A SCANNING ELECTRON MISCROSCOPIC STUDY OF THE TASTE PAPILLAE OF THE HUMAN TONGUE IN ONTOGENY

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Investigations have shown that the chemoreceptor apparatus of the tongue in children and adults differs in its structure and in the number of its functioning units. However, there is no unanimity in the literature regarding the times of appearance of mature bulbs in the different papillae of the tongue in human fetuses and infants [7, 11]. The vallate papillae have been studied most [12, 13]. Unfortunately, however, nowhere is it stated what are the morphological and physiological criteria of maturity of the taste bud. In the present writer's opinion, a firm criterion of the beginning of functioning of the taste bud could be the appearance of a pore in it [2]. From that moment contact can take place between chemoreceptor cells and stimulus. Disappearance of the pore may indicate termination of the function of the chemoreceptor. Scanning electron microscopy is a suitable method for detecting bulbs with pores in the various lingual papillae.

There have been few investigations into the structure of the adult human tongue by means of the scanning electron microscope. Fungiform papillae of the tip of the tongue in persons aged from 20 to 50 years were studied previously [4].

The object of the present investigation was to detect activity of chemoreceptor units of the infant's tongue at birth and to examine its changes with age.

EXPERIMENTAL METHOD

Cadaveric material was used. Tongues of newborn infants, 30- and 32-week fetuses, and adults aged 60-80 years were used. The tongues were washed to remove saliva and mucus for 20-30 min, first with tap water, then with distilled water, and fixed in 4% formalin or 2.5% glutaraldehyde solution for 10-12 h. The tongues were then washed again to remove the fixative and frozen. The frozen material was dried. Different parts of the tongue were studied in Stereoscan 2A and JSM-50A scanning microscopes.

EXPERIMENTAL RESULTS

Fungiform papillae (Fig. 1A) of different shapes were found on the anterior free surface of the adult human tongue: barrel-shaped (Fig. 1B), club-shaped (Fig. 1C), and dome-shaped (Fig. 1E). The fungiform papillae of the 30-week fetus and newborn infant differed considerably in shape from the adult human papillae (Fig. 2A, B, D, G, H). As a rule the taste buds found in the papilla of a 30-week fetus were still without open pores. The number of pores in papillae of the newborn infant varied from one to three (Fig. 2D, G-I). Some papillae in the medial part of the tip of the tongue had no pores. The pores of the bulbs had irregular edges (Fig. 2F). The dorsal surface of the fungiform papilla consists of closely packed epithelial cells, and the boundaries of the cells and nuclei were distinct (Fig. 2A, B).

In material from subjects aged 80 years the pores in the papillae of the anterior free surface of the tongue were found less frequently than in persons aged 60 years. "Closed" pores could also be found in the former (Fig. 1A-F). Only a few fungiform papillae were seen on the dorsal surface of the body of the adult human tongue. On the lateral surface the papillae were conical and club-shaped. Single pores or no pores whatsoever were present in them (Fig. 1K, L). Fungiform papillae in the root and body of the tongue of the newborn infant were usually larger and contained more bulbs with pores than papillae at the tip of the tongue. Even in the 30-week fetus, bulbs with pores were present in the medial papillae.

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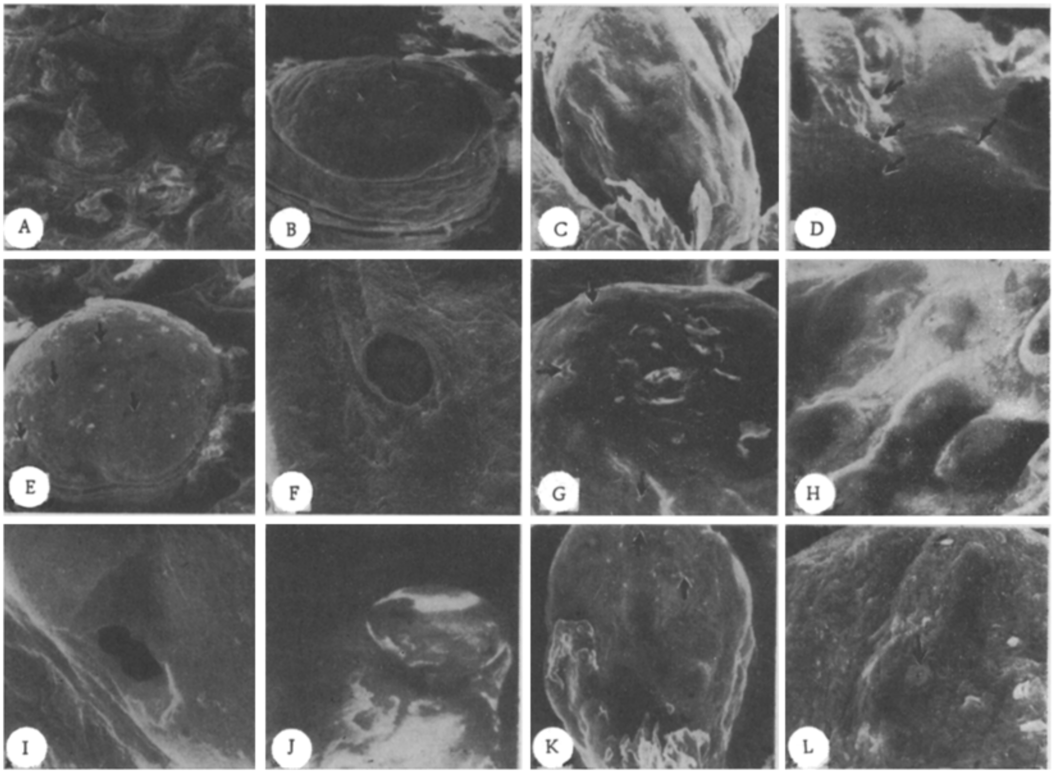

Fig. 1. Chemoreceptor papillae in the adult human tongue. A) General view of receptor formations at the tip of the tongue. Arrow indicates fungiform papilla, 70×; B) barrel-shaped fungiform papilla at the tip of the tongue. Arrows indicate pores of bulbs, 180×; C) club-shaped fungiform papilla, 150×; D) general view of lateral part of tongue with foliate papillae. Arrows indicate efferent ducts, 20×; E) dome-shaped fungiform papilla. Arrow indicates pores of bulbs, 100×; F) pore of fungiform papilla, 3000×; G) duct of gland. Arrow indicates pores of taste bulbs around it, 200×; H) pores in bulbs of foliate papilla, 600×; I) pore of bulb of vallate papilla, 3000×; J) vallate papilla, 20×; K) club-shaped fungiform papilla in medial part of root of tongue. Arrow indicates pores, 80×; L) pores in club-shaped fungiform papilla (arrow), 300×. A-D, F, H, K) Aged 60 years; I, J) 80 years.

Foliate papillae were found on the lateral surface of the body and root of the tongue (Fig. 1D). Folds of foliate papillae on the adult human tongue were shallow and taste buds were present on their inner walls. Most bulbs of the lingual papillae of the 60-year-old subjects had pores (Fig. 1H). Efferent ducts of glands opened in the region of the foliate papillae. Some of them were located on the dorsal surface of the folds of the foliate papillae. The outlets of these ducts were often surrounded by taste bulbs (Fig. 1G). Other ducts were found beneath the foliate papillae (Fig. 1D). Sometimes the foliate papillae of 80-year-old subjects had no folds and the papillae were cup-shaped. Bulbs with open pores could not be found in them. The foliate papillae of the newborn infant differed from those of the adult primarily in the larger number of taste buds located on the whole surface of the transverse, middle, and posterior folds. The number of bulbs per papilla varied from 20 to 400 (Fig. 3A-E). The anterior and posterior papillae could contain only a few bulbs with pores (Fig. 2C). Here also, in the lateral part of the tongue, fungiform papillae, with more bulbs than in the papilla at the tip of the tongue, could be seen in the lateral part of the tongue in front of the foliate papillae (Fig. 2J, K). Taste buds in the foliate papillae were often very tightly packed together, and all had pores (Fig. 3F).

The vallate papillae differed in shape. Often papillae grouped in pairs could be seen. A characteristic feature of adult human vallate papillae was a gradual decrease with age in the size of the ridge surrounding the papilla. For instance, vallate papillae in persons aged 80 years had no ridge (Fig. 1J). In shape they were coming to resemble large fungiform papillae. In persons aged 60 years, just as in those aged 80 years, very few bulbs in the vallate papillae had pores (Fig. 1I).

Vallate papillae in the newborn infant had many taste buds with pores (Fig. 3I, J). The papillae could be grouped in pairs, with shallow depressions around them (Fig. 3G, H). Bulbs were present in the papilla itself and in the ridge surrounding it (Fig. 3H).

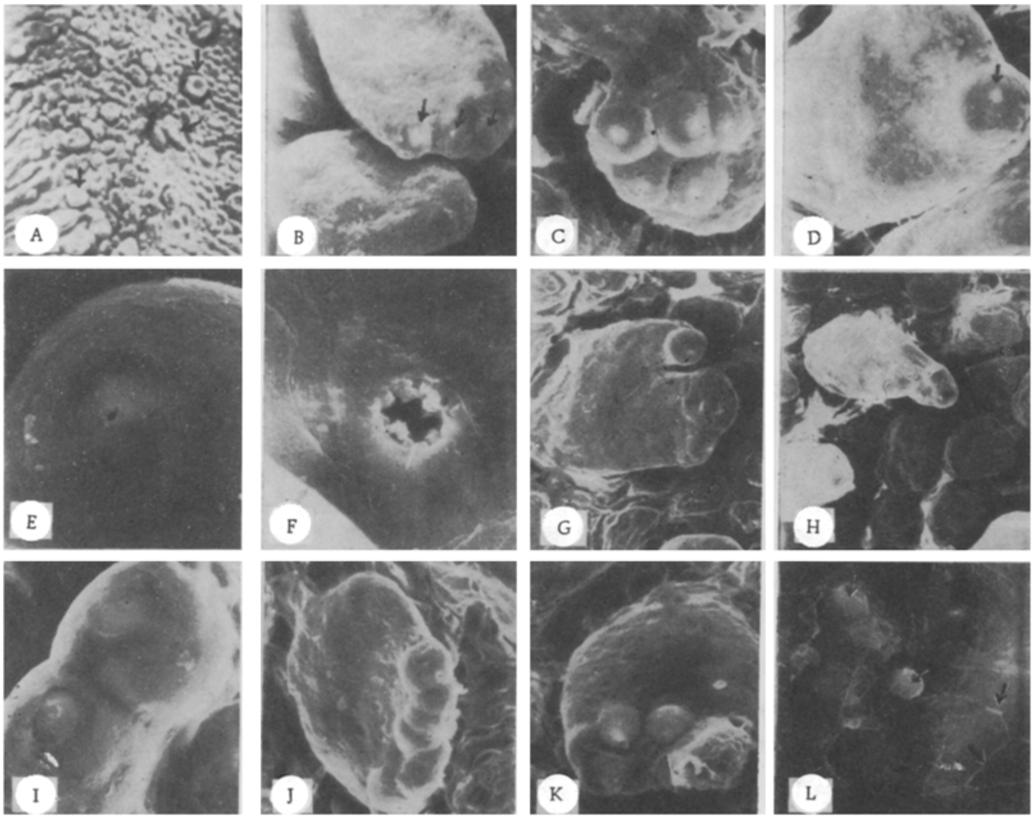

Fig. 2. Fungiform papillae on tongue of 30-week (A, B) fetus and newborn infant (E-I, K). A) General view of lateral part of tip of tongue. Arrows indicate fungiform papillae, 20×; B) fungiform papillae. Arrows indicate bulb swellings, but they have no pores, 150×; C) small foliate papillae, usually present on anterior and posterior lateral folds, 300×; D) fungiform papilla with one bulb and pore (indicated by arrow), 240×; E) bulb swelling and pore in fungiform papilla, 1100×; F) pore of fungiform papilla, 10,000×; G) fungiform papilla on tip of tongue with three bulbs, 120×; H) fungiform papilla on tip of tongue with three bulbs, 100×; I) bulb swellings and pores in fungiform papilla (tip of tongue), 600×; J) lateral fungiform papilla close to foliate papillae, 300×; K) lateral fungiform papilla on body of tongue, 300×; L) surface epithelial cells of fungiform papilla. Arrows indicate nuclei and boundaries between cells, 2000×.

Considering that it is this part of the surface of the tongue in the newborn infant that is in contact with the chemical stimulus (milk) during the action of sucking, it can be considered that during this age period its chemoreceptor function is at its most active. This is shown, first, by the presence of bulbs on the dorsal surface of the vallate papillae (see Fig. 3H), which is not found in the adult, and second, by the greater number and density of the taste buds in papillae of all types in this part of the tongue (vallate, fungiform, and foliate), and third, by the presence of mechanical adaptations retaining the liquid food (milk) and directing it toward the chemoreceptor formations at the root of the tongue – the high part of the ridge of the medial vallate papilla at the side of the root of the tongue (Fig. 3K), and the directing folds in front of the vallate papillae (Fig. 3L).

Early maturation of particular chemoreceptor papillae of the tongue in man, just as in other mammals, is connected with the mode of infant feeding. First to mature are papillae in the region of contact of the surface of the newborn infant's tongue with the mother's nipple. Papillae on the anterior free surface of the tongue are formed later, evidence that the complete chemosensory apparatus is not formed all at the same time.

The use of the scanning electron microscope thus established not only the presence of different types of fungiform papillae (barrel-shaped, club-shaped, dome-shaped) on the adult tongue, but also revealed their topography. The possible existence of so-called skittle-shaped fungiform papillae has already been reported by some investigators [5]. The different forms of fungiform papillae may perhaps reflect their definite specialization. The existence of such "specialized" papillae was demonstrated by the results of psychophysio-

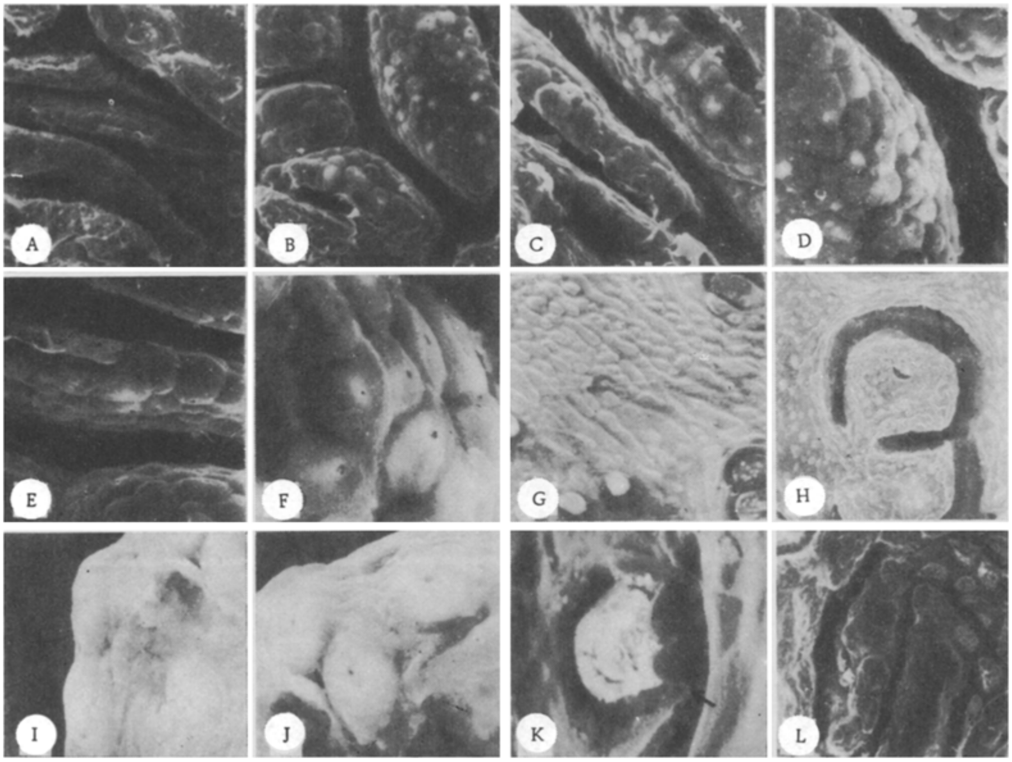

Fig. 3. Foliate and vallate papillae of 30-week fetus (G) and newborn infant (A-F, H-J, L). A) Foliate papillae (general appearance), 100×; B) peripheral foliate papillae, 200×; C-E) foliate papillae (middle folds). Magnification: C) 200, D, E) 300×; F) bulbs of foliate papillae with pores, 1000×; G) general view of part of tongue in front of vallate papillae. Arrows indicate vallate papillae, 20×; H) lateral vallate papilla. Pale spots on dorsal surface are swellings of taste bulbs, 50×; I, J) bulbs on dorsal surface of vallate papilla. Magnification: I) 400×; J) 600×; K) medial vallate papilla with "shutter" on side of root of tongue (indicated by arrow), 50×; L) folds on medial part of tongue, 50×.

logical experiments [6], in which stimulation of individual papillae created the sensation of only a sweet, bitter, acid, or salty taste. Furthermore, other investigations have shown the existence of more than one type of papilla sensitive to different types of sweetness [9].

By scanning electron microscopy it was possible not only to determine the number of pores in the different papillae of the tongue, but also to study changes in their number with age. Although the number of bulbs with open pores could not be counted in all types of fungiform papillae, a marked decrease in their number was found in persons aged 80 years compared with those aged 60.

In earlier studies by light microscopy [8] the presence of a stable number of bulbs (245) was found in the vallate papilla of persons under 20 years of age. In elderly individuals their number in the papilla decreased to 13. It was shown by scanning microscopy that although bulbs (in the form of swellings in the papilla) were found in persons aged 60 years, they did not necessarily have pores. By the age of 80 years bulbs with open pores were found extremely rarely in vallate papillae. A similar phenomenon may also be observed in the foliate papillae.

With age the number of active chemoreceptor formations thus diminishes. This decrease must lead to a decrease in the overall chemical sensitivity of the tongue, as is revealed by psychophysiological studies [10].

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POSSIBLE ROLE OF MUSCLE RECEPTORS IN REGULATION OF ARTERIAL BLOOD PRESSURE DURING DISTURBANCES OF THE ACID–BASE BALANCE IN THE MUSCLE

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One of the main problems in the physiology of muscular work is the nature of the stimulus responsible for the cardiovascular and respiratory changes observed during muscular activity. Investigations have shown [9, 12, 13] that these changes can be induced by a reflex mechanism from receptors transmitting information about the working muscles along afferent fibers of groups III and IV. There is also evidence that chemical substances liberated in the muscle during its work are among the principal factors stimulating these receptors. In other words, these receptors can be regarded as metabolic [7-10, 14, 16]. However, to confirm these ideas data are needed on the nature of the adequate chemical stimuli for perception of which muscle receptors are adapted. It has been shown that during changes in the concentration of potassium ions, lactic acid, and phosphate in the solution perfusing a muscle, activity of the muscle afferents is increased [16]. Meanwhile, during intensive muscular work not only do the concentrations of the above-mentioned agents change, but considerable disturbances of the acid–base balance also arise in the blood and tissues, and are reflected chiefly as a fall in the bicarbonate concentration and pH [11, 15]. Previously [1, 4] the writer showed that the interoceptors of the small intestine are sensitive to physiological changes in bicarbonate concentration and pH.

The object of this investigation was to study the sensitivity of skeletal muscle receptors to changes in acid–base balance of metabolic acidosis type.

EXPERIMENTAL METHOD

Experiments were carried out on 26 cats anesthetized by intravenous injection of chloralose (50 mg/kg) and urethane (500 mg/kg). The gastrocnemius muscle was isolated from the systemic circulation, while maintaining its innervation intact, by the method in [5] and perfused through the popliteal artery with Ringer's bicarbonate solution of the following composition (in mM): NaCl 125.0, KCl 4.3, $CaCl_2$ 2.5, $MgCl_2$ 1.0, $NaHCO_3$ 25.0, glucose 5.5; pH 7.4. The value of pCO_2, calculated by the Henderson–Hasselbalch equation, was 38 mm Hg. Solutions with reduced pH but constant pCO_2 were used for stimulation. Changes in pH of the solutions were obtained by reducing the bicarbonate concentration. The surface of the solutions was covered with a thin layer of mineral oil to prevent possible diffusion of CO_2 into the atmosphere. The technique of perfusion and preparation of the solutions was described in more detail previously [1, 4]. The arterial blood pressure was recorded in the right common carotid artery by means of a bridge circuit, with the mercury manometer connected into one arm of the bridge.

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