Palatine and mandibular tori

A morphologic study in the current Norwegian population

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Five thousand Norwegians, 2783 females and 2217 males, ranging in age from 16 to 89 years, have been screened for the presence of torus palatinus and/or torus mandibularis and analyzed with regard to size and shape of tori, sex, and age. The tori have been classified according to size as small, medium, and large. No measurements have been made, consistent with the view that these characteristics are non-metrical and should be assessed by means of a standard procedure. The prevalence figures of both tori were fairly low, in accordance with former reports. In torus palatinus there was female predominance, with a sex ratio of 5:3. In torus mandibularis the males were in majority, and the sex proportion was 4:3. In both sexes prevalence of the two tori was highest in the 35- to 65-year age group. Further analysis indicated in both tori a real correlation between prevalence and size and some correlation also between size and shape of torus palatinus but not of torus mandibularis. The figures of concurrence of the two tori were low, denoting a non-significant correlation. Still, the analysis showed that each torus occurred more than twice as frequently in an individual bearing the other torus. Torus morphoanalysis, explaining diverging patterns of clinical conduct in the two tori, and the relative weight of hereditary versus environmental factors as morphogenetic determinants of the condition, including a quasi-continuous genetic or threshold model, have contributed to shed new light on the torus phenomenon. The occurrence and propagation of torus mandibularis complies reasonably well with this model, and the present analysis indicates that even torus palatinus should appropriately be considered a threshold character.
□ *Morphogenesis; prevalence; size; torus mandibularis; torus palatinus*

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The most remarkable tori of the human jaw skeleton are the two formations called torus palatinus and torus mandibularis. Although the former has been the object of extensive study for more than 100 years and the latter since the beginning of the present century, their biologic meaning and morphologic significance are still incompletely understood. A large number of investigations, both of ancient and more recent date, have so far illustrated the influence of genetic (1–10) and environmental factors, including functional, nutritional, behavioral, and, possibly, climatologic factors (11–21), but a final, synthesizing theory on their occurrence and *raison d'être* has until quite recently been lacking. Progress in this field has long been hampered by polarization of the theories into two opposing scientific camps, the main issue being the disagreement on the morphogenetic role of hereditary versus environmental factors. Only during rather recent years has a more elaborate, dynamic theory been developed, which seems to be able to account for many of the contrasting observations and apparently incompatible interpretations of the past (22–26). Another problem so far unsolved is the question of whether the two conditions share a common morphogenetic background or represent separate biologic units. The investigations in this field are limited and the results contrasting (7, 10, 12, 26–30).

It is common knowledge that racial divergencies or ethnic group differences with regard to the occurrence of these characteristics are considerable. Yet, in spite of the substantial number of investigations carried out in materials of various origins, information about larger population groups on a

global scale is defective and fragmentary. The literature in this field is far from easily surveyable, and the reported figures vary considerably even within groups with apparently identical or closely related ethnic and genetic background (28, 31, 32). Methodologic deficiencies and shortcomings may be partly responsible, such as ill-defined criteria for selection of material and its classification, doubt about its ethnic representativity, insufficient size, and unsuitable methods applied in handling the material. Inadequate presentation of the results obtained may also contribute to loss of valuable information. A characteristic problem arises when findings reported from skull materials are matched with others obtained by investigations in living individuals. For obvious reasons, higher figures of prevalence in the two torus categories are generally obtained in skull materials than in the living, but the sex difference of prevalence is smaller (33).

The contributions by Scandinavian, and particularly by Norwegian, investigators to the elucidation of torus problems, their occurrence in the population, and the explanation of their biologic nature have been rather scanty, and the existing reports have mostly been based on cranial material. Many of these investigations are also rather old (20, 34, 35). Exceptions are several etiologic and statistical studies of late years on torus mandibularis performed by Eggen (36, 37), and Eggen & Natvig (38, 39). The aim of the present study, which is part of a treatise (40), was to perform a morphologic analysis of both categories of tori in a large clinical material of living Norwegian citizens.

Materials and methods

Five thousand dental school patients, 2783 women and 2217 men, ranging from 16 to 89 years of age, were during the years 1980–90 submitted to a screening examination with regard to the presence of torus palatinus and/or torus mandibularis by an assessment of their size (expressivity) and shape. Every precaution was taken to come as close as possible to the standard of random sampling. Only 43 of the 5000 probands were referred to the Department of Oral Surgery and Oral Medicine because of problems directly related to the presence of a torus already discovered. These problems were mostly caused by diagnostic incertitude on the part of the physician or dentist previously involved or by the patient's fear of serious disease. The biasing effect of this factor on the composition of the total material was considered so negligible that these probands were not excluded. In the great majority of cases the torus was small and a fortuitous finding, unnoticed or unheeded by the patient in advance. Only 11 patients, referred for the evaluation of large tori, had to have these removed operatively, 9 of them as necessary corrective treatment before the insertion of a dental prosthesis. In the two other cases extremely large bilateral tori of the lower jaw were removed because they interfered with speech and mobility of the tongue.

Great care was taken to ensure the ethnic homogeneity of the material by strictly defined criteria of selection. The probands were all Norwegian citizens and had Norwegian-born parents, and none of the grandparents were of extra-Scandinavian descent. The minimum age limit was set at 16 years, and the oldest individual in the material turned out to be a woman of 89 years. Regionally, there was predominance of individuals from the Oslo area and the southeastern part of Norway. However, a portion of young people from all parts of the country staying in the capital for educational and occupational purposes brought some adjustment into the material towards greater national variety.

A total number of 5000 probands was considered the ultimate goal of the examination to enable the implementation of the analyses planned. After 10 years this desired material was attained, and it also had an acceptable sex distribution: 2783 females (55.7%) and 2217 males (44.3%). In both sexes the material was divided into three age groups: 16–34 years, 35–65 years, and 66 years and more (Table 1).

The relatively large number of individuals less than 35 years old reflects a characteristic property of the material: the large pro-

Table 1. Distribution of the material with regard to sex and age, presented as numerical values and in percentages

Sex	Probands	16–34 years	35–65 years	66 years and more
F	2783	1706 (61.3%)	854 (30.7%)	223 (8.0%)
M	2217	1323 (59.7%)	726 (32.7%)	168 (7.6%)

portion of young people attending the clinic because of problems with their wisdom teeth. However, in the absence of any known association between the occurrence of tori and disorders of wisdom tooth eruption, this circumstance was considered selectively neutral on the material.

The procedure of screening for tori was performed by simple inspection, followed by palpation. No measurements were made, consistent with the view of leading physical anthropologists (9, 41) that these structures are non-metrical and can advantageously be assessed as to size in accordance with a standard procedure of inspection, based on careful training. I have had similar experience in previous methodologic examinations (40).

Accordingly, the tori were classified dimensionally in three groups: small, medium, and large, thereby omitting the category 'trace', applied by some earlier investigators (10, 13, 20). I believe that unqualified use of this term in doubtful cases is one of the main reasons for the highly diverging prevalences reported in ethnically and genetically closely related materials. This impression has been strengthened by re-examination (40) of older materials published by other investigators (20).

The goal of the investigation also required the application of certain criteria for shape in each of the two tori. With regard to the torus palatinus a slight simplification of the typologic system of Thoma (42) was chosen, applying three categories: ridge-shaped (a combination of the groups flat and spindle-shaped), nodular, and lobular. In the torus mandibularis no corresponding criteria were usable. In accordance with the number of bony nodes and their placement, four categories were applied: bilateral solitary, bilateral multiple, unilateral solitary, and unilateral multiple.

The results of the examinations are shown below, by presenting the prevalences of tori in the two sexes, collectively and separately for each age group. Furthermore, the sex differences have been examined, in the material as a whole and in the separate age groups. Besides, the prevalences have been compared within each sex in the various age groups. The relationship between the size categories and prevalences of tori in the age groups has been analyzed as far as considered expedient and meaningful. The findings in the palatine and mandibular tori have been dealt with separately, apart from a final presentation in which the prevalence of their concurrence has been calculated, in the total material and in the two sexes separately. A correlation table for the two tori in the total material has been arranged. The examinations of statistical significance have been carried out by means of the chi-square test.

Results

Torus palatinus

Prevalence. The total number of palatine tori in the 5000 probands was 461, or 9.22%. Their sex distribution was 312 of 2783 women, or 11.21%, and 149 of 2217 men, or 6.72%. This sex difference is significant at the 0.1% level ($p < 0.001$).

The prevalence figures in the age groups of the two sexes are shown in Table 2. In all the three age groups prevalence was markedly higher in the females than in the males. The sex difference shows up almost as distinctly in the individual age groups as in the total sex materials. In the youngest and the medium age groups the difference was significant at the 0.1% level. In the oldest group, however, the difference was not statistically significant.

Table 2. The prevalence of torus palatinus, expressed as a function of age and sex, presented numerically and in percentages

Sex	Age	Probands	Prevalence	%
F	16–34 years	1706	183***	10.73
	35–65 years	854	105***	12.30
	66 years and more	223	24	10.76
M	16–34 years	1323	88	6.65
	35–65 years	726	51	7.02
	66 years and more	168	10	5.95

Significant sex differences are indicated with asterisks: ***$p < 0.001$.

A comparison of prevalence in the age groups within each sex, by testing the medium group against each of the other two, showed no significant differences. However, higher prevalence figures have been found in the medium age group in both sexes than in the younger and the older ones. The sex prevalences in the young and old age groups are approximately at the same level.

Size. Size assessment showed that small tori made up more than two-thirds of the total number, 322 of the 461, or 69.85% (Table 3). The number was relatively somewhat higher in the males than in the females, whereas the situation was the reverse with regard to tori of medium and large size. In the total material the two groups were slightly more than 20% and 7.5%, respectively.

The sex differences in the distribution pattern of torus palatinus according to size, expressed in percentage of the number of tori recorded, were not statistically significant. Table 3 indicates, however, that an increased prevalence of torus palatinus was associated with a relatively higher share of medium and large tori. Conversely, the relative proportion of small tori was highest in the group showing the lowest prevalence.

The distribution of torus palatinus according to size in the individual age groups was also examined in both sexes (Table 4). The observations confirmed the tendency shown in Table 3. The relatively higher share of small tori in the males was most clearly demonstrated in the youngest age group. Correspondingly, the relative proportion of larger tori was more pronounced in the two higher age groups in the females than in the males. The proportion of medium-sized and large tori was highest in both sexes in the age group 35–65 years, the group showing the highest torus prevalences irrespective of size (Table 2). The figures may even indicate a slight tendency towards regression in the oldest group, particularly with regard to the

Table 3. The distribution of torus palatinus by torus size and sex in the total material. The results are presented as percentage of the tori recorded and the number of probands in the groups (n)

	Females			Males			Females and males		
Torus size	No. of tori	% of tori	% of probands, n = 2783	No. of tori	% of tori	% of probands, n = 2217	No. of tori	% of tori	% of probands, n = 5000
Small	213	68.27	7.65	109	73.15	4.92	322	69.85	6.44
Medium	73	23.40	2.62	31	20.81	1.40	104	22.56	2.08
Large	26	8.33	0.94	9	6.04	0.40	35	7.59	0.70
Total	312	100.00	11.21	149	100.00	6.72	461	100.00	9.22

Table 4. The distribution of torus palatinus by size, age groups, and joint sex groupings, presented numerically (in parentheses) and as percentages of the tori recorded in the individual groups

	Females				Males			
Torus size	16–34 years	35–65 years	66 years and more	Total material	16–34 years	35–65 years	66 years and more	Total material
Small	(130) 71.04%	(67) 63.81%	(16) 66.67%)	(213) 68.27%	(67) 76.14%	(35) 68.63%	(7) 70.00%	(109) 73.15%
Medium	(39) 21.31%	(28) 26.67%	(6) 25.00%	(73) 23.40%	(17) 19.32%	(11) 21.57%	(3) 30.00%	(31) 20.81%
Large	(14) 7.65%	(10) 9.52%	(2) 8.33%	(26) 8.33%	(4) 4.54%	(5) 9.80%	—	(9) 6.04%
Total	(183) 100.00%	(105) 100.00%	(24) 100.00%	(312) 100.00%	(88) 100.00%	(51) 100.00%	(10) 100.00%	(149) 100.00%

largest tori. No statistically significant sex differences were demonstrated, but the tendencies were consistent (Table 4).

Shape. Most of the small tori were registered as ridge-shaped and nodular, whereas the more bulky ones were mainly grouped as nodular and, more rarely, lobular. The classification was, however, far from problem-free, because of a considerable number of transitional forms. No attempt at precise numerical registration was made. It was believed that more detailed registrations in this particular field might be deceptive and even misleading (40). No pattern indicating sex difference in the morphologic shape of the palatine tori, independent of size, could be demonstrated. However, the more frequently occurring tori in the females, associated with a relatively higher element of larger tori, were in turn also reflected in the form pattern. By far the largest size range was shown by the nodular variety. Altogether, this morphologic variant was the predominant one in the material, but a substantial number of the more bulky tori showed transitional forms towards the lobular type. The definitely lobular variety fell with few exceptions within the category of large tori.

Torus mandibularis

Prevalence. The total number of probands presenting with a mandibular torus was 366 (7.23%), comprising 177 (6.36%) females and 189 (8.53%) males. This sex difference is significant at the 1% level ($p < 0.01$).

The distribution of the mandibular tori in the three age groups of the two sexes is presented in Table 5. The prevalence was

Table 5. The prevalence of torus mandibularis, expressed as a function of age and sex, presented numerically and in percentages

Sex	Age	Probands	Prevalence	%
F	16–34 years	1706	101	5.92
	35–65 years	854	62	7.26
	66 years and more	223	14	6.28
M	16–34 years	1323	106*	8.01
	35–65 years	726	68	9.37
	66 years and more	168	15	8.93

* Significant sex difference, $p < 0.05$.

Table 6. The distribution of torus mandibularis by size and sex in the total material. The results are presented as percentage of the tori recorded and the number of probands in the groups (n)

	Females			Males			Females and males		
Torus size	No. of tori	% of tori	% of probands, n = 2783	No. of tori	% of tori	% of probands, n = 2217	No. of tori	% of tori	% of probands, n = 5000
Small	112	63.28	4.02	108	57.14	4.87	220	60.11	4.40
Medium	49	27.68	1.76	54	28.57	2.44	103	28.14	2.06
Large	16	9.04	0.58	27	14.29	1.22	43	11.75	0.86
Total	177	100.00	6.36	189	100.00	8.53	366	100.00	7.32

higher in the males than in the females in all the three age groups. In the age group 16–34 years the sex difference is statistically significant at the 5% level, whereas in the other two groups the differences are not significant. Within each sex, prevalence in the medium age group tested against each of the other two showed no significant difference. The highest prevalence in both sexes occurred in the age group 35–65 years. In the females prevalence was roughly at the same level in the youngest and the oldest group, whereas in the males prevalence of the oldest group was relatively closer to the medium group level.

Size. Approximately 90% of the mandibular tori were of small and medium size. The relative share of small tori was higher in the female than in the male material, while the medium-sized tori were fairly equally distributed in the two sexes. The proportion of large tori was markedly higher in the males (Table 6).

None of the sex differences in the pattern of size distribution of the tori are statistically significant. Table 6 demonstrates, however, that an increased prevalence of torus mandibularis implies a relatively larger share of tori of the higher size order and, conversely, that the relative proportion of small tori was highest in the group with the lowest prevalence.

The size distribution of torus mandibularis in relation to the age groups has also been examined (Table 7). The observations are in accordance with those of Table 6, showing a relatively higher share of small tori in the females, and highest in the youngest age group. The medium-sized and large tori collectively had a relatively greater represen-

Table 7. The distribution of torus mandibularis by size, age groups, and joint sex groupings, presented numerically (in parentheses) and as percentages of the tori recorded in the individual groups

	Females				Males			
Torus size	16–34 years	35–65 years	66 years and more	Total material	16–34 years	35–65 years	66 years and more	Total material
Small	(70) 69.31%	(37) 59.68%	(5) 35.71%	(112) 63.28%	(64) 60.38%	(39) 57.35%	(5) 33.33%	(108) 57.14%
Medium	(26) 25.74%	(18) 29.03%	(5) 35.71%	(49) 27.68%	(30) 28.30%	(18) 26.47%	(6) 40.00%	(54) 28.57%
Large	(5) 4.95%	(7) 11.29%	(4) 28.58%	(16) 9.04%	(12) 11.32%	(11) 16.18%	(4) 26.67%	(27) 14.29%
Total	(101) 100.00%	(62) 100.00%	(14) 100.00%	(177) 100.00%	(106) 100.00%	(68) 100.00%	(15) 100.00%	(189) 100.00%

tation in the males than in the females, in accordance with the higher prevalence of the male group. The proportion of tori of the higher size order in the oldest age group in both sexes was conspicuously high. The sex differences shown in Table 7 are not statistically significant, but the observations are devoid of inconsistencies.

Shape. By far the most frequently occurring variant of torus mandibularis was the bilateral solitary form, which in the total material showed a prevalence of about 5%. Number two in the order of frequency was the bilateral multiple form, present in approximately 2% of the material. Together the bilateral varieties made up more than 90% of all the mandibular tori present. The unilateral variants were rare, particularly the unilateral multiple form, which was observed in less than 0.1% of the probands. In most of the few cases of unilaterality the nodes were located on the right side. Sex differences with regard to shape and outline could not be substantiated, apart from the observation that extremely large mandibular tori occurred almost exclusively in the males. This particular finding was only partly reflected in the division and gradation of the material of mandibular tori by size.

Concurrence of torus palatinus and torus mandibularis

The degree of combined occurrence of the two torus formations has been examined, both in the total material and in each sex separately. The prevalence figures of concurrence were low; of the 5000 probands 111 showed both a palatine and a mandibular torus—that is, 2.22%. The figures were slightly higher in the females than in the males. Among the 2783 female probands 65, or 2.34%, demonstrated a combination of the two tori, whereas in the male group the figures were 46 of the 2217 individuals, or 2.07%. This sex difference of prevalence is not statistically significant.

From these figures it can easily be calculated that among the 461 probands in the total material with a torus palatinus 111 also had a torus mandibularis—that is, 24.07%. Correspondingly, among the 366 probands with a mandibular torus 111, or 30.33%, also had a palatine one. In the female material with 312 palatine tori, 65 (20.83%) had an additional mandibular torus. Among the 177 with mandibular tori 65 (36.72%) also presented with a palatine torus. In the male group with 149 cases of torus palatinus, 46 (30.87%) had a torus mandibularis, and among the 189 with a mandibular torus, 46 (24.34%) showed an additional palatine torus.

Since no real difference was found between the two sexes with regard to the prevalence figures of concurrence, correlation of the two tori is presented in the total material. The findings, also showing the size grading of the formations, are given in Table 8. The proportion of concurrence was low compared with the frequency with which the tori occurred separately. Among the 716 probands in the material with one or both tori, 111 had the combination, and 605 had

Table 8. Correlation between torus palatinus and torus mandibularis in the total material

		Torus palatinus				
		Absent	Small	Medium	Large	(Total)
Torus mandibularis	Absent	4284	263	76	11	(4634)
	Small	158	39	10	13	(220)
	Medium	79	12	7	5	(103)
	Large	18	8	11	6	(43)
	(Total)	(4539)	(322)	(104)	(35)	(5000)

either a palatine or a mandibular torus. In other words, among the 716 individuals affected by torus formation, 111 showed concordance and 605 discordance of the trait combined torus formation. This difference is statistically significant at the 0.1% level. The finding indicates a low or non-existent correlation between the occurrence of the two tori. No correlation coefficient has therefore been calculated, as it will evidently be far below significance level.

These findings, together with the somewhat contrasting evidence from the calculations made above, are further dealt with in the discussion.

Discussion

The primary purpose of the present study has been to present a survey of the occurrence of jaw tori in the contemporary Norwegian population 16 years of age and older. Elucidation of the biologic background of torus formation is largely outside the scope of the investigation. Still, it seems possible to discuss some aspects of these problems; that is, the material may shed some light on basic concepts and formative factors within this dynamic interplay.

The analysis shows that the prevalence figures in both tori are fairly low, both in a global context and compared with the results from other population groups of Caucasian stock, ethnically and genetically assumed to be similar to the Norwegian population (1, 6, 7, 15, 28, 31, 43, 44). Likewise, the figures are low compared with those reported from previous Norwegian investigations of cranial materials (20, 34) and in scattered population groups of more recent date (35). In fact, the prevalence figures are among the lowest ever reported in a living population of the Western world.

With regard to the pattern of torus distribution in the two sexes the results are in accordance with what has long been recorded in comparable populations (15, 31). There is a clear female predominance of torus palatinus, in most materials with a proportion around 2:1. In torus mandibularis the pattern is not equally consistent, and the proportion varies from approximately equal representation to a distinct male majority. In the present material the sex proportion in torus palatinus was about 5:3 in favor of the females, and in torus mandibularis 4:3 with male dominance. Both differences are statistically significant, at levels of 0.1% and 1%, respectively.

The sex differences were also distinct in many of the individual age groups, most clearly demonstrated in the youngest group, with the largest number of probands. Both tori occurred most frequently in the medium age group in both sexes. The relative difference of prevalence between the medium age group and each of the other two, in both sexes and both torus categories, was approximately at the 10% level. This finding may indicate a general trend for tori to be more frequently observed during the middle phase of life than at a younger and older age. This in turn suggests that a torus, in both its forms of manifestation, should be interpreted rather in terms of a dynamic phenomenon than as a stationary or progressively growing lump of bone. It also indirectly supports the hypothesis that during the course of life tori respond not only to genetic but also to environmental and functional factors, in particular those of masticatory stress. The latter is well known to increase during adolescence until adulthood and to decrease during senescence, offering a reasonable interpretative background for the phenomena observed. However, it might be expected that a torus, as a marker of a reactive, dynamic process, would show up more conspicuously by expressivity (size) than by prevalence, in both its manifestation forms. Such a relationship seems to be corroborated by the distribution of the tori by size in the two sexes.

In torus palatinus there was a tendency for a relatively larger proportion of tori to be of the larger size in the female group, associated with the generally higher prevalence figures than in the males. Conversely, the relative share of small tori was highest in the males, with the lowest prevalence. The size distribution in relation to the separate age groups further confirmed this tendency. The

relatively largest share of medium-sized and large palatine tori appeared in the medium age group, most pronounced in the females, in accordance with the highest prevalence figures. The highest percentage share of small tori occurred in the youngest group in the males, in which prevalence was much lower than in the females. The figures may also indicate a slight decrease in the occurrence of large tori in the oldest group of both sexes, most pronounced in the males. These findings were, however, not in accordance with those of some investigators of a somewhat earlier date (15, 30, 33, 43, 45), although the latter also to some extent show disagreement among themselves.

Findings fairly analogous to those in torus palatinus were also demonstrated in torus mandibularis. The relative share of tori of the higher size order was largest in the male group, in conformity with the highest prevalence, and, conversely, the percentage of small tori was highest in the females. The same basic pattern was reflected in the size distribution in relation to the age groups. Large tori occurred relatively more frequently in the medium age group in the males than in the females, and the relative proportion of small tori was predominant in the youngest group in the females, in both cases in harmony with the prevalence pattern shown in torus palatinus. The findings in torus mandibularis seemed to differ markedly from those of their palatine counterpart only in one respect: in the mandible the relative proportion of large and fairly large tori in the oldest group was distinctly higher in both sexes. The difference was particularly outstanding with regard to the largest tori, which were observed to be present almost exclusively in the males of this group. This finding may be an indication of certain biologic differences between the two tori, showing up mainly during the final phase of life. Whereas torus palatinus apparently in its reactive modalities complies with the pattern of dynamic response to function and environmental influence, with an inclination to size regression and possibly declining prevalence in old age, the findings in torus mandibularis indicated a somewhat different trend. General prevalence was highest in the medium age group, but the relative share of large tori was highest in old age, indicating a more autonomous course of growth during the whole span of life and implying an apparently less pronounced retrogressive response to subsiding functional load in senescence. Although the latter notion in no way precludes the probability of a basically dynamic reactive pattern of development, the findings are consistent with several clinical observations, based on longitudinal studies and follow-up registrations, with exact metric and photographic methods (46). These apparently diverging modes of conduct in the two tori may reflect basic, biologically distinctive features, implying both etiologic and morphogenetic determinants.

It should be observed that, despite the size of the initial material, many of the figures in the numerous subgroups finally tend to become so small that mostly consistent numerical group differences can be interpreted in terms of tendencies only. Even in the absence of full statistical significance such findings render a reasonable degree of credibility in the results. Thus, there seems to be a real correlation between prevalence and size in both categories of tori; that is, an increased occurrence of tori implies a relatively larger proportion of tori of the higher size order. This is in accordance with what has formerly been shown by Ossenberg (26) for torus mandibularis and with what can be gathered from the material of Hrdlicka (13)—however, without apparently having been noticed or at least mentioned by the latter author himself. The same conclusion can be drawn from the observation of Woo (33), that sex difference of prevalence in torus palatinus is less pronounced in skull materials than in living individuals representing the same population groups. Hence, the conclusion of a correlation between prevalence and size seems to be valid even in torus palatinus. To the extent that the torus phenomena are submitted to the control of genetic factors, this also means a correlation between penetrance and expressivity. This relationship has important bearing on the discussion of relevant genetic models associated with the propagation of tori, which will be dealt with below.

The problems with regard to variation of shape in palatine and mandibular tori represent a field less accessible to meaningful examination in the present material, as fundamental biologic and conceptual sources of incertitude will cast doubt on any more detailed interpretation and analysis. The topic has been dealt with in the present context mainly because it has been the object of considerable interest in the past (30, 33, 42, 45). Studies of archaeologic material have given rise to the concept that genetic factors may be involved in the development not only of size but also of morphologic shape of the tori (47). However, scientifically representative criteria of form hardly seem to exist, as the traditional typologic variants bear no convincing evidence of representing discrete biologic units. The conclusions drawn must therefore be cautious and of a general character.

In the present material it can be pointed out with a reasonable degree of confidence that in torus palatinus some correlation between size and shape exists. This statement is supported by the finding that an increased occurrence of palatine tori was reflected not only in the proportion of large tori but also to some extent in the form pattern. According to the slightly modified, traditional typologic system applied in the present material most of the small tori were classified as ridge-shaped and nodular types. The more voluminous tori were also mainly of the nodular variety, but with many transitions towards the lobular type. The largest tori were mostly of the lobular variety. In the mandible, however, no corresponding size-related form pattern could be ascertained.

With regard to the degree of concurrence of the two torus manifestations previous findings have been highly controversial. Geographically, the investigations are also scattered and performed in population groups of widely different racial and ethnic backgrounds (10, 27, 30). So far, little precise information has been available in this field.

In the present material the figures for combined occurrence of the two tori are low: 2.22% in the total material and with no valid sex difference. The figures are among the lowest ever reported for living subjects and may aptly be compared with those of Kolas et al. (30). In a large, ethnically compound material of American white and black citizens they found a concurrence of 3.03% and concluded that no correlation between the occurrence of palatine and mandibular tori exists. In the present material the findings of a numerical expression of concurrence lower still than that of the American investigators, and a statistically significant difference at high level with regard to concordance versus discordance of the trait combined torus formation, would seem to argue against a valid correlation between the two tori and preclude their possibly causal relationship. The same statement can be made with regard to the apparently infrequent observation of coexisting tori in the same individual.

However, such reasoning may be deceptive. In the present analysis it can be easily deduced from the figures that the probability of finding a mandibular torus in a person bearing a palatine one is more than twice as high as in a person without this trait, and vice versa. Such considerations make it difficult to reject the notion that there must after all be some sort of causal relationship between the occurrence of the two tori.

Genetic aspects

That the appearance of both palatine and mandibular tori rests on an interplay of genetic and environmental factors seems today to be well established. The main problem of recent years has been to disclose the genetic model compatible with the great variety of clinical data, morphologic observations, and propagation of the condition through the generations. Such a solution now seems to be arrived at in the shape of the so-called quasi-continuous genetic, or threshold, model (24–26, 37). According to this theory, the appearance of a torus, as a quasi-continuous character, is caused by a multiplicity of genetic plus environmental factors, with a threshold effect. The trait is explained in terms of an underlying continuous and normally distributed variable, 'liability', with a

threshold value beyond which individuals will be affected (24). Both genetic and environmental factors determine liability, making the system multifactorial. The model has proved useful in the analysis of congenital malformations of familial distribution, not accountable for by the ordinary single-gene Mendelian patterns. It has been applied with success even in the explanation of more extreme normal anatomic and morphologic variants, including torus mandibularis (26, 37). The present material, although unfit for a direct analysis of the problem, still presents some evidence compatible with the idea that the model may form an acceptable background hypothesis on the genetic aspects also in torus palatinus.

Looking back on the demonstrated correlation between prevalence and size in torus palatinus, in genetic terms between penetrance and expressivity, this relationship has important implications. Grüneberg (23), the 'inventor' of the term quasi-continuous variants, in his enumeration of what he calls the 'stigmata' of such traits, includes correlation between penetrance and expressivity of the underlying genetic system, sensitivity to environmental differences such as diet and maternal physiology, and sensitivity to genetic differences, such as sex and major mutant genes. These qualities make torus palatinus an appropriate candidate for the role of quasi-continuous variant or threshold character. It has been shown that in several morphologic traits of the teeth and jaws a quasi-continuous model more fully explains the phenotypic behaviors of the traits than does a single-gene model, and it has been pointed out that the concept of incomplete penetrance should be replaced with that of heritability when a quasi-continuous model is assumed (26). With regard to torus mandibularis attention has already been drawn by earlier investigators to the association between increased prevalence and the enhanced proportion of large tori among the affected individuals, and it has specifically been underlined that this pattern of positive regression of expressivity on prevalence is one of the characteristics of a quasi-continuous trait (26). As shown by the present study, the same properties apply to torus palatinus, and it would seem well worth while to test the model in pedigrees.

Vista

With regard to the low prevalences of both tori in the contemporary Norwegian population shown by the present investigation, the possibilities for a further explanation of these findings seem to be meager. The relative lack of other materials fit for comparison in ethnically related populations and the small chances of obtaining reliable results by comparing the present findings with those made in Norwegian population groups of a more remote past cause the outcome of such attempts to be rather conjectural. In view of the relatively strict criteria of definition and registration of tori in the present investigation not even a trend of subsiding occurrence of the tori in the contemporary population can be maintained with reasonable credibility, although the probability of such a development is felt to be rather hard to reject. With regard to the possibly genetic background of such a trend, nothing is known for sure, and no valid statement can be made. What may have contributed to a decreasing tendency in the population to produce tori, however, is the presumably reduced masticatory stress in large groups of the population, caused by the ever-increasing use of highly refined victuals, needing very little chewing for consumption. Still, in Norway considerable regional differences are present in this field (39), and further investigations are needed to draw more detailed conclusions. Even the value of the traditionally asserted (20, 48) but mostly doubted (33) argument that torus formation is initiated by mechanical and chemical irritation of the palatal and mandibular mucosa has some relevance to these problems of 'civilized' nutritional habits. However, it should be kept in mind that the general notion of a reduced function of the masticatory apparatus in the modern population may be more apparent than real, counteracted by the tendency of large population groups of today to retain their natural teeth into old age, many of them their whole life through. The prevalence of toothlessness in

the population is constantly decreasing and may, according to repeated Gallup polls, have been reduced by more than 50% during the past 10–15 years. This is an important objection to the unqualified statements often met with in this field, taking for granted what is by no means evident. That a reduction of the total masticatory activity in the population has taken, and may still be taking, place seems probable, but its degree and biologic implications are far from clarified. Further investigations are needed, applying epidemiologic methods and bringing in new factors for analysis, such as attrition of the teeth, individual habits of function, and periodontal disease (36–39). The importance of functional factors in the occurrence and morphogenesis of torus investigations should also be carried out, with correlations between torus formations and dimensional craniofacial variables, known to be influenced by functional and environmental factors. Norwegian investigators have shown that this particularly pertains to the breadth variables (49, 50).

Summing up, it can be stated that, although the situation is far from clarified, the demonstration of a low, and possibly decreasing, tendency of torus formation in the present Norwegian population provides some, although indirect, support to the asserted role of environmental and functional factors as morphogenetic codeterminants of the condition. Their interaction with genetic factors are, in view of our present state of knowledge, unquestionable. The details of this complicated interplay still belong to the future.

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