

Original Article

## Age-related changes in oral mechanosensitivity of symptom-free subjects

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The purpose of this study was to determine the effect of aging on the tactile and pain sensitivity, and the factors influencing threshold change in the oral mucosa using Semmes-Weinstein Pressure Aesthesiometer. The touch and pain thresholds of 81 healthy elderly (40 males and 41 females,  $77 \pm 4.5$  years) were compared with those of 58 young volunteers (27 males and 31 females,  $27 \pm 2.5$  years). We measured the pain thresholds, the touch thresholds, PCR score and amount of salivation. Semmes-Weinstein Pressure Aesthesiometer was applied to 9 points in the oral region and 4 points in the hands; the dorsum manus, the palma manus, the incisive papilla, the palatal mucosa, the buccal mucosa, the margin of the tongue, and the dorsum of the tongue. Elderly subjects showed significantly higher touch thresholds than those of young subjects in the dorsum manus, the palma manus, the buccal mucosa, the incisive papilla, the margin of the tongue, and the dorsum of the tongue ( $P < 0.05$ ). The pain thresholds of elderly subjects were significantly lower than those of young subjects in the buccal mucosa and the palatal mucosa ( $P < 0.05$ ). The touch threshold was not influenced by the smoking

habit, denture and amount of salivation. The pain threshold was influenced by the denture on the palate.

**Key words:** Oral mucosa; Aging; Semmes-Weinstein Pressure Aesthesiometer; Sensation

### Introduction

Many of the elderly have difficulties with their dentures. These difficulties are mainly caused by the decrease of salivation and the change of the mechanosensitivity in the oral mucosa.

Many studies have recorded experimental results on the touch and pain thresholds<sup>1-4</sup>. Some authors also reported aging effects on the sensation in the orofacial region. Wohler<sup>5</sup> indicated that spatial acuity at the lip vermilion decreased significantly in the elderly and that females tend to have better acuity than men in two-point discrimination. Besne *et al.*<sup>6</sup> reported that epidermal innervation in the face decreases with aging. There has been, however, no research on the quantitative effects of aging in terms of oral sensation.

We paid a particular attention to the touch and pain thresholds in the oral mucosa and the skin of hands. We examined the influence of aging, salivation, the smoking habit, presence of denture on palate, plaque control record (PCR) score to the mechanosensitivity of the oral mucosa. The purpose of this study was to

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determine the effects of aging on tactile and pain sensations in the oral mucosa, and to determine the factors influencing threshold change in the oral mucosa. In addition, the touch and pain thresholds in the skin of the palma manus and the dorsum manus were also measured in the same subjects to examine the difference between the effects of aging on the oral mucosa and the skin.

### Materials and methods

#### Subjects

Eighty one elderly (40 males and 41 females; age range 70 to 91 years,  $77 \pm 4.5$  years [mean  $\pm$  standard deviation]) and 58 young volunteers (27 males and 31 females; age range 21 to 34 years,  $27 \pm 2.5$  years) were recruited for this research. All subjects did not have pain in the orofacial region, history of orofacial trauma, nor general diseases. They were not taking medicine. All subjects were informed of the purpose of this study, safety, risks, benefits, protection of privacy, and signed written consent forms. The methods were approved by the Ethics Committee of the Tokyo Medical and Dental University (2005.8.3 Admission No. 160).

#### Measurements

One of the authors carried out all the measurements, that are the measurement of the amount of salivation, mechanosensitivities of the oral mucosa, and oral

cleanliness. All measurements were executed in a noise-free room under approximately constant temperature and barometric pressure, and moderate lighting.

Followings are how to carry out each measurement.

#### (A) Salivation

A subject chewed a sheet of polyester film (4 cm  $\times$  4 cm of Parafilm™) for 10 minutes. Saliva secreted during this period was gathered in a cup and its amount was measured.

#### (B) Mechanosensitivity

The touch and pain thresholds of the oral mucosa and the skin of the hands were determined with Semmes-Weinstein monofilaments™ (US Neurologicals, USA). (Fig. 1)<sup>7-9</sup> We confirmed the repeatability of this measurement in the preliminary study.

Subjects were seated in a supine position of a dental chair with their heads on the headrest and their eyes closed. The touch and pain thresholds were measured at 9 sites in the oral region and 4 sites in the skin of the hands (Fig. 2). The measurement of the touch threshold was followed by that of the pain threshold.

For measurement of the touch threshold, filaments were placed vertically to the surface of the skin or mucosa. A pressure was applied for approximately 1.5 s through the filament within the elastic limit of it. At each site, a thinnest filament was applied first, and then the thicker filaments were applied step by step. The subject raised his/her hand when he/she recognized a tactile sensation from the filament and reported the site. The handlemark (Hm) of the filament was recorded as

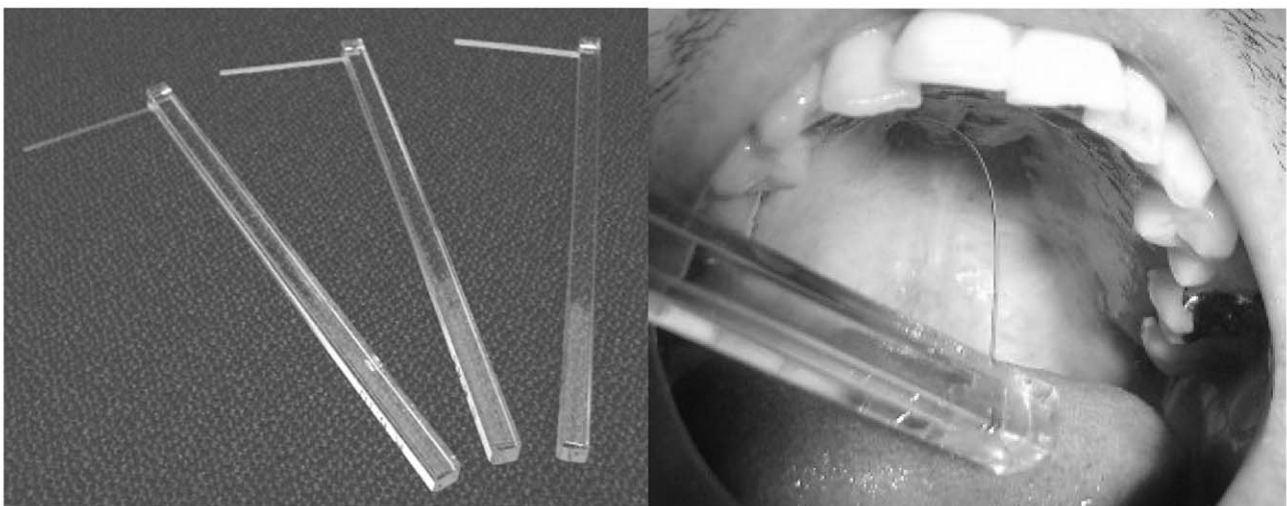


Fig. 1. S-W monofilaments; Application of S-W monofilament to intraoral testing site.

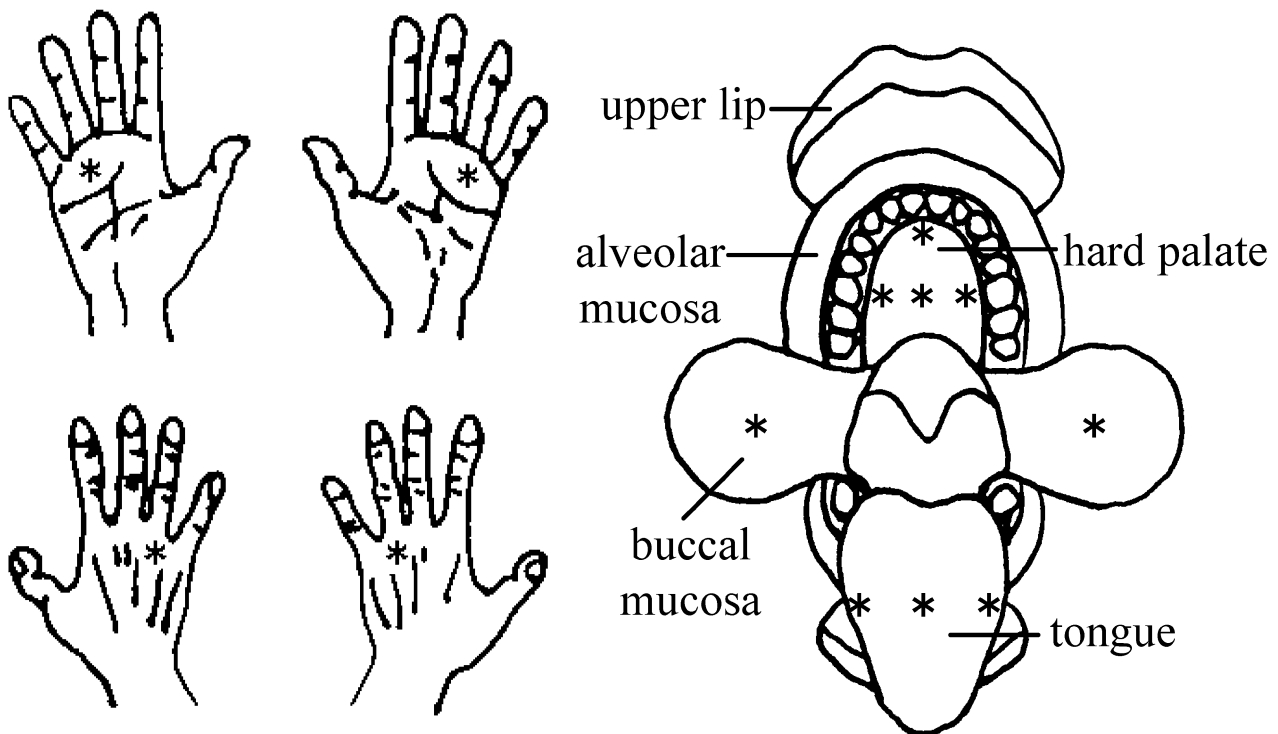


Fig. 2. Measurement points (\*): 9 points in the oral region and 4 points in the hands.

the touch threshold if the reported site and the stimulated site is the same. The Hm is defined as  $Hm = \log_{10}[\text{Force}(\text{gw}) \times 10^4]$ , and its value was used in the touch and pain thresholds (Table 1).

The measurement of the pain threshold started 30 seconds after the measurement of the touch threshold. Mechanical stimuli were applied by S-W monofilaments in the same way as the measurement as the touch threshold. The stimuli started from the filament corresponding to the touch threshold in the same site, and then the thicker filaments were applied step by step. The subjects were instructed to raise their hand when they feel a prick pain, the strength of which was equivalent to the value of 3 cm on the visual analog scale (VAS). The Hm of the filament was recorded as the pain threshold when the subject raised his/her hand. When a subject showed no positive response to the stimulus with the thickest filament ( $Hm = 6.65$ ), the value 6.65 was recorded as the pain threshold. Thresholds of right and left side of the same site (tongue, the buccal mucosa, etc.) are averaged to give a single value. S-W monofilaments were sterilized with the rubbing alcohol.

### (C) Plaque control record (PCR)

All the teeth of a subject were dyed with a plaque detection dye. The ratio of the area that was dyed red to the total area of all teeth, the ratio that is called PCR, was determined.

### Statistical analyses

The touch and pain thresholds are given as medians and quartiles. Mann-Whitney test was used for comparison of non-parametric data between the elderly group and the young group. P-values of  $<0.05$  were regarded as statistically significant.

The touch and pain thresholds in the palatal mucosa of elderly were analyzed by multi-regression analysis to determine the influences of the smoking habit, presence of denture on palate, PCR score, and amount of salivation to the mechanosensitivities. A value 1 was allocated for the group with the smoking habit ( $n = 9$ ) and a value 2 for the group without the smoking habit ( $n = 72$ ). A value 1 was allocated for the group with denture on the palate ( $n = 36$ ) and a value 2 for the group without denture on the palate ( $n = 45$ ). Analyses of the data were performed using SPSS 13.0J for Windows (SPSS Inc., Chicago, USA).

**Table 1.** Relationship between Hm value and diameter and force.

Hm	Diameter (mm)	Force(gw)
1.65	0.063	0.0045
2.36	0.075	0.0230
2.44	0.104	0.0275
2.83	0.132	0.0677
3.22	0.137	0.1660
3.61	0.171	0.4082
3.84	0.214	0.6958
4.08	0.228	1.1940
4.17	0.244	1.4940
4.31	0.284	2.0520
4.56	0.313	3.632
4.74	0.322	5.500
4.93	0.423	8.650
5.07	0.475	11.70
5.18	0.525	15.00
5.46	0.582	29.00
5.88	0.732	75.00
6.1	0.805	127.0
6.45	1.033	281.0
6.65	1.142	447.0

## Results

### (1) Mechanosensitivities of elderly and young

The touch thresholds of elderly were significantly higher than those of young in the dorsum manus, the palma manus, the buccal mucosa, the incisive papilla, the margin of the tongue, and the dorsum of the tongue (Fig. 3). The touch thresholds of elderly and young, however, showed no significant differences in the palatal mucosa except for the incisive papilla.

The pain thresholds of elderly were significantly lower than those of young in the buccal mucosa and the palatal mucosa. They were not significantly higher than the pain thresholds of young in the palma manus, the dorsum manus, the center of palatal mucosa, the incisive papilla, the margin of the tongue and the dorsum of the tongue (Fig. 4).

### (2) Factors influencing mechanosensitivities (Table 2)

The multi-regression analysis showed that the

touch thresholds were not affected by the smoking habit, presence of denture on palate, PCR score, or amount of salivation. The multiple correlation coefficient of the touch threshold was 0.054. Regression coefficients and p-values are shown in Table 2.

The pain thresholds were significantly affected by presence of denture on palate. The multiple correlation coefficient of the pain threshold was 0.273. Regression coefficients and p-values are shown in Table 2. The pain thresholds were reduced by presence of denture on palate. (Fig. 5)

## Discussion

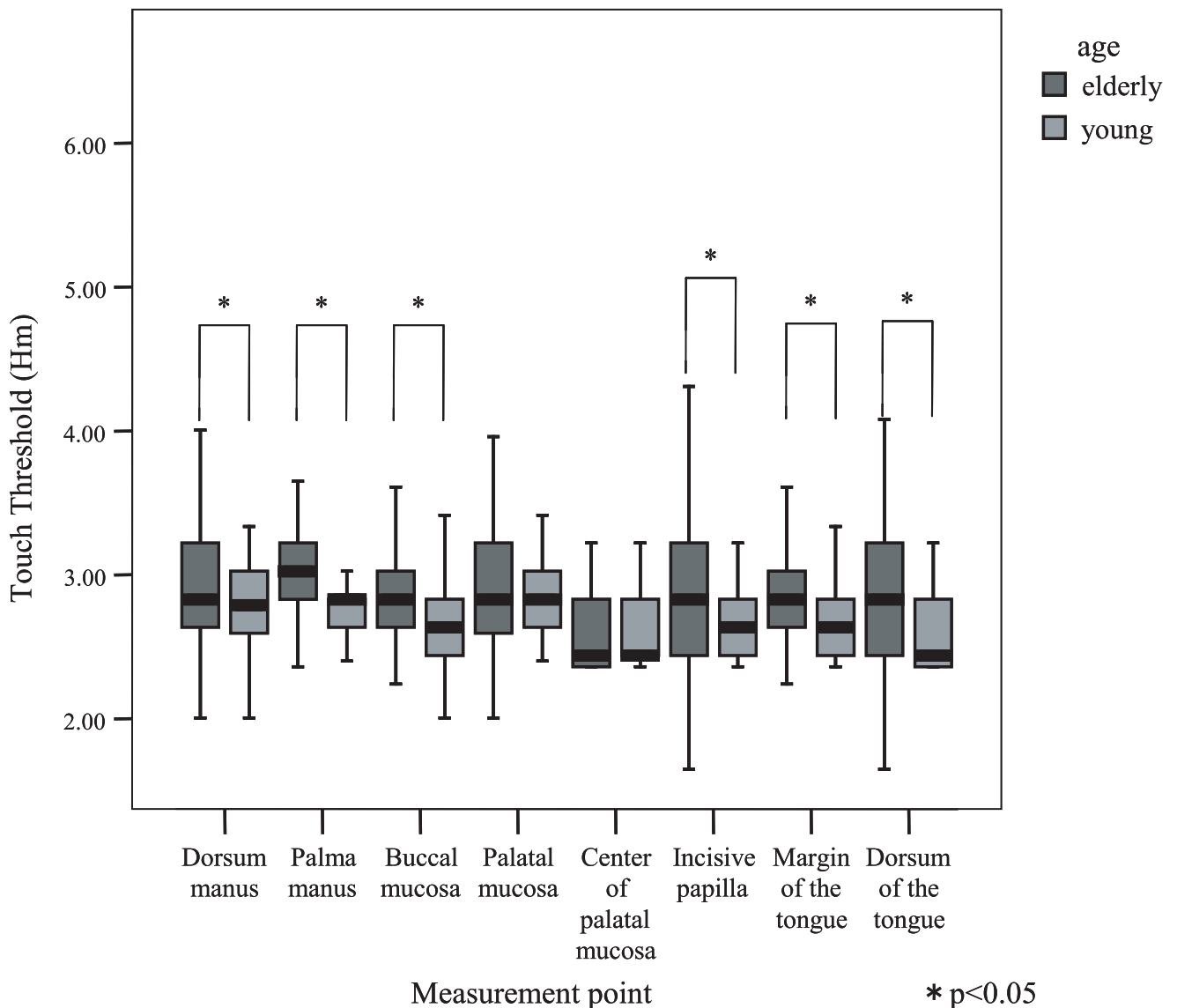
Oral sensations, such as tactile, pain, thermal and vibrational sensations, would change with aging. And these changes in oral sensations might relate to discomforts in the oral mucosa. We paid a particular attention to tactile and pain sensations in this study because some elderly patients complain stickiness, roughness, or burning pain in the oral mucosa.

There are some reports on tactile and/or pain sensations in the orofacial region. Komiyama *et al.*<sup>10</sup> determined the tactile detection threshold, filament-prick pain detection threshold, pressure pain threshold, and pressure pain tolerance threshold in the orofacial region using S-W monofilaments for healthy young subjects. Mashu *et al.*<sup>11</sup> determined the mechanical pain thresholds in the oral mucosa and in the facial and hand skin of the healthy subjects. They described the differences of the pain thresholds in the various sites of orofacial region. Cooper *et al.*<sup>12</sup> determined the tactile and pain thresholds of children. They mentioned that the examination with S-W monofilaments was convenient because very young subject needs to say only yes or no.

We used S-W monofilaments because both tactile and pain thresholds can be determined with them, and because elderly subjects can easily understand the method.

Psychophysical experiments have traditionally used three methods for testing subjects' perception in stimulus detection and difference detection experiments: the method of limits, the method of constant stimuli, and the method of adjustment<sup>13-16</sup>.

In the method of limits the subject reports whether he/she detects the stimulus. In ascending method of limits, some property of the stimulus starts out at a level so low that the stimulus could not be detected, then this level is gradually increased until the participant



**Fig. 3.** Comparison of the touch thresholds between elderly and young subjects.

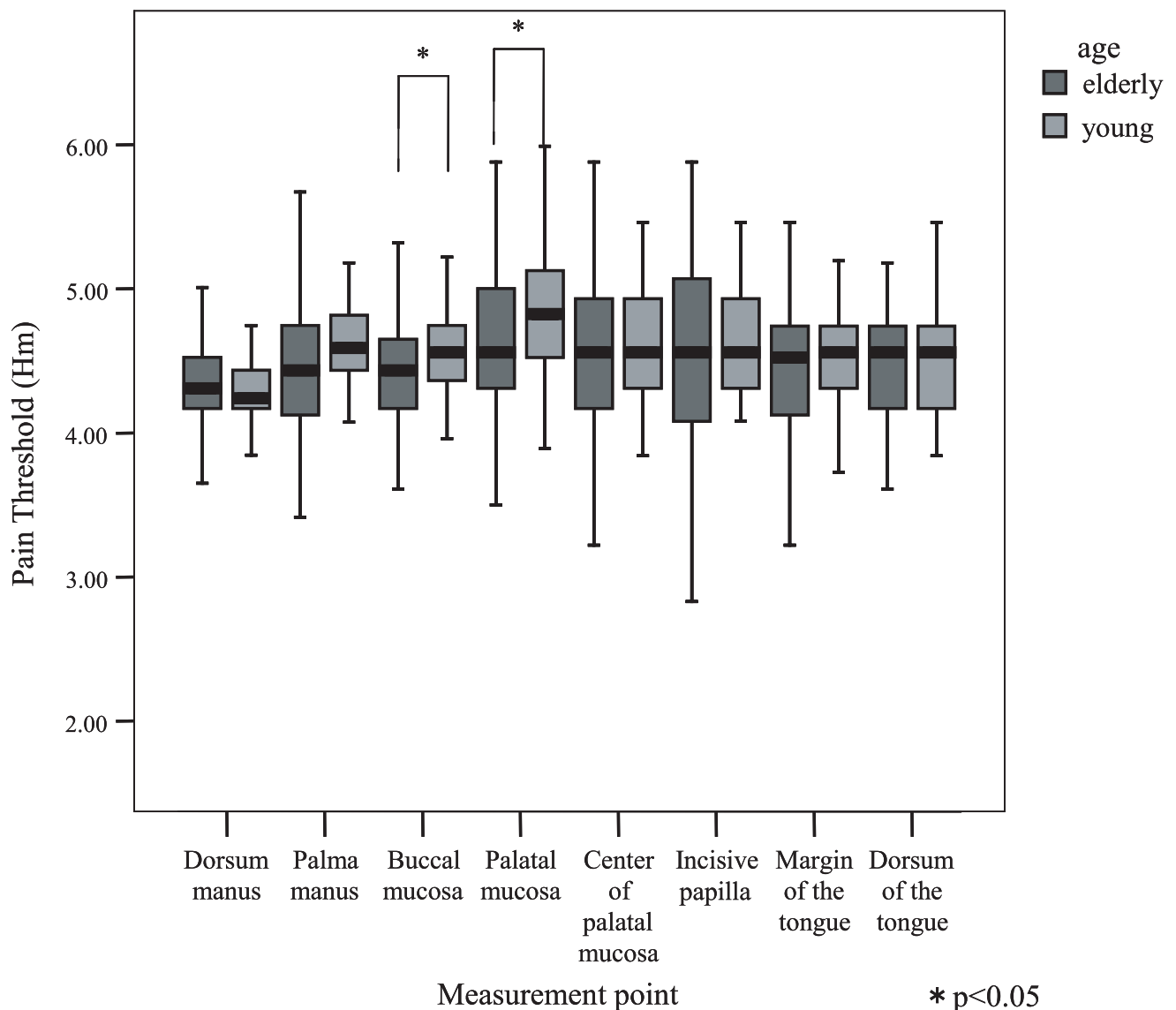
The touch threshold of the elderly was significantly increased at the dorsum manus, the palma manus, the buccal mucosa, the incisive papilla, the margin of the tongue, and the dorsum of the tongue.

The upper limit of the vertical bar in the boxplot indicates the maximum value, upper limit of the band presents 75th percentiles, the middle line of the band presents median, the lower limit of the band presents 25th percentiles, and the lower limit of the vertical bar indicates the minimum value.

reports that they are aware of it. In the descending method of limits, this is reversed. In each case, the threshold is considered to be the level of the stimulus property at which the stimuli is just detected. A possible disadvantage of these methods is that the subject may become accustomed to reporting that they perceive a stimulus and may continue reporting the same way even beyond the threshold (the error of habituation).

Conversely, the subject may also anticipate that the stimulus is about to become detectable or undetectable and may make a premature judgment (the error of expectation).

To avoid these potential pitfalls, the staircase method was used in the study of auditory perception. In this method, the sound starts out audible and gets quieter after each of the subject's responses, until the sub-



**Fig. 4.** Comparison of the pain thresholds between elderly and young subjects.

The pain thresholds of the elderly were significantly lower than those of the young in the buccal mucosa and the palatal mucosa. The data are shown using the boxplot.

ject does not report hearing it. At that point, the sound is made louder at each step, until the subject reports hearing it, at which point it is made quieter in steps again. This way the experimenter is able to “zero in” on the threshold. However, the staircase method needs more time to determine a threshold, and this might make it difficult for elderly to participate in this study. So we selected the simplest method of the ascending method of limits.

Instead of being presented in ascending or descending order, in the method of constant stimuli, the

levels of a certain property of the stimulus are not related from one trial to the next, but presented randomly. This prevents the subject from being able to predict the level of the next stimulus, and therefore reduces errors of habituation and expectation. The subject again reports whether he or she is able to detect the stimulus. Also called the method of average error, the method of adjustment asks the subject to control the level of the stimulus, instructs them to alter it until it is just barely detectable against the background noise, or is the same as the level of another stimulus.

**Table 2.** Regression coefficients and p-values with four autonomous variables for the touch and pain thresholds of the elderly. Smoking group contained 9 subjects and non-smoking group contained 72 subjects. Thirty-six subjects wore their dentures on the palates and 45 subjects did not wear dentures on the palates.

Independent variable	Touch Threshold		Pain Threshold	
	regression coefficient	p-value	regression coefficient	p-value
PCR score	-.009	.937	-.028	.807
Amount of salivation	.051	.669	.041	.722
The smoking habit	-.018	.875	.119	.291
Presence of denture on palate	-.010	.929	.245	.033*

\*:  $P < 0.05$

The method of constant stimuli and the method of adjustment are useful when there exists an expected value of the intensity of the stimulus. But the tactile and pain thresholds have large variances in this study. This is why these methods are not appropriate to determine the tactile and pain thresholds in this study.

The touch thresholds of elderly were higher than those of young in the specific parts of the oral mucosa (the buccal mucosa, the incisive papilla, the margin of the tongue and the dorsum of the tongue). This result may be caused by the decrease of the number and the sensitivity of mechanoreceptors.

The front part of the oral mucosa has a well-developed network of sensory nerves, and there are abundant Meissner's corpuscles<sup>17</sup>. That is why the front part of the oral mucosa is more sensitive than other parts of the oral mucosa.

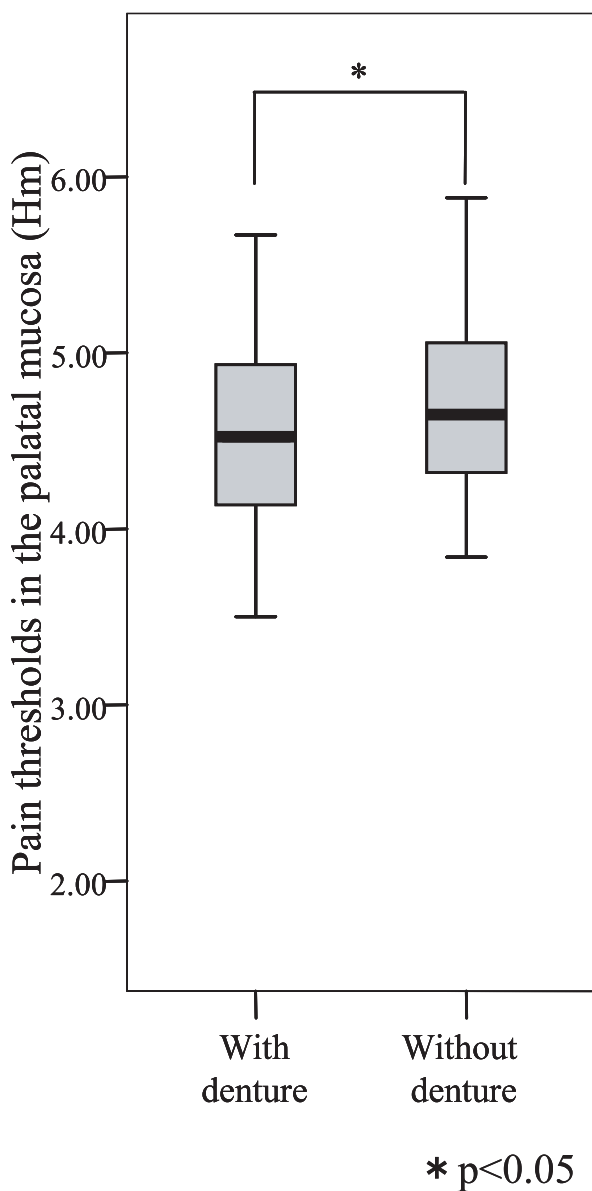
Number of Meissner's corpuscles decreases with aging. The decrease of Meissner's corpuscles is more remarkable in the front part of the oral mucosa than in the other part<sup>18,19</sup>. This fact corresponds to the results of this study.

Bolton *et al.*<sup>19</sup> have reported that Meissner's corpuscles suffer from morphological atrophy with aging. This suggests the mechanosensitivity related to Meissner's corpuscles is lower in the elderly than in the young.

The pain thresholds decreased in the specific parts of oral mucosa (the buccal and palatal mucosa). These results would be caused by the change of the thickness and hardness of oral mucosa with aging. McMillan<sup>20</sup> discussed the lower thresholds observed in the mandible mucosa could be attributed to reduced tissue resistance associated with thinner mucosa. Breustedt<sup>21</sup> reported reduced thickness of oral mucosal epithelium with aging. However the thickness change of the skin is controversial. Ultrasound revealed the appearance of a subepidermal low echogenic band that thickens with age<sup>22</sup>. It is widely accepted that hyperkeratinization occurs with age.

The force applied by a S-W monofilaments makes stress and strain in the oral mucosa. The stress can be divided into vertical and horizontal components. When the oral mucosa is thick, the horizontal component of the stress is larger than that in the thin oral mucosa. The vertical component of the stress in the thick oral mucosa, therefore, is smaller than that in the thin oral mucosa. Prick pain is caused by the stress component vertical to the oral mucosa. Consequently, the pain threshold of the thick oral mucosa is higher than that of the thin oral mucosa because the same force makes smaller vertical component of stress in the thick oral mucosa than that in the thin oral mucosa.

The multi-regression analysis showed that the pain



**Fig. 5.** Comparison of the pain thresholds of the group with denture on the palate and the group without denture on the palate.

The pain thresholds of the elderly were significantly reduced by presence of a denture on the palate. The asterisk means the  $p < 0.05$  in the multiple regression analysis shown in Table 2.

thresholds in the palatal mucosa are lower in the denture-wearing group. Oral mucosa covered by a denture is pressed due to occlusal force. This probably causes chronic inflammation of oral mucosa. Jennings *et al.*<sup>23</sup> reported that palatal mucosa covered by the denture exhibited the signs of chronic atrophic denture-induced stomatitis. This inflammation, consequently,

would reduce the pain threshold of oral mucosa. Another cause which reduces the pain threshold would be the thin mucosa compressed by a denture. The mucosa under a denture is thin because of compression by the denture. And Kydd *et al.*<sup>24</sup> reported that the thickness of the mucosa under a compression for 10 minutes required 4 hours to recover its original thickness. In a similar study, Tanaka *et al.*<sup>25</sup> reported that the pressure pain threshold reduction may be associated with mechanical stress on the mucosa generated by bite force. Compression of oral mucosa by a denture, consequently, would reduce the thickness of mucosa, resulting in the lower the pain threshold.

### Conclusion

We examined the effects of aging on tactile and pain sensitivity, and the factors influencing threshold change in the oral mucosa using the Semmes-Weinstein pressure aesthesiometer. Elderly subjects showed significantly higher touch thresholds than those of young subjects in the dorsum manus, the palma manus, the buccal mucosa, the incisive papilla, the margin of the tongue, and the dorsum of the tongue. The pain thresholds of elderly subjects were significantly lower than those of young subjects in the buccal mucosa and the palatal mucosa. The decrease in the pain threshold was caused by the presence of a denture on the palate.

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