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Quantitative histology of the maxillary sinus

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SUMMARY

The entire mucosa from 10 normal maxillary sinuses was removed post-mortem and stained by the PAS-alcian blue whole-mount method. The density of goblet cells and of mucous glands was investigated. The median density of goblet cells was 170 cells/field, corresponding to 9,600 cells per mm², with wide individual variations, but there were no significant differences in density between the various walls. The density of goblet cells was somewhat higher than in the nose. Glands were very scarce and small in the maxillary sinus. Their median density in most walls was 0.15-0.20 gland/mm², but in the medial wall significantly higher, 0.5 gland/mm². The lower density of glands in the maxillary sinus than in the nose, where it is 8-9 glands/mm², is in complete agreement with the lesser requirement of the antral mucosa for moistening, cleaning, and warming of the air. Quantitative histological studies of normal mucosa will form the basis for studies of abnormal mucosa.

THE mucous membrane of the maxillary sinus is a continuation of the nasal mucosa. Its epithelium is also stratified, ciliated, with goblet cells. The lamina propria, thin as compared with the nasal mucosa, contains tubulo-alveolar glands and a vascular system less developed than in the nose. The delicately adapted automatic control of blood circulation and of the secretion in the nose (Änggård, 1976; Ishii et al., 1976) also seems to be demonstrable histologically in the maxillary sinus (Nishimura et al., 1976).

From a qualitative point of view there so not seem to be major histological differences between the nasal and the antral mucosa, but from daily clinical practice we know that secretion is considerably greater in the normal nose than in the maxillary sinus, and that under abnormal conditions, e.g. during acute rhinitis, the secretion may increase very considerably in the course of a short time. To better understand the physiology and pathophysiology of the maxillary sinus, quantitative studies of the mucus-producing elements — the epithelial goblet cells and the subepithelial glands — are needed. Such quantitative histology — which we have performed in the case of the nasal mucosa (Tos and Mogensen, 1976; Mogensen and Tos, 1977 a and b) — is time-consuming, it is true, but it is hoped that it will afford more exact information about the occurrence of these elements, their distribution, and density in the various parts of the maxillary sinus. This was the object of the present study.

PREVIOUS INVESTIGATIONS

Goblet cells

Reports on their occurrence have differed somewhat: Shall (1932) found numerous goblet cells in the maxillary sinus, Eggston and Wolff (1947) only a few. Latta et al. (1934) found occasional goblet cells, varying in size and shape. Bauer (1960) reported a marked difference in the occurrence of goblet cells between the medial and lateral wall. Alyea (1951) felt that in the maxillary sinus there was a preponderance of goblet cells as compared with the nasal cavity, while Scott Brown (1971) holds the opposite view.

Mucous glands

In the literature it is agreed that glands are less numerous in the maxillary sinus than in the nose, but there is much disagreement concerning their distribution in the individual walls. Heiss (1936) merely stated that glands are few, and that they occur mainly in the medial wall and roof. Hansel (1930) found the glands arranged in groups scattered over the mucosa, being abundant in some areas and scarce in others. According to Eggston and Wolff (1947) the largest quantity occurs in the medial wall and the density decreases towards the lateral wall in which there are few. Schiefferdecker (1900) could study several square cm of the mucosa without finding any glands. According to Proetz (1947) and Alyea (1951) the few glands that do occur are localized around the ostium, and the occurrence of glands is in conformity with the physiological requirement for secretion, areas far from the ostium containing but few glands, just sufficient to moisten the mucosa, unlike the ostial region where secretion is said to be greater.

Ash and Raum (1949) investigated embryonic maxillary sinuses, where they found a great abundance of glands, but gradually as penumatization and thinning of the mucosa took place, the density of glands decreased, and at the same time the glands got smaller and of simpler structure.

The present whole-mount technique of preparation, the principle of which is to stain the mucosa in toto and examine mucous elements in major areas, does not appear to have been applied previously to mucous membranes from the maxillary sinus.

Material and methods

The material is derived from autopsies on 10 persons, 3 women and 7 men in the age range 60-94 years, who had died of cardio-pulmonary or malignant diseases. During the period immediately preceding death, they had not shown any signs of sinusitis or catarrhal states. None had been subjected to nasal intubation. There was no history of any disease of the nasal sinuses or allergy. Objective examination of the nose showed no secretion or gross pathological changes. In the maxillary sinuses there was no secretion, and the mucosa was thin and smooth.

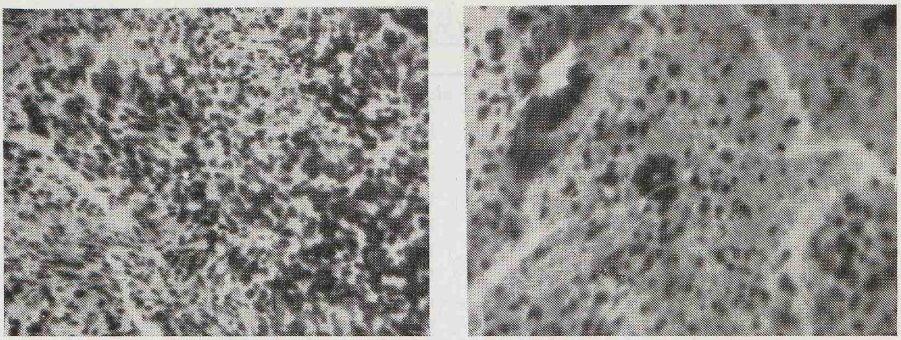

Figure 1. Goblet cells in the maxillary sinus as seen in a whole mount. PAS-alcian blue x 200.
(a) high density, (b) low density and a gland orifice.

The entire mucosa was removed by a Luc-Caldwell operation 3-10 hours after death and fixed in formol alcohol.
The specimens were stained by the PAS Alcian blue whole-mount method (Tos, 1970). Moreover, histological sections were cut and stained with haematoxylin-eosin, PAS, Alcian blue, or combinations thereof.
Goblet cells were counted in a projection microscope at a magnification of x 500. In each of the six walls (superior, inferior, anterior, posterior, medial, lateral) 10 fields of 0.01768 mm^2 were counted, and the median density in each wall was calculated. The glands were counted in a stereomicroscope in a magnification of x 50, in each wall in 3-8 four mm^2 large fields, and the median density (glands/mm^2) in each wall was calculated.

RESULTS

Throughout the maxillary sinus the epithelium was ciliated, pseudostratified, columnar. The basement membrane was very thin and did not vary from the medial wall to the others. The underlying stroma — the lamina propria — was thickest in the medial wall; it contained rather few migratory cells, but a number of fibroblasts. In the depth collagen fibrils weaved their way into the periosteum without any sharp limits.

Goblet cells:

In the whole mount specimen the goblet cells were seen from above as round to oval, blue, sharply delimited spots — thecae — on a pale blue background (Figure 1). They were scattered throughout the epithelium, but even within small areas they were of irregular distribution. This irregularity was seen in all walls. The diameter of the goblet cells — in whole-mount preparations — ranged from 5 to 10 μ, and only a few were outside this range.
Their size was the same as in the nasal cavity (Mogensen and Tos, 1977 a).

Table I: Median density of goblet cells (cells/0.01768 mm² field) in the different walls of the normal maxillary sinus.

Case No.	Walls of the sinus						Individual Median
	Sup	Inf.	Ant.	Post.	Med.	Lat.	
1	188	179	170	200	158	165	175
2	126	164	124	171	150	149	150
3	—	185	241	201	160	182	185
4	199	142	191	148	153	141	151
5	262	218	205	148	195	175	200
6	135	108	141	121	122	—	122
7	168	187	151	168	193	169	169
8	206	213	204	—	155	175	204
9	216	200	123	176	186	213	188
10	145	165	151	143	165	152	152
Inter-individual Median	194	182	160	168	159	169	172

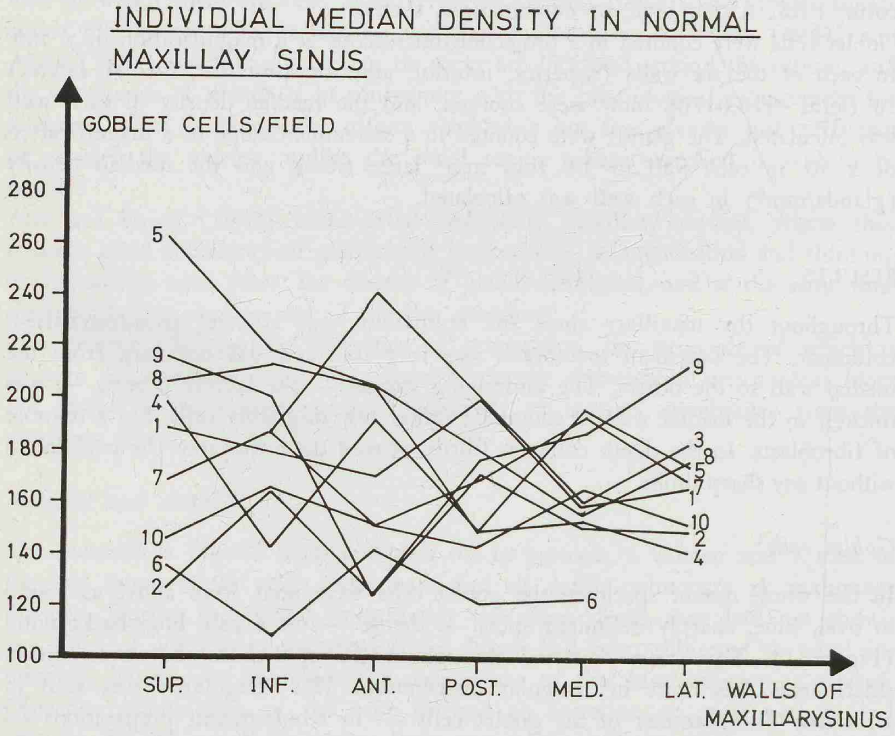

Figure 2. Variation in median density of goblet cells in different walls of the normal maxillary sinus.

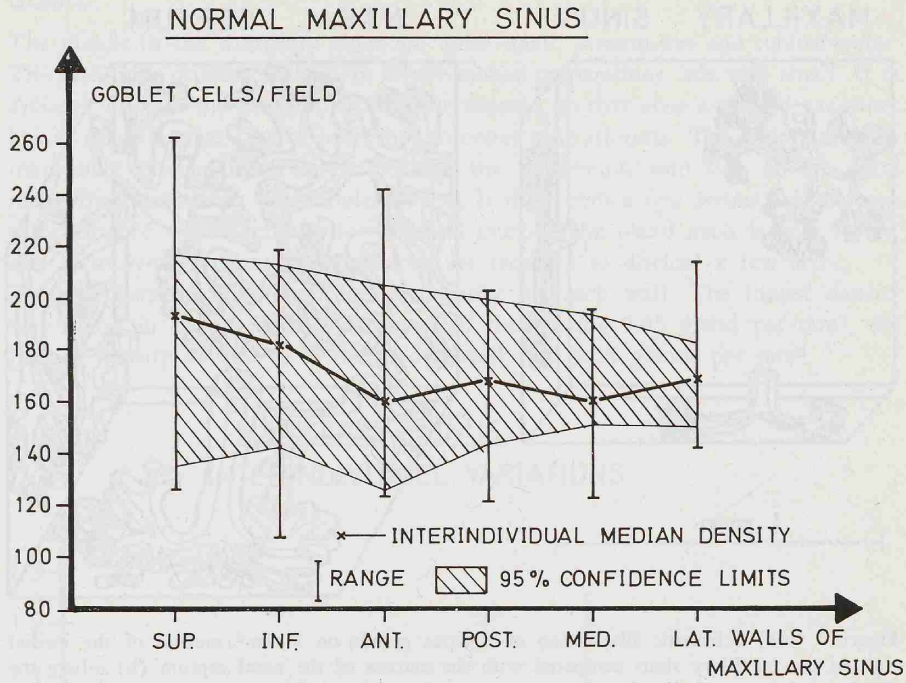

Figure 3. Interindividual median density of goblet cells, range, and 95% confidence limits in the walls of the normal maxillary sinus.

The irregular distribution of the goblet cells is illustrated by the finding that counts of 10 fields in the individual walls showed a difference between lowest and highest density of about 50 goblet cells per field — only exceptionally exceeding 100 per field.

Table I shows for each case the median density in each wall. The lowest median density was found in Case 6 in the inferior wall, viz. 108 goblet cells per field. In general, Case 6 had the lowest density of all the maxillary sinuses studied. The highest median density was found in Case 5 in the superior wall, viz. 262 goblet cells per field. The interindividual variation between the highest and lowest density did not differ essentially from the findings in the nose (Mogensen and Tos, 1977 a). Individual density curves are plotted on Figure 2.

From Figure 3 may be seen the interindividual median density for each wall. Statistical analysis of the material could not disclose any significant difference between the goblet cell density in the individual walls ($P > 0.80$, Kruskal Wallis test). The interindividual median density for all walls combined was about 170 goblet cells per field, corresponding to 9,600 cells per mm^2. In the nose we had previously found a significant increase of density in the septum into the anteroposterior direction and a median density lower than in the maxillary sinus, less than 100 cells/field, corresponding to about 5,600 cells/mm^2.

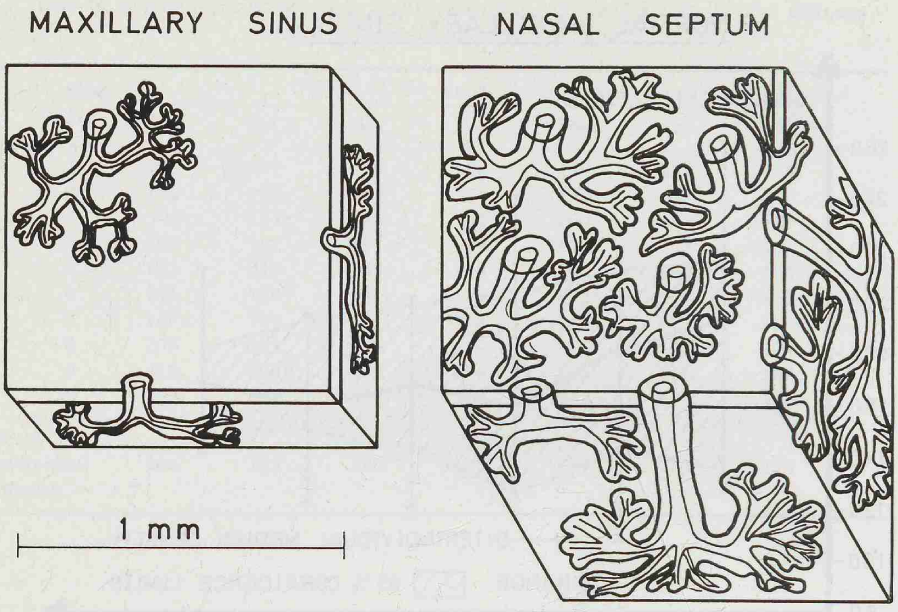

Figure 4. (a) Schematic illustration of mucous glands on 1 mm² mucosa of the medial wall of the maxillary sinus compared with the mucosa of the nasal septum (b) where the glands are longer and distributed mainly in two layers, a superficial layer with small glands, and a deep layer with larger glands.

Table II: Median density of glands (glands/mm²) in the different walls of the normal maxillary sinus.

Case No.	Walls of the sinus						Individual Median
	Sup.	Inf.	Ant.	Post.	Med.	Lat.	
1	0.12	0.20	0.15	0.15	1.25	0.07	0.15
2	0.07	0.07	0.12	0.12	0.40	0.07	0.09
3	—	0.20	0.20	—	0.57	0.12	0.20
4	0.15	0.70	0.20	0.20	0.45	0.25	0.22
5	0.20	0.15	0.20	0.15	0.50	0.15	0.17
6	0.32	0.12	0.12	0.40	0.66	—	0.32
7	0.25	0.25	0.32	0.27	0.37	0.07	0.26
8	0.12	0.15	0.37	0.25	1.05	0.15	0.20
9	0.15	0.05	0.20	0.27	0.37	0.15	0.17
10	0.15	0.40	0.40	0.20	0.52	0.25	0.32
Inter-individual Median	0.15	0.17	0.2	0.2	0.5	0.15	0.20

Glands:

The glands in the maxillary sinus are quite small, seromucous and tubloalveolar. The glandular orifices, as seen in whole-mount preparations, are very small. It is difficult to trace the ducts down into the mucosa, so that even a trained examiner has to expend great care in order not to count also artefacts. The short and thin main duct divides immediately beneath the epithelium into two lateral ducts into which debouch a few tubules having at their ends a few serous and mucous acini (Figure 4). In relation to the nasal mucosa, the gland mass is very scarce, and in studying sections many sections are required to disclose a few acini.
Table II lists the individual median density for each wall. The lowest density was found in Case 9 in the inferior wall there being 0.05 gland per mm^2, the highest density in Case 1 in the medial wall, viz. 1.25 glands per mm^2.

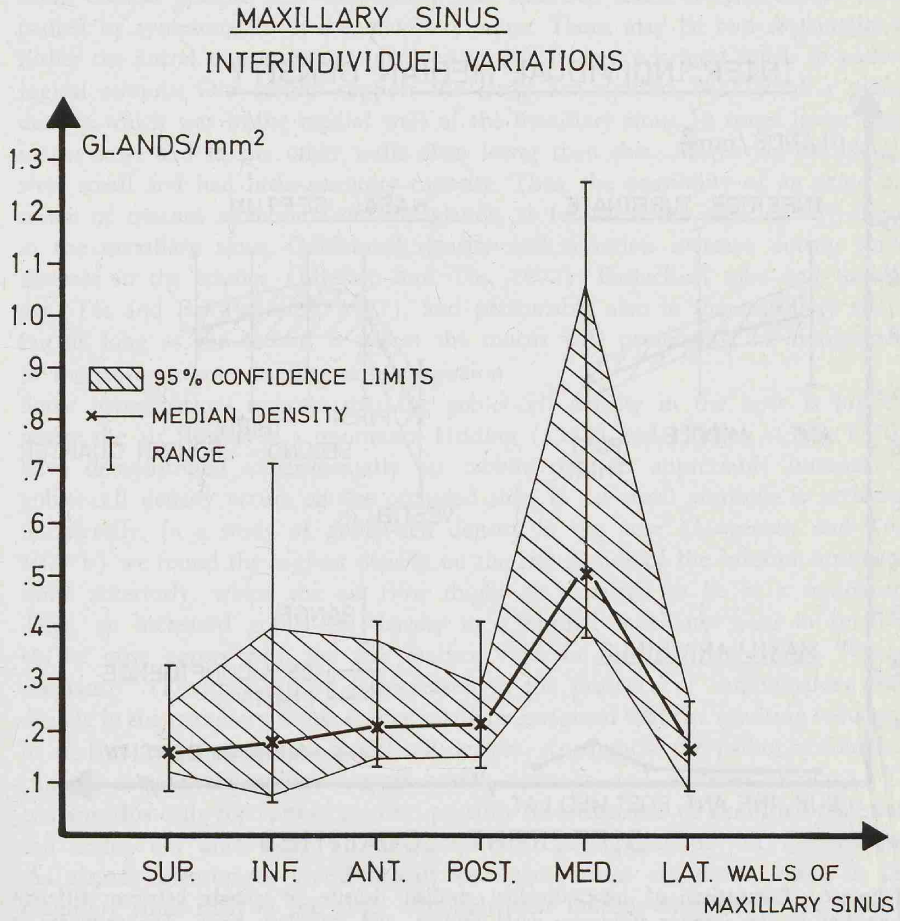

Figure 5. Interindividual median density, range, and 95% confidence limits of mucous glands in the walls of the normal maxillary sinus.

The interindividual median density for the individual walls, excluding the medial wall, does not appear to differ much mutually (Figure 5). The medial wall has a definitely higher density, 0.5 gland per mm^2, and this difference is highly significant ($p < 0.003$, Mann-Whitney U test).

Gland density is much lower than in the nose (Figure 6) in which we have found in the septum somewhat more than 8 glands per mm^2 and in the turbinates somewhat less than 8 glands per mm^2 (Tos and Mogensen, 1976, 1977).

Between the goblet-cell and gland density there is no correlation. In a maxillary sinus having high gland density there may be a high or there may be a low goblet-cell density.

Our material cannot be used to decide whether age-conditioned changes of the mucosa occur, in the form of a lower height of the epithelium and fewer goblet

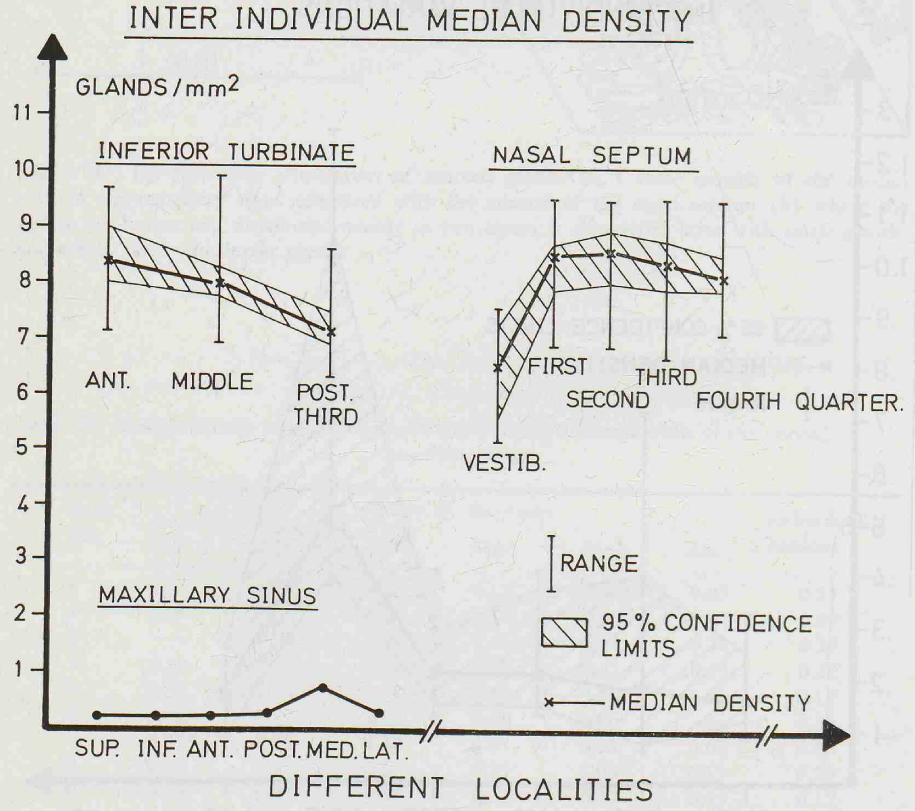

Figure 6. Comparison of interindividual median density of glands between different localities in the inferior turbinate, nasal septum, and maxillary sinus. The turbinate is divided anteroposteriorly into three thirds (anterior, middle and posterior), the septum into four quarters (first to fourth) and the vestibule.

cells, as has been claimed by some authors in the case of the nose (Malaty et al., 1970) or whether there are sex differences.

DISCUSSION

It may cause difficulties to define a normal material. Our anamnestic data were derived from case records from non-rhinological departments. Therefore, the emphasis laid on rhinological problems must have varied. That these patients had previously had catarrhal conditions is beyond doubt, and it cannot be ruled out that they may have had mild symptoms of sinusitis several years ago. Examination of histological sections, however, showed that this could not have been to an extent entailing any noteworthy changes, as round-cell infiltration was slight and the mucosa thin.

From clinical practice it is well-known that catarrhal states are not always accopanied by symptoms from the maxillary sinus. There may be two explanations: Either the antral mucosa is not involved or else it does not react much to pathological stimuli. Our results support the latter assumption: We found a gland density which was in the medial wall of the maxillary sinus 10 times lower than in the nose and in the other walls even lower than that. Moreover, the glands were small and had little secretory capacity. Thus, the possibility of an acute increase of mucous secretion from the glands, as found in the nose, is very slight in the maxillary sinus. Goblet-cell density and secretion increase during acute diseases in the trachea (Ellefsen and Tos, 1972), Eustachian tube and middle ear (Tos and Bak-Pedersen, 1977), and presumably also in the maxillary sinus, but as long as the ostium is patent the mucus will presumably be transported to the nose without causing any congestion.

Some investigations indicate that the goblet-cell density in the nose is highest where the air flow is at a minimum. Hilding (1932) and Hilding et al. (1970) have demonstrated experimentally on rabbits that an appreciable increase of goblet-cell density occurs on the occluded side, if the nasal vestibule is occluded unilaterally. In a study of goblet-cell density in the nose (Mogensen and Tos, 1977 b) we found the highest density on the lateral side of the inferior turbinate, quite anteriorly, where the air flow might be expected to be at a minimum. Thus, an increased goblet-cell density in a normal maxillary sinus in relation to the nose agrees with the less marked flow in the maxillary sinus. "Ostial resistance" (Drettner, 1967) is increased in the presence of inflammatory conditions in the maxillary sinus. It may easily be imagined that the resulting reduction in air flow may increase the goblet-cell density. Apparently, the pathophysiological changes around the ostium impair antral drainage and increase secretion. To confirm this calls for further studies; possibly investigations of abnormal materials can widen our knowledge of the complicated pathophysiology of the mucosa.

As already mentioned, gland density and gland mass are much lower in the maxillary sinus than in the nose, although their mucous membranes are qualitatively identical. The same finding has been made in the middle ear, which has large glands in the pharyngeal part of the Eustachian tube, none in its bony

part, and none in the tympanic cavity (Tos, 1971). The low density of glands in the maxillary sinus is in complete agreement with the slight physiological requirement of moistening the mucosa and of cleaning the respiratory air with its slow exchange.

Our preliminary studies of pathological materials indicate an increased density of glands under pathological conditions, which again indicates that in chronic sinusitis there will be new-formation of glands, as in chronic middle-ear diseases (Tos, 1974).

As the density of glands in the maxillary sinus is low, the glands small, and the goblet-cell density somewhat higher than in the nose, it must be assumed that the greater part of the mucus produced in a normal maxillary sinus is produced by the goblet cells. This is in contradistinction to the nasal mucosa, in which by far the greater part of the mucus is produced by the glands. There has been quite some discussion as to whether in a normal nose there occurs transudation or exudation apart from secretion. Most workers (Ingelstedt and Ivstam, 1949 a; Messerklinger, 1958; Terrahe and Backwinkel, 1970; Jahnke, 1972) have found no signs of transudation or exudation under normal conditions, but in the presence of acute pathological states (Ingelstedt and Ivstam, 1949 b; Terrahe and Backwinkel, 1970; Jahnke, 1972; Lenz, 1972). These considerations possibly apply also to the antral mucosa.

ZUSAMMENFASSUNG

Die ganze Schleimhaut von zehn normalen Kieferhöhlen wurde postmortal ausgenommen und nach PAS-Alzianblau Ganzpräparatmethode gefärbt. Dichte der Becherzellen und der mukösen Drüsen wurde untersucht. Es wurde eine Medianbecherzelledichte von 170 Zellen/felt, entschprechend 9600 Zellen per mm^2 gefunden, aber keine signikante Unterschiede der Dichte zwischen der verschiedenen Wänder. Dichte der Becherzellen ist etwas höher in der Kieferhöhle als in der Nase. Die Drüsen sind in der Kieferhöhle sehr sparsam und klein. Mediandichte der Drüsen ist in der meisten Wänden 0.15-0.20 Drüsen per mm^2, in der medialen Wand ist sie signifikant höher, 0.5 Drüsen per mm^2. Die kleine Dichte der Drüsen in der Kieferhöhle in Vergleich zu der Nase, wo es 8-9 Drüsen per mm^2 gibt, ist in voller Übereinstimmung mit Kieferhöhlens kleines Bedürfniss zur Befeuchtung, Reinigung und Wärmung der Luft. Die kwantitative Histologie der normalen Schleimhaut soll eine Grundlage für kwantitative Studien der pathologischen Schleimhaut geben.

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