Diameters of the main excretory ducts of the adult human submandibular and parotid gland

A histologic study

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Minimally invasive methods of diagnosis and therapy have promoted a reevaluation of established medical measures, especially in the case of salivary stone diseases.[1,2] Sonography as a noninvasive method of diagnosis can largely replace noncontrast radiography and sialography in the initial diagnosis of tumorous and inflammatory salivary gland diseases.[3]

Miniaturized endoscopes (mini-endoscopy) enable a direct view into the excretory duct system of the large salivary glands of the head and neck.[4-6]

Although the anatomic course of the excretory ducts of the salivary glands is sufficiently known, there are no conclusive reports on the intraluminal diameters of the salivary ducts of the parotid gland and submandibular gland. In view of methodologic problems, the results of sialographic examinations published so far deserve some critical reviewing.[7-9]

An exact knowledge of the dimensions of the excretory salivary ducts is of prime importance especially with respect to the further development of salivary duct endoscopes and in view of intracorporeal and extracorporeal lithotripsy, which is gaining increasing importance in the treatment of salivary stone disease.[1] The aim of this study was to achieve, with the help of pathoanatomic preparations, a histologic and in vivo determination of the diameters of the major excretory ducts of the human submandibular gland and parotid gland.

MATERIAL AND METHODS

Salivary glands

A total of 25 excretory ducts of the parotid gland and 20 excretory ducts of the submandibular gland were examined. The salivary glands, together with their excretory ducts, were dissected in cooperation with the Department of Pathology of the University of Erlangen-Nuremberg. The tissue was harvested within 24 hours after the death of the donors. At the same time, a tissue specimen of each salivary gland was histologically examined in order to exclude disease of the respective gland.

The donors of the preparations of the parotid gland were 11 men and 14 women. Their ages ranged from 49 to 89 years (mean, 71 years). The donors of the submandibular glands were 11 men and 8 women between 50 and 71 years (mean, 57 years).

Preparation and histologic reconditioning

After a minor incision, the ducts were probed with a venous cannula (Abbocath G 24) at their proximal endings in order to avoid an obliteration of the duct. The cannula was fixed with a purse-string suture.

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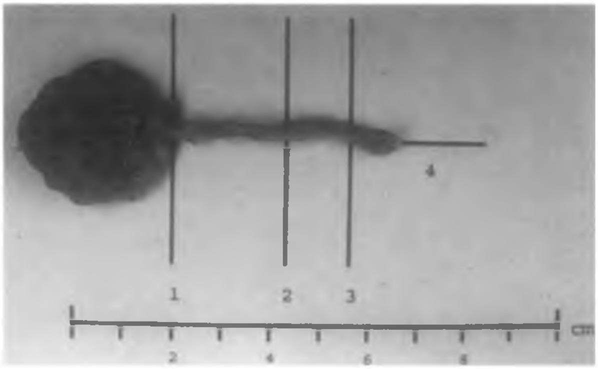

Fig. 1. Excised part of parotid gland shows marks of incisions for examination of duct diameters: incision 1 (close to gland/proximal), incision 2 (middle of duct), incision 3 (close to ostium/distal), incision 4 (ostium).

Table I. Diameters of excretory ducts of parotid gland at different locations of incision in mm ($n = 25$)

	Close to gland/proximal	*Middle of duct*	*Close to ostium/distal*	*Ostium*
Mean value	1.4	1.2	1.4	0.5
Standard deviation	0.3	0.3	0.3	0.4
Minimum	0.9	0.9	0.9	0.1
Maximum	1.9	2.0	2.3	1.9

Subsequently, the preparations were deposited in a 10% formaldehyde solution for fixation. At the same time, an infusion pump perfused a 10% formaldehyde solution with a flux rate of 63 ml/hour over the cannula, which is equivalent to a physiologic salivation rate of 1.5 L saliva per 24 hours. Each excretory duct was rinsed for 12 hours at room temperature. The macroscopic reconditioning of the duct preparations was carried out in four different sectional planes in which, on the basis of clinical considerations, alterations of the duct lumen could be expected (Fig. 1)

- Incision 1: cross-section at the transition duct/parenchyma
- Incision 2: cross-section at the middle of the duct (between ostium and parenchyma)
- Incision 3: cross-section 4 mm before the ostium
- Incision 4: longitudinal section through the ostium

At each cross-section site, slices of 1 mm thickness were cut off distally and proximally and used for further histologic assessment. The two corresponding pieces obtained by the longitudinal section in the ostium area were directly prepared for histologic examination.

All preparations were then dehydrated by the usual method of an ascending alcohol series and finally embedded in paraffin. The duct sections were positioned with great care in the paraffin, so that sectioning would cut them at a right angle to the longitudinal axis, thus avoiding methodical errors. An obliquely positioned duct section would have distorted the precise measurement of the duct diameter. Paraffin sections of the duct preparations were taken at intervals of 5 μm. The subsequent staining was performed with standardized hematoxylin-eosin (Figs. 2 and 3).

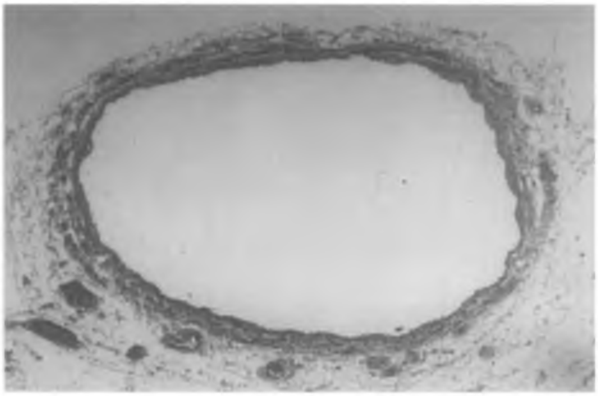

Fig. 2. Histologic view of submandibular duct in section 2 (middle of the duct) with elliptic shape.

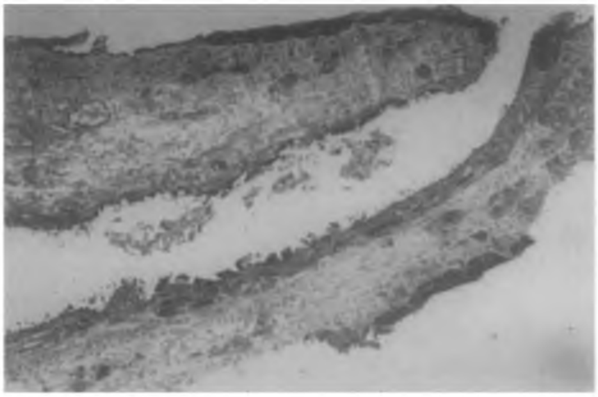

Fig. 3. Histologic view of section 4 (ostium) of parotid duct with narrowest diameter located at its end.

Measurement of the duct diameters and assessment of the in vivo parameters

Formalin causes shrinkage of the tissue, thus affecting the duct volume and diameter.[10] Before the study, preliminary measurements were performed on two parotid ducts and two submandibular ducts in an unfixed state and compared afterward to their measurements in a formalin-fixed state. For this purpose 16 slices, "rings" with a thickness of 1 mm each were cut from the ducts at the aforementioned locations. These rings were slit, and the length of the unrolled preparations was measured (yielding in the inner circumference of the duct). Thereafter,

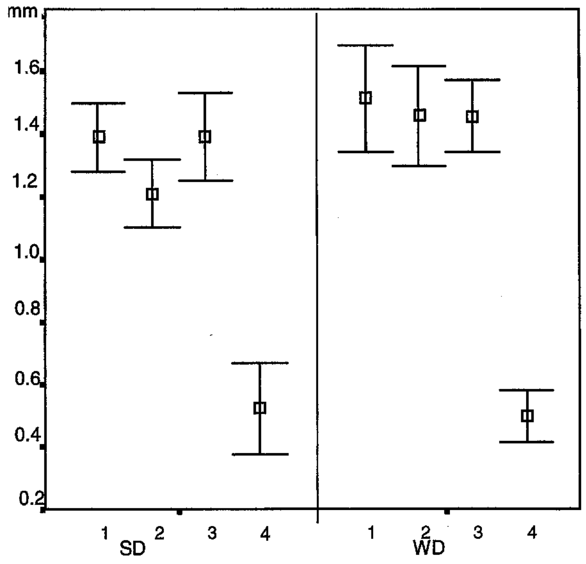

Fig. 4. 95% confidence intervals of different diameters (in mm) of Stensen's (SD) ($n = 25$) and Wharton's duct (WD) ($n = 20$) at different locations (1: close to gland, proximal; 2: middle of the duct; 3: close to the ostium/distal; 4: ostium).

the slit duct sections were fixed in 10% formalin for 12 hours before being measured again. From a total of 32 measurements, a multiplication factor M was determined to compensate for the formalin-induced shrinkage of the ducts and to assess the in vivo diameters:

$$M = \frac{\text{sum inner wall circumference unfixed}}{\text{sum inner wall circumference formalin-fixed}}$$

From these preliminary experiments the following multiplication factors were obtained:

$$M_p = 1.17$$

for the excretory duct of the parotid gland, and

$$M_s = 1.10$$

for the excretory duct of the submandibular gland.

Under the microscope the histologically prepared ducts were not necessarily round but, possibly because of the fixation, had elliptical shapes. By means of microscopic scaling the largest (a) and the smallest (b) duct half diameters of these ellipses were determined in each case. From these diameters we calculated the cross-sectional area of the duct (according to the area equation of the ellipse: $ab\pi$).

The area value was then inserted as a known quantity into the equation for the area of a circle ($\pi[d/2]^2$). By isolating the unknown factor d (circle diameter) the equation could be solved and thus the diameter d of the duct lumen determined assuming the lumen to be round: $d = 2\ (ab)^{0.5}$. With the aforementioned multiplication factor (M) a value for the diameters of the respective excretory ducts in the in vivo state could be obtained: $d = 2\ M\ (ab)^{0.5}$.

Table II. Diameters of excretory ducts of submandibular gland at different locations of incision in mm ($n = 20$)

	Close to gland/proximal	*Middle of duct*	*Close to ostium/distal*	*Ostium*
Mean value	1.5	1.5	1.5	0.5
Standard deviation	0.4	0.4	0.3	0.2
Minimum	1.0	0.9	1.1	0.2
Maximum	2.2	2.0	1.9	0.8

RESULTS

Parotid gland

For the four different incisions, the diameters of the excretory ducts ($n = 25$) showed the following mean values in vivo (also see Table I and Fig. 4):

- Incision 1: cross-section at the transition duct/parenchyma 1.4 mm
- Incision 2: cross-section at the middle of the duct 1.2 mm
- Incision 3: cross-section 4 mm before the ostium 1.4 mm
- Incision 4: longitudinal section through the ostium 0.5 mm

All values of the diameters of Stensen's duct ranged between 1.4 mm and 0.5 mm on average with a maximum of 2.3 mm (close to the ostium) and a minimum of 0.1 mm (ostium). A narrowing at the middle of the duct was remarkable. This narrowing was significant ($p < 0.01$; Wilcoxon rank test) compared with the hilus-diameter and the diameter close to the ostium of Stensen's duct and also to the diameters of incisions 1 to 3 along Wharton's duct. In all preparations examined, the minimum width of the duct was located at the ostium (incision 4; $p < 0.01$; Wilcoxon rank test).

Submandibular gland

The diameters of Wharton's duct ($n = 20$) were determined analogously. For the different sites of incision the following mean values were obtained (also see Table II and Fig. 4):

- Incision 1: cross-section at the transition duct/parenchyma 1.5 mm

- Incision 2: cross-section at the middle of the duct 1.5 mm
- Incision 3: cross-section 4 mm before the ostium 1.5 mm
- Incision 4: longitudinal section through the ostium 0.5 mm

A narrowing of the duct lumen at the ostium was also identified in Wharton's duct. The mean values for the duct diameters ranged between 1.5 mm and 0.5 mm on average. The largest duct diameter reached 2.2 mm (transition duct/parenchyma), the smallest one 0.2 mm (ostium). The diameter of the ostium was significantly smaller compared with the other locations along Wharton's duct ($p < 0.01$; Wilcoxon rank test) whereas only incision 2 was significantly ($p < 0.01$) wider compared with the locations of Stensens's duct. All the other diameters showed no difference.

DISCUSSION

The submandibular gland and the parotid gland are the two largest salivary glands of the head with similar duct systems. The excretory duct of the parotid gland runs along the lateral surface of the masseter muscle and takes a right-angle turn toward the medial at its front edge. Then it passes through the buccinator muscle and penetrates the oral mucosa in the buccal vestibule opposite the maxillary second molar. On closer inspection of our data on duct diameters, Stensen's duct proved remarkable insofar as the incision at the middle of the duct showed a smaller diameter than the proximal and distal incisions. This peculiarity might be explained by the course of the duct through the buccinator muscle leading to a permanent narrowing of the duct. The other three sectional planes revealed a slightly decreasing diameter with a tapering of the duct at the ostium.

The submandibular duct runs along the lower edge of the mylohyoid muscle toward dorsal, bends sharply at the back edge of this muscle before running in opposite direction along the medial side of the sublingual gland toward ventral and ending in the sublingual papilla.

The diameters of the submandibular duct showed relatively constant values over the entire course the duct. In contrast to the parotid duct and despite the sharp bend that the submandibular duct takes at the edge of the mylohyoid muscle, there was no histologically detectable narrowing. To what extent a contraction of the musculature of the floor of the mouth can lead to a transient functional narrowing could not be elucidated by this study.

The comparison between Stensen's duct and Wharton's duct showed larger diameters in the case of the submandibular duct.

Although the number of preparations chosen offered a sufficient quantity of measuring points and the carefully performed embedding procedure should have minimized error sources of a technical nature, variances and standard deviations that serve as a measure of the precision of the measurements showed relatively high values. On the one hand, this could be attributed to interindividual differences among the donors. On the other hand, an age range of 40 years gives rise to a heterogeneous patient group, in which great differences from multifactorial influences have to be expected.

Before comparing our results with previously published data and results based on sialographic measurements of the excretory ducts, some basic differences between the methods have to be pointed out.

In the case of sialographic representation of the excretory ducts of the salivary glands, retrograde filling with a contrast medium is carried out under pressure and causes an unphysiologic widening of the duct lumina that probably affects the measurements. Furthermore, a radiologic representation involves the danger of a distorted projection; thus the applied x-ray technique may produce results that differ from the anatomic dimensions. Finally, it should be noted that a two-dimensional image does not allow exact conclusions about three-dimensional structures.

In 1968, Hettwer et al.[7] sialographically examined and evaluated 35 excretory ducts of the parotid gland and of the submandibular gland in healthy patients. The data, which lack a topographic differentiation of the diameters, are considerably higher than the histologically determined data of this study, yielding a mean value of 1.7 mm for Stensen's duct (this study, 1.3 mm) and of 2.7 mm for Wharton's duct (this study, 1.5 mm).

By sialographic measurement of the excretory duct of the parotid gland Ericson[8] reported a mean diameter of 2 mm, a result which also exceeded our histologic findings.

Kilpinen[9] sialographically examined the duct system of the parotid gland among wind musicians and arrived at the conclusion that playing a wind instrument does not affect the width of the parotid duct. The values for the duct lumina (1.8 mm to 2.2 mm) were also higher than in the present histologic study, but in accordance with the findings of Ericson.[8] Interestingly, Kilpinen noted that at the middle of the duct, at the anterior edge of the ramus of the mandibular bone, the lumen narrows to a mean value of 1.3 mm. This narrowing was also detected in our examinations.

Altogether it is evident that the values of the diameters obtained by sialography differ considerably from our data. For reasons already mentioned, the elasticity of the excretory ducts in particular seems to influence radiologically determined duct diameters, i.e., the ducts are unphysiologically dilated by contrast media. This behavior is due to elastic fibers within the submucosa of the duct epithelium.[11]

Our results also have direct consequences for clinical practice and are relevant for salivary gland sonography, duct endoscopy and intracorporeal or extracorporeal lithotripsy of salivary stones.

In extracorporeal piezoelectric lithotripsy, the average size of the fragments, the grain size median, amounted to about 0.7 mm in in vitro studies.[12] In this study, all topographically defined parameters were larger than 0.7 mm, except for the width of the ostium. As a consequence, the passage of the fragments produced by extracorporeal lithotripsy would not be prohibited by the determined magnitude of the duct diameters. At the ostium, where the excretory ducts of the parotid gland and submandibular gland narrow to 0.5 mm, a physiologic barrier appears to exist, corresponding to a median grain size of 0.7 mm. Clinical experience with duct bougienage, or ductal dilation, and sialography showed, however, that the ostium can be expanded to a diameter of up to 2 mm without a macroscopically detectable lesion of tissue.[13]

In spite of the sometimes strong tension of both ostium and duct, the dilation applied during sialography does not cause pathologic symptoms of functional failure or changes within the duct-gland system unit.[14] Furthermore, sonographic findings in the case of sialolithiasis showed duct dilations of up to 8 mm in diameter, without any iatrogenic manipulation.[15] Thus, duct and ostium are expansile within certain limits.

If a disease of the parotid gland requires bougienage of the duct, this treatment should not be limited to the ostium but extended by balloon catheters to include the further course of the duct. Especially at the point of passage through the buccinator muscle there is a relative narrowing of the duct lumen that can transiently be overcome by a duct dilation. In the case of the submandibular gland, bougienage can be limited to the ostium region. However, the nature of the histologic alterations of the duct epithelium and of the adjacent tissues after sialography and after duct bougienage remains unclear.[16]

Thus, endoscopes, balloon catheters, and stone-extraction-baskets probably should, despite the extensibility of the duct, conform as much as possible to the physiologic duct widths. A diameter of 1.2 mm would be the ideal caliber of these instruments in order to minimize iatrogenic damage to the ducts.

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