ten minutes, the differences were preserved and slightly increased, but

TABLE 2. *Two-way analysis of variance.*

Source of variation	Sum of squares	Degrees of freedom	Mean square
Teeth	13467.5	3	4489.2[a]
Age/sex blocks	2833.5	9	314.8
Interaction between these	893.8	27	33.1
Individuals (age/sex blocks eliminated)	15916.5	90	176.9[a]
Residuals	5785.0	270	21.4
Total	38896.3	399	

[a] $p < 0.001$.

TABLE 3. *Average of individual's mean temperatures (° C) by sex and ages.*

	AGE					
	Under 16	16-25	26-35	36-45	Over 45	Total
Males	35.76 (10)[a]	35.90 (16)	35.57 (6)	35.56 (8)	34.62 (3)	35.67 (43)
Females	35.80 (10)	35.54 (21)	35.36 (9)	35.62 (10)	35.14 (7)	35.52 (57)
Average temp. total	35.78	35.70	35.45	35.59	34.98	35.59

[a] Figures in parentheses indicate number of patients.

TABLE 4. *Mouth closed experiment (° C).*

Tooth region	Initial	After 10 minutes with mouth closed	Difference
$\underline{1}$ Upper incisor	34.51	34.47	—0.04
$\overline{1}$ Lower incisor	34.98	35.09	+0.11
Mean difference between the two regions	0.47[a]	0.62[a]	+0.15

[a] Significantly different from zero: $p < 0.001$.

this increase was rendered nonsignificant ($p = 0.20$) by an increase in the variation between individuals.

In the noseclip experiment (Table 5), a similar differential was noted initially between upper and lower incisor regions, but this disappeared after ten minutes of pure mouth-breathing with the noseclip in position. The change was due to the temperature of the lower incisor region falling by a mean of 0.92° C.

Measurements at points along the tooth axis (tooth tip, gum margin and sulcus) revealed an obvious difference at the three locations (Table 6) which applied across a broad spectrum of individuals. There was a significant linear trend in both upper and lower central incisor regions ($p < 0.001$), but in the lower incisor region this was moderated by a relatively higher mean figure at the gum margin.

Series 3. The subjects were exercised with the mouth closed, to produce forced nasal breathing (Table 7). The pre-exercise readings again showed a significant difference between upper and lower incisor regions, and this became even more apparent after exercise, with the difference increasing to 1.62° C ($p < 0.001$). The sublingual temperature significantly increased during exercise (mean increase 0.34° C, $p < 0.01$), but the temperature increase in the lower incisor region was

TABLE 5. *Noseclip experiment (° C).*

Tooth region	Initial	After 10 minutes	Difference
⌊1 Upper incisor	33.91	33.85	—0.06
⌈1 Lower incisor	34.67	33.75	—0.92[a]
Mean difference between the two regions	0.76[a]	—0.10	

[a] Significantly different from zero: $p < 0.001$.

TABLE 6. *Vertical gradient (° C).*

Tooth	Location of probe			Difference in °C between tip of tooth and sulcus
	Tip	Gum margin	Sulcus	
⌊1 Upper incisor	34.7	35.0	35.3	0.6[a]
⌈1 Lower incisor	34.8	35.3	35.5	0.7[a]

[a] Linear trend significant: $p < 0.001$.

TABLE 7. *Series 3: ten subjects before and after exercise to accentuate forced nasal breathing with the mouth closed (° C).*

Position	Initial	After 1½ minutes exercise	Difference
Sublingual	35.57	35.91	+0.34[a]
⌊1 Upper incisor	33.76	33.17	—0.59[b]
⌈1 Lower incisor	34.61	34.79	+0.18
Difference between incisors	0.85[b]	1.62[b]	

[a] $p < 0.01$.
[b] $p < 0.001$.

not significant (mean change 0.18° C, $p = 0.20$). Conversely, the mean temperature of the upper incisors fell by 0.59° C ($p < 0.001$). The rise of sublingual temperature during exercise and the possible effect of this on the teeth is clinically and statistically difficult to assess, and beyond the scope of this study. However, one possible way to interpret the results is that exercise simply magnified the differentials present initially.

DISCUSSION

Gum involvement and ulceration in leprosy was described in the Middle Ages when the condition was endemic to Europe and loss of the upper central incisors was recognized by the early part of the 16th century ([6, 7]). De La Sota ([8]) recorded central incisor "paradentitis" in 1894, and Pinkerton ([19]) described the frequent involvement of the lingual surface of the alveolar processes adjacent to the upper central incisors with consequent loosening. In the last 25 years the exhaustive studies of Møller-Christensen ([15–18]) working on osteo-archeological material from several Danish medieval leprosaria, have revealed bone changes typical of low resistance leprosy. The principal changes involving the facial bones and constituting the so called *facies leprosa* are: 1) atrophy of the anterior nasal spine; 2) atrophy and recession of the premaxillary alveolar process, confined to the incisor region beginning cen-

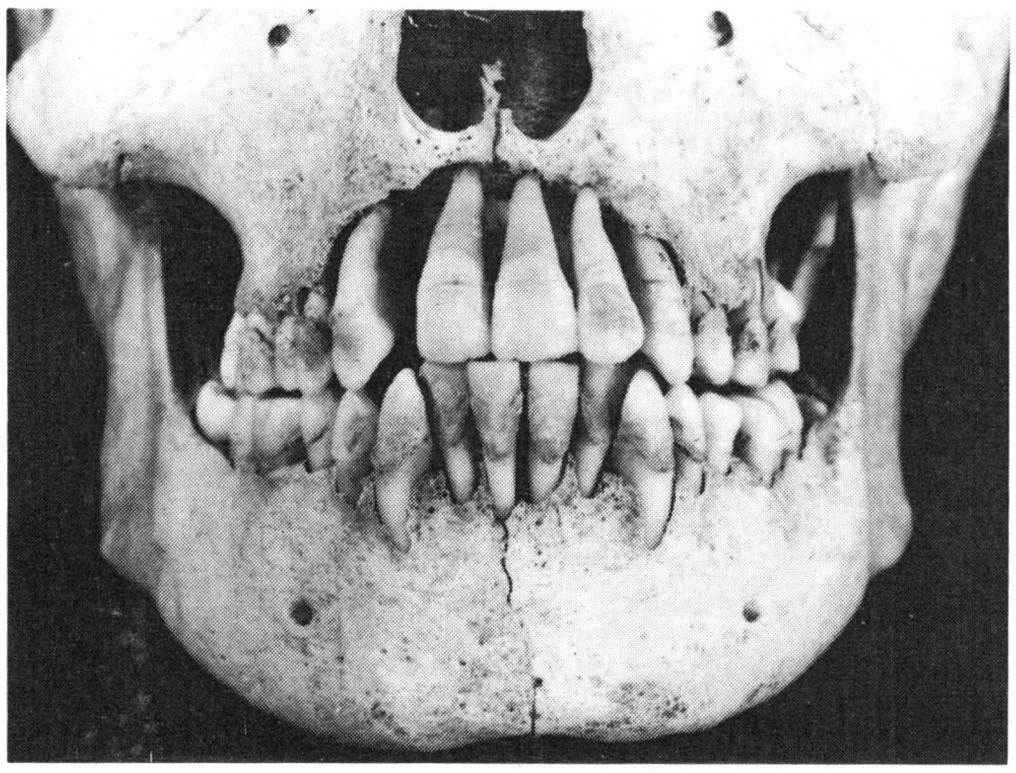

FIG. 1. Lepromatous leprosy: *facies leprosa.* Medieval juvenile skull showing atrophy of the alveolar process in the premaxillary region. Reproduced by courtesy of Dr. Knud Danielsen, The Royal Dental College, Copenhagen. Museum No. N 384.

trally (at prosthion), resulting in loosening and possible loss of the incisors; and 3) endonasal inflammatory changes (Fig. 1). It was subsequently confirmed that the *facies leprosa* had a direct clinical and radiographic contemporary equivalent, "the Bergen syndrome." These changes concern the support tissues of the upper central incisor teeth. *Odontodysplasia Leprosa* is the term used by Danielsen ([6, 7]) for the changes in the teeth caused by leprosy which he observed from the same medieval material and which he found to be more pronounced when the teeth had been involved by leprosy during development. Abnormalities were seen most commonly in the central incisors, upper more than lower, less commonly in the canines and premolars, and least of all in the molars. A most comprehensive study of involvement of dental pulp by leprosy was undertaken by Itakura in 1940 ([10]), in which 400 teeth were examined histologically and a number of important observations made. First, incisor teeth were involved more commonly than canines, the latter more than premolars, and molar teeth least commonly involved of all. Secondly, teeth in the upper jaw of each type were involved more commonly than those in the lower and in any one tooth the pulp chamber was more heavily involved.

There is now extensive evidence that lepromatous leprosy evolves more readily and rapidly in low temperature situations ([2, 3, 4 23, 24]). A number of studies of temperature variation within the oral cavity have been performed. Brown and Goldberg ([5]), utilizing a rubber dam to isolate anterior teeth, showed that the anterior teeth were cooler than posterior, that the labial surfaces of anterior teeth were cooler than the lingual, and that there is a temperature gradient along a cusp, the distal margin being coolest. Selden ([21]) has inserted thermistor probes along the canal of anterior teeth prior to surgery. Recordings were made at the root tip and all the temperatures obtained were below the corresponding sublingual temperature for each subject by a range of ½-1°C. Bergstrom and Varga ([1]), working on healthy normal subjects established that the gum area of the premaxillary region is cooler than elsewhere, that within the vestibular fornix the gums of the upper jaw were cooler than the lower and that the temperature increased when the probe was moved in a posterior direction. They also demonstrated bilateral symmetry of temperature within the mouth. Our own findings are entirely consistent with these three papers ([1, 5, 21]) and the combined evidence suggests strongly that the relative frequency of involvement of teeth in lepromatous leprosy, as reported in such detail by Itakura ([10]), could be predicted on grounds of temperature alone. The relatively extensive involvement of the coronal end of the pulp chamber which he reported is in keeping with the gradient we have demonstrated along the axis of a tooth.

It has been suggested that the low temperature of the premaxillary region is related to mouth-breathing, and that latent heat of evaporation from the moist surface accounts for the heat loss. This is true when the mouth is open, but our studies show that even when the mouth is closed the premaxillary region remains cool. Furthermore, during a period of forced nasal breathing its temperature falls in absolute terms, even against an upward tendency from the effects of exercise, and the differential between the upper and lower incisor regions widens (Table 7). We conclude that the low temperature of the premaxillary region is mainly achieved by the nasal air stream. When this route is eliminated by the use of a noseclip, the low temperature of the premaxillary alveolar process is maintained by the direct effect of the oral airstream, and the lower incisor region falls to a similar temperature (Table 5).

Whereas the relatively low temperature of the premaxillary alveolar process may be

maintained directly by latent heat of evaporation from the floor of the nose, it is important to note that part of the region's blood supply is derived from the posterior septal branch of the spheno-palatine artery on each side. These vessels run across the nasal septum, a known cool area, to reach the incisive canal, and may thus contribute to the cooling effect.

Leprosy infection could reach the premaxillary alveolar process in a number of ways. Danielsen ([7]) has commented that the gap between the incisor roots and the floor of the nose may be minute, so that direct spread is quite possible. There is now strong evidence ([9, 22]) for a heavy bacteremia in lepromatous leprosy and this mode of spread is probably of paramount importance, and certainly the most credible route of involvement as far as the teeth of the lower jaw are concerned. Peripheral nerve involvement is a characteristic of leprosy and spread of bacilli along the nasopalatine nerve from the heavily infected nasal cavity to the anterior third of the hard palate may also be of significance. Finally, spread may be achieved along lymphatic pathways.

The loss of the anterior nasal spine and destruction of the premaxillary alveolar process combine to produce a highly distinctive deformity (Fig. 1), the appearances being clearly atypical of classical periodontal disease. We believe that it can be explained by a consideration of relative temperature and differing bone density. The coldest position in the upper jaw is at prosthion, and there is a gradual increase in temperature from this point in both an upward and lateral direction (Tables 1, 6). Intensity of lepromatous osteomyelitis and gingival infection might be expected to conform to this temperature distribution. The inferior aspect of the pyriform aperture consists of an arch of bone which is dense in comparison to that of the remainder of the premaxillary alveolar process. Taken together, these two factors could account for the deformity as seen in practice.

We conclude that certain anatomical features of this region are closely linked to the factor of low temperature in accounting for its heavy involvement in lepromatous leprosy. In view of the continuing failure to culture *Mycobacterium leprae in vitro,* its highly successful growth in the armadillo ([11, 12, 13]), which has a core body temperature of 30-35°C, suggests that the behavior of this organism in the relatively cool tissues of man may repay further study.

SUMMARY

The predilection of lepromatous leprosy for body sites substantially below core temperature is well known, and within the oral cavity the premaxillary alveolar process and upper central incisor teeth are especially affected.

In this study, intra-oral temperatures were recorded by means of a series of thermistor probes applied to the teeth and labial surfaces of the gums of normal subjects. The temperature distribution established showed a close correlation with the known pattern of involvement of teeth and supporting structures derived from clinical, pathological and archeological data.

Relatively low temperature of the premaxillary alveolar process was demonstrated, a factor which may be of prime importance for the localization of disease in this region, as it is for other tissues in the lepromatous patient.

RESUMEN

Es bien conocida la predilección de la lepra lepromatosa por las regiones del cuerpo que tienen una temperatura acentuadamente menor que la central y, dentro de la cavidad oral, el proceso alveolar maxilar y los dientes incisivos superiores están entre los más afectados.

En este estudio se registraron las temperaturas intra-orales por medio de una serie de sondas con termistores aplicadas a los dientes y superficies labiales de las encias de sujetos normales. La distribución de temperatura establecida mostró una estrecha correlación con los patrones conocidos de compromiso de los dientes y estructuras de soporte, derivados de datos clínicos, patológicos y arqueológicos.

Se demostró la temperatura relativamente baja del proceso alveolar pre-maxilar, un factor que puede ser de primordial importancia para la localización de las lesiones en esta zona, lo mismo que en otros tejidos del paciente lepromatoso.

RÉSUMÉ

La prédilection de la lèpre lépromateuse pour des endroits corporels qui présentent une température nettement en-dessous de l'ensemble de l'organisme est bien connue. A l'intérieur de la cavité buccale, le processus alvéolaire prémaxillaire et les incisives supérieures centrales, sont particulièrement affectés.

Dans cette étude on a procédé à l'enregistrement des températures intra-buccales, au moyen

d'une série de thermistances appliquées sur les dents et sur la surface des lèvres au niveau des gencives de sujets normaux. La distribution des températures a montré une corrélation étroite avec les profils connus d'atteinte au niveau des dents et des structures annexes, telles qu'ils ont été établis à la suite d'études cliniques, pathologiques et archéologiques.

On a pu démontrer une température relativement basse au niveau du processus alvéolaire prémaxillaire. Ce facteur pourrait être de grande importance pour expliquer la localisation de la maladie à ce niveau, ainsi qu'il en est pour d'autres tissus chez le malade lépromateux.

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