

ACTA ODONTOLOGICA SCANDINAVICA

Volumen 13, Supplementum 18

616.314(05)
7a

PLICAE PALATINAE TRANSVERSAE

AND

PAPILLA INCISIVA IN MAN

A morphologic and genetic study

BY

LENNART LYSELL

Universidade do Rio Grande do Sul
Faculdade Odontologia de Porto Alegre
BIBLIOTÉCA

ERRATA

- Page 52 legend in Fig. 8 *For WAVY read CURVED*
56 line 5 *For 3 read 5*
59 heading to second part of table *For VIII read VII*
59 line 7 from foot of page *For DISTRIBUITON read DISTRIBUTION*
69 line 7 from foot of page *For 16 read 17*
70 heading to Table 16 *For secondary read fragmentary*
71 heading to Table 17 *For fragmentary read secondary*
line 5 *For 17 read 16*
85 line 7 from foot of page *For : read ;*
90 line 1 of legend to Fig. 26 *For length read length (in mm)*
102 line 3 *For i read a*
104 line 25 *For subjects read rugae*
29 *For appear read appears*
105 line 2 from foot of page *Delete length,*
126 line 7 *For heredit read heredity*

Universidade do Rio Grande do Sul
Faculdade Odontologia de Porto Alegre
BIBLIOTECA

ACTA ODONTOLOGICA SCANDINAVICA

Volumen 13, Supplementum 18

From the Department of Orthodontics, the Royal School of Dentistry and
the Department of Anatomy, the Caroline Institute, Stockholm



UFRGS



06438063

PLICAE PALATINAE TRANSVERSAE

AND

PAPILLA INCISIVA IN MAN

A morphologic and genetic study

BY

LENNART LYSELL

Universidade do Rio Grande do Sul
Faculdade Odontologia de Porto Alegre
BIBLIOTECA

STOCKHOLM 1955

TRANSLATION

BY

Victor Braxton

Almqvist & Wiksells

BOKTRYCKERI AKTIEBOLAG

UPPSALA 1955

CONTENTS

	Page
PREFACE	5
HISTORICAL OUTLINE	7
SYSTEMS OF CLASSIFICATION	20
Systems not reported in detail	20
Systems reported in detail	21
The author's system	25
THE ERROR	35
Impression-taking and preparation of casts	35
Drawing the pattern on the casts	39
Estimation and measurement of a given pattern	40
Summary	45
THE VARIABILITY OF THE RUGA PATTERN IN AN ADULT GROUP	48
Summary	63
THE POST-NATAL ONTOGENIC DEVELOPMENT	65
Cross-sectional study	65
Longitudinal study	88
Summary	103
Discussion of certain changes in the rugae and incisive papilla	106
THE IMPORTANCE OF HEREDITARY INFLUENCE TO THE VARIABILITY OF THE RUGAE	110
Pilot study	110
The incisive papilla	117
The direction of the rugae	122
The general similarity of the ruga pattern	122
Summary	127
PATERNITY DETERMINATION	128
GENERAL SUMMARY	132
REFERENCES	134

PREFACE

This investigation arose out of a discussion with Associate Professor Torsten Romanus, at The Caroline Institute, on the possibility of using the plicae palatinae transversae as a guide in the determination of paternity. It became evident that any approach to the problem would demand more detailed information of the variability and developmental changes of the plicae palatinae transversae and the papilla incisiva than was offered by the scant literature on the subject. The primary object of the investigation was then to amplify our knowledge on these anatomic features.

An essential to any such study is a system of classification based on clear definitions. Such a system was devised which would give an as far as possible objective recording of the plicae.

The variability of the plicae in adults was tested in a group of 23-year-old subjects, comparisons being made with previously reported data.

The changes occurring in the plicae during a lifetime were studied in groups of subjects of various ages and in two groups on whom two observations were performed at an interval of 5 and 20 years, respectively. These studies may indicate whether the changes are so small that the plicae and papilla incisiva might be used for identification.

Hereditary similarities were studied in twins and in families. For guidance on some questions on heredity I am indebted to Professor Gunnar Dahlberg, Head of the National Institute of Race Biology and Human Genetics, Uppsala.

The results of these studies served as a guide in tests in which the conditions resembled those obtaining in paternity cases.

This investigation has been performed at the Department of Orthodontics at the Royal School of Dentistry, Stockholm. I should like to take this opportunity of expressing my thanks to Professor Anders Lundström, Head of the Department, for his kindness in placing at my disposal his collection of twin casts.

To Professor Ture Petré, Head of the Department of Anatomy at the Caroline Institute, Stockholm, I am indebted for making available to me the facilities of his department.

Arne Sollberger, med. kand., and Ulf Strömberg, fil. lic., med. kand., have offered advice on statistical matters. The diagrams were drawn by Mrs. Gertrude Voulethe, who also rendered valuable assistance in tabulating the data.

Financial support for this investigation has been gratefully received from the State grant for the furtherance of medical research at the Royal School of Dentistry. A Doctorate Scholarship has also been awarded.

STOCKHOLM

March, 1955

Lennart Lysell

HISTORICAL OUTLINE

The ridges situated in the anterior part of the palatine mucosa on each side of the palatine raphe and behind the incisive papilla are known by a variety of names. *Nomina Anatomica* (1949) prefers *plicae palatinae transversae*. Dorland's *American Illustrated Medical Dictionary* (1944) recognizes *ruga palatina*, defining it as "any one of the transverse ridges extending outward on both sides of the raphe of the palate"; *plica* is not mentioned at all in this connection. Another frequently used Latin term is *plicae palati*.

Among the others found in the literature in the various languages are: English, *palatine ridges*, *palatal rugae*; French, *rides*, *crêtes transversales*, *palatines*; German, *Gaumenleisten*, *Gaumenfalten*, *Gaumenstaffeln*; Italian, *pieghe palatine*, *rughe palatine*, *rughe del palato*; Spanish and Portuguese, *rugosidades paladales*, *rugas palatinas*, *rugas*, *crestas*, *pliegues* or *listones*. In Portuguese literature the terms *papilla palatina* and *crista palatina* are used with the same meaning as *ruga palatina*.

Throughout this paper *ruga* is used for the sake of brevity.

The following survey of the literature is divided according to the approach of the various authors. As the investigations and observations of an author occasionally pertain to divergent aspects of the subject some of the names recur in various sections.

General morphology

The earliest references to the rugae would appear to occur in various works on anatomy. J. B. Winslow (1732, 1743 and 1753) seems to have been the first to describe them and the earliest illustration is probably that by J. D. Santorini (1775) in Tabula VII of his *Septemdecim Tabulae*—a drawing depicting three continuous wavy lines which cross the midline of the palate.

The anatomical works of the following century do not provide more detailed description of the rugae. J. Cruveilhier (1837, 1843), G. Cuvier (1845), H. Milne Edwards (1860), J. Henle (1862) and J. Quain (1848, 1876) mention them summarily as corrugations or folds in the anterior region of the hard palate.

PH. C. SAPPEY (1857–64) seems to have made the first close morphologic study of the rugae in man. He gives the number as three or four, arranged step-wise upwards and backwards. Between these main rugae (*crêtes principales*) there are often smaller ones.

H. VON LUSCHKA (1867), G. ROMITI (1895) and FR. MERKEL (1885–90) provide more detailed descriptions. The two first give the number as 5–7 and 3–4, respectively, while Merkel observes that they range from 2 to 7.

HARRISON ALLEN (1889) differentiates between longitudinal and transverse rugae. The former are divided into the palatine raphe and incisive papilla, and the latter—*plicae palatinae transversae*—into pre-sutural, sutural and post-sutural (in relation to the suture between the intermaxillary bone and the maxilla), the first two of which never consist of more than one ruga while the last may contain from 4 to 7. They do not extend posterior of the first molar. Allen differentiates between continuous and broken rugae. The vertical, lateral parts of the rugae are the least variable, being particularly well developed in high narrow palates. The rugae on the left side tend to develop better; high, laterally compressed and wide, flat palates have continuous rugae; where the torus palatinus is well-defined the rugae are broken.

He performed observations on two groups of 90 persons, one of cases of chronic nasal catarrh and the other normal in this respect. Variations in the ruga patterns seemed to be greatest in the former group.

Allen considers that the absence of rugae may be due to a nevus, a fibrous tumour or pressure exerted by a denture. Resorption of the alveolar ridge following extraction of teeth may be accompanied by resorption of the rugae.

C. GEGENBAUR (1901, 1903) maintains that palatal *ridge* is a more accurate description of the feature than palatal *fold*. The number is put as 2 to 4, situated in the fore part of the palate, the posterior region being smooth.

I. N. BROOMELL (1902) mentions that the palatine raphe generally

diminishes in the posterior direction. In the anterior part of the palate and on each side of the raphe there are varying numbers of rugae; in exceptional cases they may be completely absent.

Even in the present century the rugae have received little attention in the surveys of anatomical works. Descriptions are generally limited to a few lines by, for example, L. Dieulafé & A. Herpin (1909), G. Wetzel (1920, 1951), W. Spalteholz (1920), E. Loth (1931), G. Häggqvist (1934), I. Broman (1936), G. Korkhaus (1939), H. Shapiro (1947), T. Petrén (1948), A. Rauber & Fr. Kopsch (1948), B. Orban (1949), H. Sicher (1949) and G. Port & H. Euler (1951). The number of rugae is given as ranging from 2 to 7.

Ontogenesis

The rugae are sometimes described as tending to regress with age. This property was examined by C. GEGENBAUR who in 1878 published an article entitled "Die Gaumenfalten des Menschen" which reported a study of the rugae in human subjects of different ages, from the embryo. He found that in the embryo of sitting height 4.2 to 4.5 cm the palate was quite smooth. At 5.5 cm there are 5 to 7 rather symmetrically disposed ridges of which the anterior ones begin at the raphe, and the others somewhat laterally. Towards the end of intra-uterine life the pattern of the rugae is less regular; the posterior ones disappear and the anterior become considerably more pronounced and compressed in the front of the palate. On birth the pattern is well defined and weakens only a little during childhood, although in later years there is a pronounced decrease in prominence. The regression may be so marked as to leave the palatine mucosa quite smooth.

G. RETZIUS (1906) studied the rugae in man and practically all other classes of mammal. His material included a large number of human foetuses (22 of them illustrated), 9 persons aged 9 to 29 years of which plaster casts of the maxilla were prepared, and three specimens (ages 21, 30 and 56 years) where the maxilla was resected.

One of the foetuses of sitting height only 3.1 cm presented rugae. Their number is put at 4 but their irregularity prevented any accurate count. Retzius does not consider as typical the regular disposition reported by Gegenbaur; if it exists it is the exception rather than the rule. In older foetuses and newborn infants the pattern is

extremely variable: the rugae may be crowded, few and dispersed, narrow, wide, straight, curved, and discontinuous, the sections being joined in various ways. One characteristic is that they never extend over the mid-line. At this stage there are 4 to 5 of them, but their irregular nature makes it difficult to ascertain their number with any degree of certainty. The casts and specimens of all except the oldest subject (56 years) presented rugae of varying width and prominence, the anterior rugae being commonly more prominent than the posterior. Retzius agrees with Gegenbaur that the rugae undergo a continuous and more or less extensive reduction from intra-uterine life onwards. They would appear to be a rudimentary organ.

Comparison between the rugae of man and various classes of mammals reveals that in man and the higher apes they have regressed—a development that may be considered as a purely phylogenic reduction.

C. GORIA (1911) studied 14 persons aged 60 years and above, finding that 8 had a completely smooth palate while 6 displayed traces of rugae.

A. H. SCHULTZ (1949) made observations of (a) 30 foetuses, 15 whites and 15 Negroes, with sitting heights of 50 to 360 millimetres, (b) 240 whites aged 10 to 45 years, and (c) 11 adult male Negroes. He points out the difficulty of determining the number of rugae with any degree of accuracy on account of their ramifying and broken nature. He maintains that the rugae do not alter in number with age; while admitting the possibility of some or all rugae disappearing in senility, he states that he himself had never seen a palate with no rugae at all.

The pre-natal ruga pattern is predominantly transverse—that is, the rugae extend perpendicularly to the raphe—but as the jaws develop there seems to be a tendency for them to assume a more mesial direction. The ramifications and breaks do not appear to vary in number with age. Moreover, apart from the changes in direction and spacing, the pattern is apparently constant throughout life. Schultz does not share the opinion that the rugae are more developed and proportionally larger in foetuses than in adults, but is “convinced that the size of the ridges in relation to the size of the palate does not decrease from fetal to adult life, and may occasionally even increase”.

He finds a definite connection between the number of rugae and the posterior limit of the pattern, the greater their number the further back the boundary. Neither in foetuses nor in adults do the rugae extend much beyond the anterior half of the hard palate.

K. NILLES (1950) found that the palate was never smooth in persons of advanced age and that in some cases, even well defined rugae could be observed. The pattern of the rugae generally covered a smaller area since their number had decreased in the forward direction.

E. HAUSSER (1951) found in a large number of casts that during the foetal stage and up to 15 years of age the variation in form, number and arrangement of the rugae was so great that no definite type could be recognized. He found rugae in every one of 103 patients aged 50 to 80 years.

Rugae in individuals and groups

Various attempts have been made to trace differences between individual ruga patterns.

I. N. BROOMELL (1902) considered that the appearance of the rugae was typical of the character and temperament of a person. For instance the bilious type would have heavy, angular rugae, while in the nervous type they would be few in number, close together, less prominent, and wavy; persons of a sanguine disposition would present many fairly prominent well-rounded rugae, graceful in outline, while those in the lymphatic would be few, flat and widely spaced, with no pronounced wave form.

C. GORIA (1911) examined 230 persons of between 5 and 70 years. They consisted of 40 criminals, 24 imbeciles, 61 epileptics and 105 normal people. It was found that the rugae of the first three groups were more primitive and numerous than those of the normal persons, in whom the number exceeded 4 in only one case, while 5 and 6 were found in more than one third of the subjects composing the other groups. Goria considered that the reduction with age was less marked in epileptics than in the normal persons.

K. O. HENCKEL (1926) studied systematic differences in the ruga patterns of different races. Comparing his 11 Melanians (10 ♂ + 1 ♀) with the Swedish group of Retzius he could find no essential difference except for one instance that he ascribed to chance.

K. MURAKAMI (1928), in 100 Japanese (50 ♂ + 50 ♀), studied the extent of the pattern, the number of ridges, their prominence, direction, ramification, continuity, their relation to the various types of dental arch and palate, and the incisive papilla and palatine raphe. On comparing his results with those of Retzius and Henckel he found definite, though minor, racial differences. A more thorough study of a larger group, supplemented with a statistical analysis, would be required for deciding whether there is in fact any racial difference in the anthropologic meaning of the term. Murakami divided the rugae into three groups according to their direction: perpendicular to the raphe (I), and inclined to the raphe, both forward (II) and backward (III). The last type was the commonest. According to Murakami a fellow countryman, Suganuma (1928), has studied 242 Japanese, grouping them according to the forward angle between the rugae and the raphe: (1) 30°, (2) 45–60°, (3) 60–90°. The last was the commonest but all three types often occurred on one hard palate.

R. LOCCHI (1930) studied 32 whites (24 ♂ + 8 ♀), 47 Negroes (36 ♂ + 11 ♀), 24 mestizos (11 ♂ + 13 ♀), 4 Japanese (♂) and one Indian (♀). He points out the difficulties presented by the multiformity of the rugae and does not attempt systematization, comparing the groups only with respect to the number and general direction of the rugae, and to the posterior limit of the pattern. The number varied from 3 to 6, but never exceeded 4 in the whites. In all the coloured groups the limit was further back than in the white. There was no correlation between the number of rugae and the posterior limit of the pattern. The direction of the rugae was generally transverse and there was no evident difference between the groups in this respect. Locchi states that the material was too small to yield definite conclusions and puts only a relative value on his results.

K. HIROTA (1933) studied 300 Japanese, giving no details of sex or age. He found it difficult to draw comparisons with European study groups on account of their small size. However, he concludes that the Japanese have fewer rugae than the Europeans. No difference in respect of sex or side could be found although it was evident that the rugae were apt to deteriorate with age. He provides a detailed and, in part, new description of the pattern and the components. (See p. 21.)

J. WELDT (1935) studied 100 inhabitants of mixed race in the town of Concepción in Chile (50 ♂ + 50 ♀), observing the number of rugae, their prominence, posterior limit, ramifications and breaks, and the prominence, shape, length and breadth of the incisive papilla. The average number of rugae was 4.26 for males and 4.05 for females. On comparing his material with Murakami's Weldt finds that in spite of the greater number of rugae in Japanese than Chilean palates the posterior limit is further back in the latter. Weldt's figures for the number of ramifying rugae are somewhat higher than Murakami's, while the number of broken rugae is roughly the same in both cases. Weldt used Murakami's system of recording the direction of the rugae and found that Type II was very uncommon in both groups, while I and III were roughly equally common in the Chilean; Murakami had twice as many Type III as Type I. The incisive papilla in Weldt's group was generally oval or pear-shaped, while Murakami found the spool shape the commonest.

S. OHSHIMA (1937) performed an anthropometric investigation of an unspecified number of Chinese males. He found that the rugae were extremely variable in shape and that they were situated mainly in front of the first molars, being particularly numerous in the region around the second premolars; they varied in number although 4 was most general, and they were most frequently inclined backwards. 43 per cent of the right rugae and 45 per cent of the left were papillate.

A. H. SCHULTZ (1949) studied foetuses and adults. In the former group the average numbers of rugae for 15 whites and 15 Negroes were 4.03 and 3.93, respectively. For the adults the figures were 4.28 (240) and 4.18 (11) with a total variation of 2–8. It is doubted whether there were any racial differences in the rugae, those differences mentioned by other workers being ascribed to the diversity of procedures for counting the rugae. There does, however, seem to be a difference between the sexes, the rugae in men being more numerous than in the women (♂ 4.33 and ♀ 4.21, the difference being hardly significant). No difference between the sides could be traced (4.25 and 4.31).

K. NILLES (1950) studied Central Europeans (Germans, Saarlanders, Austrians and Swiss), altogether 50 males and 50 females. He made comparisons with the material of Weldt and Murakami and, as they, found difficulty in deciding the number of rugae. He gives 4.25 and

4.37 for males and females, respectively. In respect of ramification this study showed closer similarity with the material of Murakami than that of Weldt. Unlike Weldt, however, he found that the incisive papilla was both longer and wider in the females.

Heredity and environment

HEREDITY

The study of racial differences between the rugae and attempts to find characteristic patterns for specific groups have directed attention on heredity in twins and families.

The first observations of the rugae in twins appear to have been those made by H. OGAWA (1940) on 45 pairs of twin foetuses of 5 to 10 foetal months, 29 of them identical (17 ♂♂ + 12 ♀♀) and 13 fraternal (3 ♂♂ + 5 ♀♀ + 5 ♂♀); in the case of three pairs (♂♂) it was not decided whether they were fraternal or identical.

He made the following observations.

(1) The rugae, ramifications and breaks were more numerous in the identical than the fraternal twins; the posterior limit of the ruga zone was further back in the former, but these differences were in no respect statistically significant.

(2) No influence of heredity could be established in respect of continuity, ramification, the posterior limit of the pattern and the decrease in the prominence of the rugae.

(3) Agreement between homologous palatal halves within the pair in respect of all the characteristics studied—viz., the shape, number, ramification, continuity, and the appearance of the rugae and the posterior limit of the ruga zone—occurred only 4 times in 29 identical pairs and not at all in the 15 fraternal pairs.

Ogawa assumed that there was an evident environmental influence on the rugae.

G. KORKHAUS (1942) studied the influence of heredity on the dentition in 5 sets of triplets and 2 sets of quadruplets, and found that in the identical sets the ruga patterns presented close similarity, although not in all details. The rugae would be much dependent on hereditary tendencies. There were much greater differences in the pattern in the multizygotic sets.

R. RITTER (1943) used a study group consisting of 81 identical and

118 fraternal twin pairs for working out a systematic classification based mainly on similarities in pattern, direction, shape, length and breadth of the rugae.

The types distinguished were:

(1) a very common pattern with 3–5 well developed rugae on each side; this may be regarded as the normal type;

(2) as (1) except that the rugae are thinner and flatter; rather common;

(3) prominent rugae; rare;

(4) small papillae; rare as (3); the rugae consist of papilla-like protuberances of the mucosa; the pattern bears little resemblance to any of the first three;

(5) characterized by lack of detail, inexpressiveness and simplicity; only 2–3 rugae, branched and rather straight; uncommon.

In each set of identical twins the patterns bore such close resemblance to one another that they always fell in the same group. Type 1 was the most common, 54 identical pairs and 60 fraternal pairs being placed in this category; where the members of a fraternal pair were assigned to different groups one of the twins always belonged to Type 1. Although the ruga patterns of identical pairs presented striking likeness, there was no pair in which all details were identical.

The loss of teeth did not change the pattern, as it did the shape of the palatine raphe, and neither was there any change with age.

K. NILLES (1950, 1952) made a study of families in an attempt to resolve the problem of the influence of heredity on the rugae. The experience so gained provided the basis for an investigation of the possibility of using the rugae in anthropologic paternity determination. Comparisons were made between the parents and the children in respect of the shape and direction of the rugae, the reduction in the posterior part of the pattern, and the shape and dimensions of the incisive papilla. Similarities were found between children and both the father and the mother.

In legal cases of paternity comparisons are made between the mother, child and the possible fathers; it is often possible "by superficial inspection" or "at a glance" to say who on anthropologic grounds is the father. Nilles considers that the method provides valuable supplementary evidence in paternity cases.

W. KLENKE (1951) maintains that in 90 per cent of the legal paternity

cases the combined anthropologic and biogenetic verdict leads to results of value to the court of law. The polysymptomatic similarity analysis is based on the assumption that the closer the similarity the closer is the familial relationship. The more numerous the characteristics that may be studied the more reliable is the diagnosis—a conception that in recent years has led to an increased interest in the palate, and the rugae in particular.

It is maintained that man generally has four rugae but that there is, in addition to this "normal type", one with a tendency to increased ruga formation—the "pharyngeal type"—which is dominant compared with the "labial type" which has a lower tendency to the formation of rugae.

In anthropologic paternity cases it has been usual to look for similarities; however, with the assistance of this rule of dominance one should be able to apply a process of elimination; if the mother and the man in question both belong to the recessive type while the child belongs to the dominant the man cannot be the father.

A study was made of 25 families with 74 children, the ages of whom ranged from 3 to 64 years. The number of rugae was 4.2 and no variation with age could be detected. In the description of the ruga pattern the chief features are the number, shape, direction and prominence.

Klenke bases his statements pertaining to hereditary transmission principally on the fact that, of 27 families where one of the parents had more rugae than the average and the other parent the average or less, 52 of 63 children had above the average number.

He considers, however, that the difficulty of establishing the number of rugae with certainty makes it impossible to obtain as reliable a result with a polygenic characteristic, as with a monogenic—with the blood group, for instance. Other characteristics of use in paternity cases are the shape, direction and prominence of the rugae, their distance apart and the posterior limit of the pattern. In addition the palatine raphe and the incisive papilla may be used.

H. SCHADE (1954) admits the value of Klenke's use of the number, shape, direction and prominence in hereditary studies but doubts the existence of the dominant hereditary transmission of the greater number of rugae than the average.

ENVIRONMENT

Closely connected with the genetic factors is the influence of environment.

E. HAUSSER (1950, 1951) studied the influence of exogenous factors on the palatal pattern and found that finger-sucking to such an extent as to deform the bone brought about changes in the pattern. In orthodontic treatment where the premolars or molars are moved in a sagittal direction the relation between the teeth and the rugae is dependent on the fact that the displacement of the latter is one half of the displacement of the teeth. This is true of the lateral parts of the rugae; nearer the raphe no such change appears to occur.

The asymmetries in the ruga pattern found by several investigators Hausser supposes to be a consequence of the asymmetric position of the premolars and first molars, since the position of the rugae is related to the teeth.

There is no evidence that pressure exerted by artificial dentures causes atrophy of the rugae.

K. NILLES (1950) examined denture wearers and in no case found a completely smooth palate but does not share Hausser's opinion of the effect of the denture on the rugae. Nilles maintains that the atrophic changes that he observed in his study group cannot be considered as due solely to age but must be ascribed in part to pressure exerted by a denture, especially as most of the subjects were under fifty years of age.

Rugae as an aid in identification

A number of investigators have concluded that the ruga pattern is unchanged over long periods of life; the rugae might then serve as a means of identification if some practical recording system could be devised.

As early as 1889 Harrison Allen sounded the possibility of using plaster casts of the maxilla recently taken in connection with dental treatment.

L. SILVA (1938) worked out a system of identification by the rugae, based on the assumption that the rugae are absolutely individual, are unchanged after the third intra-uterine month, are perennial, and, even in cases of trauma, appear after treatment in the identical positions and original configurations. The rugae are classed as simple

and compound, the latter being considered as consisting of a number of simple rugae. Each ruga is codified before inserting it on a rugoscopic record card. The incisive papilla and the palatine raphe are similarly classified. (See p. 23.)

J. U. CARREA (1937) also published a system of identification by the rugae. He states that the number of rugae varies according to the manner of classification. It is asserted that the rugae are (1) absolutely different from one another, (2) of constant shape, (3) permanent, and (4) individual. He also found that extractions have no influence on the shape of the rugae.

The rugae are classified in four groups according to their direction: forward, lateral, distal and varying. The individual ruga is either straight or curved. (See p. 22.)

Other papers published in 1940 and 1955 follow the general lines of the former but present a more detailed classification based on the author's system of odonto-legal stenography. No example of its application is given, however.

V. AUFIERO & F. CESATI (1940) studied 70 persons (30 ♂ + 40 ♀) aged 20-40 years, following Carrea's classification. They considered that a rugoscopic scheme on whatever classification it may be based has no value in legal medicine. It could be applied only through an exact reproduction of the ruga pattern, which might be provided by casts or photography. Aufiero and Cesati themselves made casts which were then photographed. A rugoscopic scheme may be of value in so far as it can limit the searches in the archives. (See p. 22.)

E. HAUSSER (1951) has published three cases followed from birth to the ages of 7, 8 and 9 years. He found that the characteristic picture of the palate is unchanged during the growth of the jaws, so that the rugae might play an important role in identification.

The physiologic importance of the rugae

It is frequently stated that the rugae in man are only rudimentary formations but that they have at the same time a function.

The importance of the rugae as an aid in grasping the maternal nipple is mentioned by G. Retzius (1906), M. Lafond (1930), G. Korkhaus (1939) and E. Hausser (1951).

RETZIUS considered that the rugae in man have no function in the uptake of nourishment after suckling is finished.

M. LAFOND points out that the rugae have a function in tasting. H. SICHER (1949) mentions that the human rugae are vestiges of the larger and more regular formations that in animals have an important auxiliary role in the process of mastication.

E. HAUSSER points out that on the eruption of the teeth the rugae lose their importance in the taking up of nourishment but subsequently have another function: they facilitate the orientation of the tongue in the oral cavity and thus aid enunciation.

SYSTEMS OF CLASSIFICATION

An essential of any study of the rugae is an objective and detailed system of examination. Definitions and information relating to the rugae are scarce in the literature, yet it must be assumed that all who have examined, for instance, the number of rugae, followed some system even though it may not be described in detail. Such must have been the case for C. Gorla, K. Murakami, R. Locchi, J. Weldt, K. Nilles and W. Klenke, all of whom publish results based on study groups of varying size.

Other authors have published very detailed systems but have not tested their practical value, or at least have not given details of their results; among them may be mentioned J. U. Carrea and L. Silva. An intermediate position in this respect is assumed by K. Hirota and V. Aufiero & F. Cesati, who evolved systems that, however, were based only in part on the results of their studies.

Systems not reported in detail

A survey of these systems must inevitably be incomplete, and embrace only a part of the details considered by the investigators.

C. GORLA (1911) asserts that the ruga pattern may be characterized in two ways—by specifying either the number of rugae or the extent of the ruga zone in relation to the teeth. He favours the former as being the simpler. He defines the ruga as a ridge that extends at least one half the distance from the palatine raphe to the dental arch; compound rugae of two or more branches he counts as one; they may be V- or Y-shaped. Gorla maintains that with the assistance of these data the numeration of the rugae is a simple matter. He distinguishes two kinds: simple or primitive and more developed. Broken rugae are most common in the posterior region of the pattern.

K. MURAKAMI (1928) remarks that the number of rugae is difficult to determine on account of their disconnected and ramifying nature. The ridges that together form a continuous row may be considered

as a unit. Of the posterior and least prominent rugae only those that are clearly discernible are counted as one unit. Murakami stresses the symmetric arrangement; symmetry may often serve as a guide in deciding in doubtful cases whether a detail should be counted as an individual ruga.

R. LOCCHI (1930) considers that the ramification makes an objective count of the rugae difficult to perform. He reckons the last ruga as an independent unit, even if, as is often the case, it appears rudimentary, consisting perhaps of no more than a row of papillae.

J. WELDT (1935) also maintains the difficulty of counting the rugae and considers that this demands a fine sense of morphology. Even with the aid of a binocular magnifying-glass he found it difficult to decide whether two ridges that separated very close to their points of origin should be considered as two independent rugae. He also observed the occurrence of small papilla-like protuberances in the posterior area of the ruga zone. Where such papillae occur singly they should not be considered as rugae, but if they form a band they may be counted as one independent ruga.

K. NILLES (1950) uses Weldt's classification; from comparisons between his results and those of Weldt and Murakami, it appears that there can be little difference between their systems of classification. A ruga that divides just after the palatine raphe is counted as two.

W. KLENKE (1951) reckons the number of rugae according to the same system as Murakami and Weldt.

Systems reported in detail

Hirota and Aufiero & Cesati may be included under this heading, as a transition between the groups.

K. HIROTA (1933) divides the ridges in the hard palate into (A) palatal rugae and (B) papillae. The palatal rugae are subdivided according to the form: (1) arcs or waves, (2) bifurcations, (3) straight lines, (4) letter S, (5) circles, Japanese key and pear pip, (6) short lines. Arcs or waves are common while the straight line occurs mainly in the first and second rugae. The S shape, circles, Japanese key and pear pip are all uncommon.

The papillae are divided into: I connected rings, II groups of closely packed points, III scattered points, IV "sponge". Of these II and IV are uncommon.

The single ruga is characterized by (1) size, (2) density, (3) shape of sections, (4) direction, (5) relation between right and left, (6) region of palate.

V. AUFIERO & F. CESATI (1940) in some respects follow Carrea's system (see below). They divide the rugae according to their shape: (1) angular, (2) angular with curved apex, (3) with two angles, (4) with three angles, (5) branched, (6) curved, (7) double, (8) multiple, (9) wavy, (10) straight, (11) broken, (12) stellate, (13) in the form of small tubercles, (14) comma-like.

70 ruga patterns (30 ♂ + 40 ♀) were analysed according to these types and set out systematically, with letters to represent the various forms.

It is stated that these descriptive details may be supplemented by, for instance, length, direction and position, which would considerably increase the number of combinations, but at the same time render the whole appraisal more complicated. Even with this systematization the authors find difficulty in classifying the rugae, especially with regard to the factor of subjective judgement. A system is presented, however, with the purpose of facilitating search in rugoscopic archives where photographs of the ruga patterns are filed.

The suggested system of classification is:

	mesial		
	distal		
direction	lateral		
	varying		
Primary rugae		Secondary rugae	broken stellate points comma-like rudimentary
	straight		
	curved		
morphology	angled		
	wavy		
	double		
	multiple		

The secondary rugae are those that occur less often. They are considered as a very important characteristic in identification. A rudimentary ruga is small and poorly defined.

The casts are photographed with the occlusal plane at an angle of 45–50° to the optical axis.

J. U. CARREA (1937) says that the number of rugae varies according to the manner of classification. As Aufiero & Cesati, he divides them into four groups according to direction. The rugae that meet the palatine raphe are classified as straight and curved, to which he adds

points. The straight line may be long or short, thick or thin, regular or irregular. The curved line may have the same variants as the straight line and, in addition, dipping and prolongation. The points may be clear or dissembling, small or large. The straight lines may form acute or obtuse angles, letters N, M or U and their inversions, and figures such as the square, quadrilateral, rhombus, rhomboid and trapezium. The curved rugae form angles, waves and major arcs of circles, which may be simple or compound. The association of the points with straight lines and with curves, compound figures of straight lines and curves, and these *inter se*, form a wealth of characteristics. For the typical figures Carrea uses the following notation:

r	straight	a	angular	t	trifurcated
c	curved	m	compound	i	internal
o	wavy	h	hooked	e	external
q	broken	u	single	p	extension
		b	bifurcated	s	supplementary

He gives similar abbreviations for the incisive papilla.

In this scheme Carrea includes one case with three rugae on each side, thus: 3|3 or, in detail, 3r 2o 1b|1o 2o 3t, to denote that on the right side the third ruga is straight, the second wavy and the first bifurcated, while the first and second on the left side are wavy and the third trifurcated.

A later paper (1940) describes a number of modifications to the system. It is still based on the curved and straight line but as the abbreviations gave rise to some confusion the fundamental signs in stenography have been introduced. The straight lines are divided into horizontal (K), vertical (T), oblique to the left (P) and straight oblique to the right (J). Letters are also used to denote the curved lines—horizontal, vertical and oblique, and for all convex and concave upwards. Various combinations of letters are also included: there are, for instance, five types of circle.

Carrea, who in his former paper expresses his scepticism of the possibility of direct intra-oral photography, now considers that this is the best way of obtaining a rugogram.

L. SILVA (1938) who, as Carrea, devised his system solely for purposes of identification, classes the rugae as simple and compound. The former are (1) straight, (2) curved, (3) angular, (4) circular, (5) wavy,

and (6) points. The compound consist of two or more simple rugae. Length and width are disregarded, as it is the pattern and not the dimensions that is the basis for identification. Silva describes a ruga from right to left. For instance, one consisting of three points is denoted as 6-6-6. One consisting of a straight line and an angle, separated by a space, is written 1-3. If the angle and the straight line are continuous they form one compound ruga which is denoted by 13, and if the angle is to the right of the line, 31. A point or a straight line situated within an angle is given as (6)31 and (1)31, respectively. One more example will suffice to illustrate this notation.

$\frac{5}{1-1}$ denotes a wavy ruga at both ends of which there are straight lines inclined backwards; had the lines been inclined forwards the symbol would have been $\frac{1-1}{5}$.

When all the rugae have been dealt with in this manner they are resolved into their elements. For instance:

<i>Right</i>		<i>Left</i>	
5	straight (1)	4	straight (1)
1	curved (2)	1	curved (2)
1	angular (3)	3	angular (3)
0	circular (4)	0	circular (4)
3	wavy (5)	3	wavy (5)
1	point (6)	1	point (6)
represented by the number		represented by the number	
51.131		41.331	

(the zero is not inserted for the circular ruga, which does not occur in this example).

The numbers for the two sides are added (51.131 + 41.331) and the sum (92.462) entered on the rugoscopic card, followed by a figure composed of the sum of the rugae on the right and left sides; in this instance the complete figure is 92.462-8. The cards are arranged in the archives in numerical order, disregarding the number of rugae which serves only as a check. An erroneous recording of an element—for instance, a wave instead of a curve—would in the example give 5.141 on the right instead of 51.131. This would place the card in quite another part of the archives.

The author's system

The purpose of this investigation was to study the variability of the human rugae, their characteristics and the incisive papilla.

Of the systems described in the literature there is none that lends itself to a discussion of the problems with which the present author is concerned. The main difficulty arises from the lack of definitions of the terms used. For example, the term *ruga* or its equivalent is used by practically all authors, but in practically none of the papers is a definition attempted. The same is true of most of the other terms such as "branched" and "broken" rugae.

Some authors, among them Silva and Carrea, have indeed provided in place of the definitions rather instructive diagrams which serve in some measure to explain the terms. The systems of these two workers are, however, so limited to the problem of identification that they cannot be readily applied to the present study.

The first step was therefore to devise a generally descriptive system of classification which, while being as objective as possible, would take into account the number and characteristics of the rugae together with the incisive papilla.

An inspection of the rugae may be made (1) directly, (2) by photography, and (3) by studying casts.

With a large study group the first method is technically impossible. Photography presents a number of difficulties in respect of accurate dimensions. The third procedure was then chosen as providing as good, if not better, possibilities of studying the rugae than the direct method. One disadvantage lies in the archiving, which demands great space.

As the impressions must be as far as possible free from bubbles a wetting agent should be applied, either by means of a spray or by rinsing. The palate is then dried with compressed air, particular care being taken in the fore part of the palate. This area is then covered with an alginate impression compound, applied by means of a wooden spatula, after which the impression is taken in the usual manner, and subsequently cast in dental stone.

For a proliferation to be designated as a ruga it should be at least two millimetres in length. (See below, however, concerning broken rugae.) Smaller proliferations are neglected.

The rugae in one half of the palate cover an area bounded medially

by the palatine raphe and laterally by the extreme lateral points on the rugae (not necessarily the ends of the rugae). The distance from the raphe to the lateral boundary is determined with a flexible tape measure along the surface of the palate. The line joining the mid-points of these distances divides the palatal half into medial and lateral halves. The lateral of these halves is similarly divided into two—the medial and lateral quarters. As the lateral limit is irregular, the boundaries between the halves and quarters are also irregular.

The rugae are classified as (1) *primary*, (2) *secondary*, and (3) *fragmentary*.

A primary ruga

(a) is visible for at least five millimetres irrespective of the direction of illumination. (Here, as in all cases of linear mensuration in the study, the length is taken as the shortest distance between the origin and termination of the ruga, measured along the surface of the palate.)

(b) is of such width that it is evident by inspection that it is not narrower than both anterior and posterior adjacent primary rugae. The first ruga is compared with the two nearest primaries. No stipulation as to width is made in respect of the last prominent primary ruga. (The general tendency is for the anterior rugae to be wider than the posterior.)

(c) begins within the medial three-quarters of the region.

If there is behind the last of these primary rugae one ruga of at least five millimetres it should be included as a primary ruga even if it is not prominent. If there are several such rugae, only the most posterior is denoted as a primary ruga. It is called an extra primary ruga—"primary (X)"—to distinguish it from the others that are termed ordinary primary rugae—"primary (O)".

Secondary rugae are all those that, irrespective of width, are at least three millimetres in length—primary rugae excepted.

Fragmentary rugae are those between two and three millimetres in length.

NUMERATION OF THE RUGAE

Only the primary rugae are numbered. The numeration is in an antero-posterior direction beginning with I. (For the sake of brevity this is often written R I, and the second R II, etc., up to R VII.)

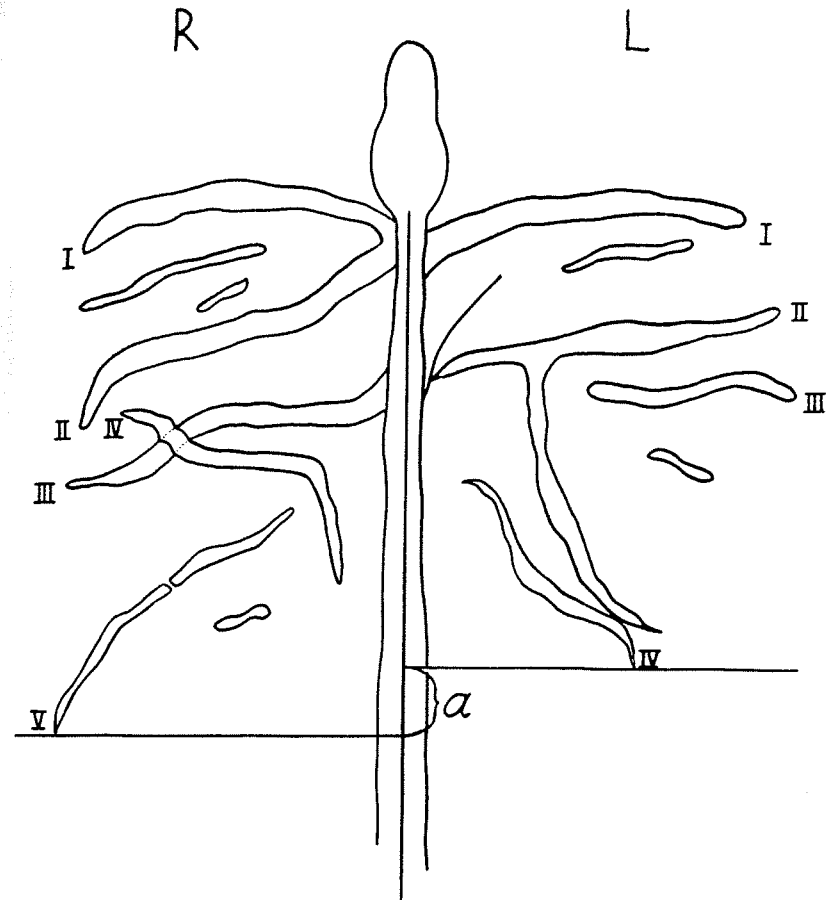


FIG. 1. Numeration of the rugae: process (at R II left); branch (R II left); united rugae with common origin (R I–II right); united rugae with separate origins (R III–IV right, "crossing"); broken ruga (R V); touching rugae (posterior branch of R II width R IV left); posterior limit of the ruga zone (the distance *a* is a measure of the bilateral asymmetry).

The order of the rugae is reckoned in an antero-posterior direction with respect to the relative positions of their mid-points. The only exception is the case where a primary ruga occurs between the branches of a ramifying primary. The branched ruga is then always given the lower number irrespective of the relative positions of the mid-points. (The mid-point of a branched ruga is the mid-point of the line from the origin of the ruga to the mid-point of the line between the extremities of the branches.) Fig. 1 illustrates the numeration of the rugae.

	NO.	NAME	DATE OF BIRTH	IMPRESSSION EXAMINED					REMARKS
				ADDRESS	TEL.	L I R	L II R	L III R	
1	STRAIGHT								
2	ANGULAR								
3	CURVED								
4	ORIGIN								
5	DIRECTION								
6	BRANCHED								
7	UNITED								
8	BROKEN								
9	SECONDARY								
10	PAPILLATE								
11	UNCOMMON DETAILS								
12	FRAGMENTARY								
13									
14									
15									
16									
17	DIST. BETWEEN TERMINATIONS								
18	PALATAL WIDTH								
19	POSTERIOR LIMIT PRIM. (Q)								
20	POSTERIOR LIMIT ALL RUGAE								
21	NO. RUGAE L/R								
22	INC. PAP. FORM								
23	INC. PAP. L/W								
24	PALATAL RAPHE								

FIG. 2. The chart.

DEFINITIONS AND CHARACTERISTICS OF THE SYSTEM

For the examination of the subjects a chart of the type shown in Fig. 2 was used. Below the normal details of name, address, etc., there is a line with the notation L I R, L II R, etc., provided for the rugae of each side. This is followed by a number of symbols defined and explained below.

THE INDIVIDUAL RUGA

(1)¹ *Straight*—completely straight, except for any slight deviation at either end that does not disturb the general impression of a straight line.

(2) *Angular*—forming one or more angles or containing one or more notches.

(3) *Curved*—neither straight or angular.

To facilitate judgement of the shape of the ruga a diagram of some variants of the three types is given (Fig. 3). The ruga is marked in the scheme by a perpendicular stroke in the appropriate square.

If a ruga has an angle or a notch but is otherwise straight or curved it is recorded as angular. Analogously, a branched ruga is not marked in two squares although the branches may be of different types. The main part and branch are considered separately. If both are straight the ruga is straight; if at least one is angular or notched the ruga is angular; otherwise it is curved.

(4) The *origin* of a ruga is taken as its medial termination. A ruga may begin at the raphe or laterally of it. The origin is denoted by R, M or L, respectively, for rugae beginning at the raphe, within the *medial half* of the ruga zone without being in contact with the raphe, or within the *lateral half* of the zone.

The palatine raphe frequently has processes. They are distinguished from the rugae chiefly by the fact that they appear to grow out of the raphe. They are narrow and generally describe a gentle arc in a forward direction. A ruga with its origin at the point where such a process just leaves the raphe is denoted by R. (Fig. 1.)

(5) The *direction* of a primary ruga is taken as that of the line joining the origin and the termination. It is represented by the angle it makes with the normal to the raphe, all points being projected on the horizontal plane. The measurement is performed by placing

¹ The figures before the definitions correspond to these of the scheme.

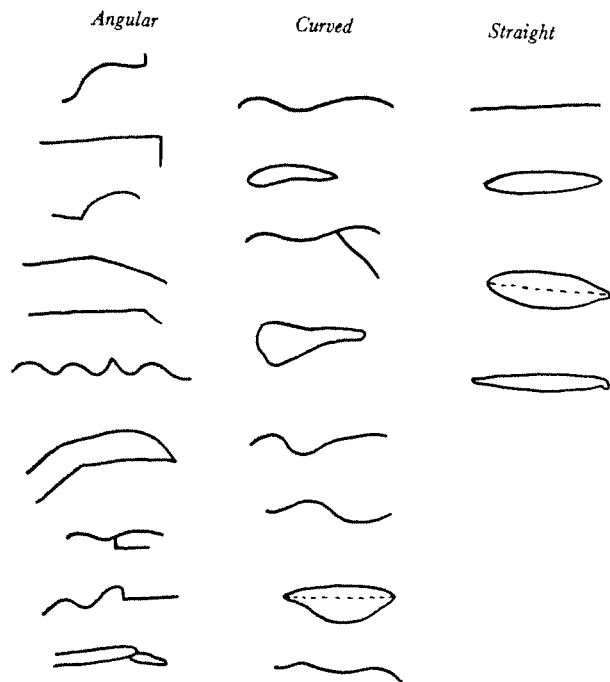


FIG. 3. Some variants of angular, curved and straight rugae.

the cast in a symmetrograph of the type described by Rudolph Schwarz, the setting being such that the occlusal plane coincides with the horizontal plane, the occlusal plane being represented by the incisal edge of the upper left central incisor and the mesiolingual cusp on the first molars or, in the deciduous dentition, the second molars. (If the first molar is missing the setting is made with the lingual cusp of the second premolar; in exceptional cases the first premolar may be used. Where many or all teeth are missing the setting is made in relation to the crista.) The palatine raphe is marked by an anterior point in the neighbourhood of R I and by a posterior point a centimetre or two behind the posterior limit of the ruga zone, depending on how far back the raphe is clearly visible on the cast. The angle for a ruga perpendicular to the raphe is zero; the forward and backward inclined rugae are then denoted by positive and negative values respectively. (Fig. 4.) The angles are read to the nearest half degree. The direction of a branched ruga is given by the line from the origin to the mid-point of the line joining the ex-

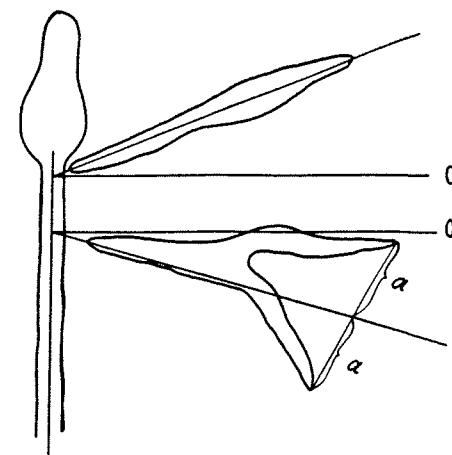


FIG. 4. Measurement of the direction of the rugae.

terminities of the branches. If a ruga has more than two branches the two outermost (the most anterior and posterior) are used.

(6) A *branched* ruga is a primary ruga in which (a) the branch is connected with the main part, (b) the point of ramification is not coincident with the origin of the ruga (when there would be two joined rugae, see below), (c) the termination of the branch does not lie nearer the raphe than the point of ramification, and (d) the branch is at least three millimetres in length.

If it cannot be decided which is the main part and which is the branch, the branch is taken as the shorter. The ramification is represented in the scheme as a digit indicating the number of branches. For branches less than three millimetres see (11).

(7) Two rugae are *united* if (a) they have the same origin but immediately diverge and (b) if they derive from separate origins and subsequently meet. A variant of this type is the case of two rugae that meet and clearly continue after crossing. The obvious continuation of one ruga is then not considered as a branch of the other. This type of union is noted also in the remarks column. For cases where one of two united rugae is not a primary, see (11). Where two rugae only touch one another and then continue on their course no union is considered to have occurred. The connected rugae are represented in the diagram by a curved line between the squares of the two rugae. An arc convex upwards represents two rugae having a common origin; an arc that is concave upwards indicates that the

two rugae with the same origin are joined at some other point. (Fig. 1.)

(8) A *broken* primary is one of which the parts form a natural continuation of the course of the ruga. There must be a discontinuity in the ruga for it to be recordable as broken, a deep indentation in the profile of a ruga not being considered as a break (Fig. 1). The length of a broken ruga is measured as if it were continuous, no account being taken of the size of the fragments. The number of interruptions is recorded in the appropriate square. (The term "broken rugae" is applied only to primary rugae.)

(9) *Secondary rugae*. Defined above. They are considered as belonging to the nearest primary. Where there is doubt as to which of two primaries a secondary shall be associated the anterior of the two is taken. The number of secondaries belonging to the primary ruga in question is entered.

(10) A primary is recorded as *papillate* if punctiform tubercles are visible on the whole or a part of the ruga. In its weakest form such a ruga presents only transverse lines but these must then cross the ruga from one side to the other. For a papillate ruga an oblique stroke is entered.

(11) *Uncommon details* such as an annular ruga or one terminating as a spiral are drawn in, if necessary with explanation in the remarks column. Branches that are less than three millimetres in length and which are thus not entered under (6) are also drawn. The same applies to cases of united rugae where one of them is not a primary—because it is too short or narrow, for instance. Such a connection is denoted by an arc, concave or convex upward according to the type of union. Secondary or fragmentary ruga in such unions are marked and entered as such.

(12) *Fragmentary rugae*, as the secondaries, are considered as belonging to the nearest primary and are represented by a figure indicating their number. For definition, see above.

THE POSTERIOR LIMIT IN RELATION TO THE TEETH

The measurements are made with the casts in the symmetrograph at the same time as the direction of the rugae is determined. On each side the posterior limit is judged for the primary (O) rugae (that is, the most posterior point on such a ruga) and for the rugae in general, irrespective of whether this point lies on a primary, a secondary or a fragmentary ruga.

For the measurement, normals to the raphe are drawn from the teeth through these points (the horizontal projection is used here, as for the other designations).

To record the points of intersection of the normal with the dental arch the teeth are divided into zones; viz., the *mesial* and *distal* zones of the first premolars (4m, 4d); the *proximal zone* of the first and second premolars (4/5); the *mesial* and *distal* zones of the second premolars (5m, 5d); the *proximal zone* of the second premolars and the first molars (5/6); the *mesial* and *distal* zones of the first molars (6m, 6d).

The proximal zones extend to the "axial angle"; that is, about one millimetre on each side of the interproximal contact.

Note is made of any teeth missing in front of the posterior limit of the pattern (only one premolar present on each side, for example). Evident crowding or over-spacing is also entered. The notes are in these cases made immediately to the right of the numbers indicating the posterior limit of the zone. If the absence of several teeth prevents any reliable estimate of the posterior limit, a horizontal stroke is placed in the appropriate square.

THE NUMBER OF RUGAE

Under the heading *No. rugae L/R* the numbers of primaries on each side are given; as, for instance, 4/4, indicating four ordinary primaries on each side. If, however, there is on, say, the left side a primary (X) ruga, it is denoted by 4 + 1/4.

The number of secondaries on each side is entered on the same line in the third and fourth squares with a stroke between them. These numbers are placed in parentheses to distinguish them from the primary rugae.

The number of fragmentary rugae on each side is noted in the fifth and sixth squares (with no stroke or parentheses).

THE INCISIVE PAPILLA

Under the heading *Inc. pap. form* the incisive papilla is described as flame-shaped (F), long and narrow (L), oval (O), pear-shaped (P), round (R), spool-shaped (S), or triangular (T) (Fig. 5).

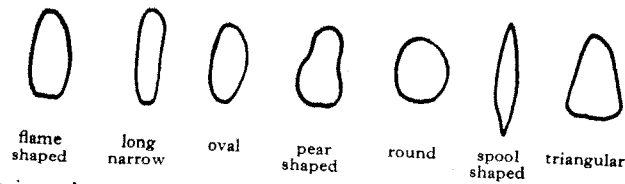


FIG. 5. Various shapes of the incisive papilla.

The figures for the greatest length and width of the papilla are inserted, the measurement being made with calipers to an accuracy of one tenth of a millimetre.

THE PALATINE RAPHE

Note is made of whether the raphe is prominent, wide, divided, multilinear, or with processes.

THE ERROR

An appraisal of the classification system required an analysis of the errors that may be incurred in its practical application.

The sources of error considered were:

- (1) impression-taking and preparation of the casts,
- (2) drawing the ruga pattern on the casts, and
- (3) estimation and measurement of a given ruga pattern.

Impression-taking and preparation of casts

On storing the impressions and during the hardening of the casts certain dimensional changes occur which vary from one material to another.

It would therefore have been an advantage had all the casts and impressions been made of the same kinds of material. However, where the collection of the series covers a long period this is generally not feasible. Table 1 shows the materials used for the various subjects.

IMPRESSION MATERIAL

Alginate. Measurements have shown that alginates on storing in air, have a linear expansion of up to 0.1 per cent after twenty minutes; this is followed by a contraction which after 80 minutes is between 0 and 0.25 per cent (Schoonover & Dickson, 1943; Skinner & Pomes, 1946, 1947; Blomquist, 1953).

Agar agar. On storing in a humidior—the method used for the casts in question—the linear contraction is, after 3 hours, 0.05–0.3 per cent (Skinner & Kern, 1938; Paffenberger, 1940; Kendrick, 1950; Skinner, Cooper & Beck, 1950).

Impression plaster. According to the English and German literature the various brands of impression plaster have different expansion figures. They are generally put at between 0.1 and 0.3 per cent on

TABLE 1 Impression and cast materials used for the various groups of the present investigation.

Group	Year of collect.	No. sub-jects	Impression material	Plaster type	Remarks
Cross-sectional study					
Foetus	1954	20	Trim paste	Coecal	
Infantile dentition (a)	1948-53	50	9 Tissuetex	23 Coecal	
			3 D.P.		
			11 Zelex	27 Plaster of Paris	
			3 Zelex		
24 Paribar					
Infantile dentition (b)	1953-54	50	Tissuetex	Coecal	
Infantile dentition (c)	1939-41	50	Dentocoll and S. S. White elastic compound	Moldano	
Adult dentition	1954	100	Tissuetex	Coecal	
Mature dentition	1951-52	50	D.P.	Coecal	
Senile dentition	1954	50	46 Tissuetex 1 D.P. 3 C.A. 37	38 Coecal 3 Moldano 9 Permastone	
Longitudinal study					
1. Younger group					
First examination	1948-50	38*	3 D.P.	11 Coecal	* subjects from the Infantile dentition group (a) in the cross-sectional study
			8 Zelex		
			3 Zelex	27 Plaster of Paris	
24 Paribar					
Sec. examination	1953-54	38	Tissuetex	Coecal	
2. Older group					
First examination	1924-41	15	7** Dentocoll & S. S. White elastic compound	7 Moldano	** subjects from the Infantile dentition group (c) in the cross-sectional study
			8 Impression Plaster	8 Plaster of Paris	
Sec. examination	1954	15	Tissuetex	Coecal	
Twin study					
Twins	1944-46	60	Dentocoll and S. S. White elastic compound	Moldano Albastone	Ages 10-40
	1952-53	40	D.P.	Coecal	Ages 7-19

mixing with water to a suitable consistency at 20° C. Intensive spatulation, warmer water and a greater proportion of powder raise the figure to 0.55 per cent (Sodeau & Gibson, 1927; Schubert, 1937, Weikart, 1950; Knischewski, 1951; Skinner, 1954).

Thermoplastic impression materials. The linear contraction on cooling to room temperature from 45° C (the maximum temperature at which Paribar may be removed from the mouth) varies between 0.7 and 1.1 per cent (Schubert).

Impression pastes. No data on the linear expansion of Trim paste has been found, but a comparison with similar pastes (Sandermann-Olsen, 1953) shows that under the conditions prevailing during the present investigation (well below room temperature) there may be a variation of -0.05 to +0.35 per cent.

DENTAL CAST MATERIALS

Dental stone. Since the accelerator-retarder system has a varying composition, the brands have different expansion ranges. Moldano dental stone has a linear expansion of between 0.1 and 0.25 per cent, while for Coecal the figure is somewhat higher—0.16 to 0.30 per cent, with moderate variations in treatment.

The values for Permastone and Albastone were not accessible. Comparison with similar materials indicates an expansion of from 0.12 to 0.35 per cent (Schubert; Weikart; Dreyer-Jørgensen, 1954).

According to various tests Plaster of Paris has a range of expansion of 0.2-0.6 per cent (Schubert; Knischewski; *et al.*).

The changes in linear measurement that may be ascribed to the material in no instance deviate appreciably from the actual values, the greatest disparity being obtained for the combination of impression plaster and plaster of Paris with a deviation of +0.3 to +1.15 per cent. (Table 2.) The systematic errors are thus small.

The random errors were studied by means of the following experiments. The materials most commonly used were Tissuetex and Coecal (Table 1). Double impressions were taken for 10 persons. On the casts so obtained measurements were made of the palatal width and height. The palatal width was taken as the distance between the first premolars and between the first molars, and was measured with vernier calipers to an accuracy of 0.1 mm. The palatal height was determined at the first molars to an accuracy of 0.5 mm using calipers

TABLE 2 Percentage linear variation of impression and cast materials.

Impression material	Cast material	Range of variation of combinations
Zelex Tissuetex D.P. (-0.25 to +0.1 %)	+ Coecal (+0.16 to +0.3 %)	= -0.09 to +0.4 %
Tissuetex D.P. C.A. 37 (-0.25 to +0.1 %)	+ Moldano (+0.1 to +0.25 %)	= -0.15 to +0.35 %
Tissuetex D.P. C.A. 37 (-0.25 to +0.1 %)	+ Permastone (+0.12 to +0.35 %)	= -0.13 to +0.45 %
Zelex S.S.W. el. compound Dentocoll (-0.25 to +0.1 %)	+ Plaster of Paris (+0.2 to +0.6 %)	= -0.05 to +0.7 %
S.S.W. el. compound Dentocoll (-0.30 to -0.05 %)	+ Moldano (+0.1 to +0.25 %)	= -0.2 to +0.2 %
S.S.W. el. compound Dentocoll (-0.30 to -0.05 %)	+ Albastone (+0.12 to +0.35 %)	= -0.18 to +0.30 %
Trim paste Paribar (-0.05 to +0.35 %)	+ Coecal (+0.16 to +0.30 %)	= +0.11 to +0.65 %
Paribar (-1.1 to -0.7 %)	+ Plaster of Paris (+0.2 to +0.6 %)	= -0.9 to -0.1 %
Impression plaster (+0.1 to +0.55 %)	+ Plaster of Paris (+0.2 to +0.6 %)	= +0.3 to +1.15 %

modified to measure in three dimensions (Korkhaus and Lundström). The reference points were: on the first premolars—the mid-point of the fissure; on the first molars—the deepest point of the central fossa. The differences thereby revealed might be due to random errors of measurement or to disparities in the impressions and casts. The standard error of the single determination calculated by the formula¹

$$\sigma_i = \sqrt{\frac{\sum d^2}{2n}}$$

for the three aforementioned measurements is small (0.12, 0.15 and 0.16 mm, or, expressed as a percentage of the measured distances, 0.4, 0.5 and 0.9 per cent) and of roughly the same order

¹ d = difference between double determinations; n = number of double determinations.

of magnitude as the pure error of measurement for the same distances obtained by double determinations on 10 casts (0.14, 0.12 and 0.16 mm). The errors incurred in taking impressions and preparing the casts may thus be considered as negligible in practice.

Drawing the pattern on the casts

It was found necessary to draw in the whole of the ruga pattern on the cast in order to be able to perform measurements and classify the various details. A hard lead pencil was used. For each of the 10 subjects 3 casts were made. One examiner drew the patterns on 2 of the 3 casts of each subject, the third being done by a second examiner.

Any error incurred in drawing may be ascribed to (a) different interpretation of the details, and (b) different dimensions of any one detail. The discrepancies in interpretation were generally in respect of whether a ruga was continuous or broken. Moreover, there was occasionally a difference in opinion on whether a feature was a branch or a secondary ruga, and whether or not there was a union between two rugae; again, a fragmentary ruga may have been too inconspicuous to be recorded. There may also have been discrepancies in the number of fragments due to differences in measurement of rugae near the minimum length of 2 mm. The results of the repeated examinations are given below.

DIFFERENCES IN INTERPRETATION

Both interpretations by the same examiner

No differences could be found.

Two examiners

In 4 subjects there was agreement. In the other 6 differences were found.

Subject	Examiner	
	I	II
G. V.	branch	secondary ruga
G. K.	-	4 breaks (3 rugae)
U. A.	- ¹	- ¹
I. L.	3 fragments	-
B. D.	-	2 breaks (2 rugae)
B. B.	-	1 break

A dash (-) denotes that one examiner did not observe the detail seen by the other. ¹ Break differently recorded.

DISCREPANCIES IN MEASUREMENT

On each of the 3 casts of the 10 subjects the same one examiner made 50 measurements of rugae with lengths between 2.7 and 16.8 mm.

The standard error of the single observation where one examiner draw the patterns on two casts was 0.35 mm while the figure where the two examiners performed the drawing was 0.59 mm.

That there were appreciable errors in drawing is clear from the fact that the error calculated in this manner on different casts is greater than that incurred in double determinations on the same casts.

A measurement error of 0.13 mm was obtained with double determinations—at intervals of some weeks—on the same 36 rugae distributed on four casts. The error of measurement of the ruga direction on different patterns was 3.00° (for 50 rugae on seven casts) while the double determinations on the same pattern gave an error of 1.61° (204 rugae on 25 casts).

Estimation and measurement of a given pattern

Double determinations were performed on a group of 25 persons taken at random—13 children and 12 adults. One examiner drew the pattern on all the casts and made two determinations at intervals of two to three weeks. A second examiner went through the material, his examination being concerned only with certain evaluations and not with actual measurements.

QUALITATIVE ESTIMATE OF THE ERROR

The various double determinations are given in tabular form.

I: 1 denotes the results of the *first* examiner for the *first* run;
I: 2 denotes the results of the *first* examiner for the *second* run;
II denotes the results of the *second* examiner for his run.

Comparisons between the examiners are made always between the values under I: 1 and II.

Primary rugae

I: 1/I: 2 The first examiner reached the same result in both runs for all 25 subjects (204 rugae).

I: 1/II Agreement: 22 subjects (180 rugae).
Disagreement: 3 subjects; distribution:

	No. subjects	No. rugae	
		I: 1	II
more than II	2	16	14
I: 1 recorded			
fewer than II	1	8	9

Secondary rugae

I: 1/I: 2 Agreement: 22 subjects (64 secondary rugae).
Disagreement: 3 subjects; distribution:

	No. subjects	No. sec. rug.	
		I: 1	I: 2
more than I: 2	2	8	6
I: 1 recorded			
fewer than I: 2	1	1	2

I: 1/II Agreement: 17 subjects (45 secondary rugae).
Disagreement: 8 subjects; distribution:

	No. subjects	No. sec. rug.	
		I: 1	II
more than II	3	11	8
I: 1 recorded			
fewer than II	3	10	15
Agreement in number but the distribution between the sides is different	2	7	7

Fragmentary rugae

I: 1/I: 2 Agreement: 21 subjects (23 fragmentary rugae).
Disagreement: 4 subjects; distribution:

	No. subjects	No. frag. rug.	
		I: 1	I: 2
more than I: 2	2	8	6
I: 1 recorded			
fewer than I: 2	1	0	1
Agreement in number but the distribution between the sides is different	1	1	1

I: 1/II Agreement: 15 subjects (13 fragmentary rugae).
Disagreement: 10 subjects; distribution:

	No. subjects	No. frag. rug.	
		I: 1	II
more than II	4	10	5
I: 1 recorded			
fewer than II	6	9	15

In the above tables relating to the number of rugae it should be borne in mind when assessing the magnitude of the error that if on one run a ruga should be recorded as primary and on the other run as secondary, an error is incurred that affects two tables. The vast majority of the discrepancies in the three tables are of this type.

In the evaluation of primary rugae no account was taken of whether they were primary (O) or primary (X).

Shape of the rugae

I: 1/I: 2 Agreement: 21 subjects (175 of 204 rugae).
Disagreement: 4 subjects; difference = 1 per subject.
I: 1/II Agreement: 5 subjects (38 of 202 rugae).
Disagreement: 20 subjects; distribution:

No. of subjects	No. of diff. per subject					total
	one	two	three	four		
No. of subjects	13	5	1	1		20
No. of differences	13	10	3	4		30

The error between the two examiners is large (30 in 202 rugae) and there is possibly a systematic difference between them. There was a tendency for the first examiner to see the rugae more angular instead of curved, and curved instead of straight, than the second examiner. This occurred for 24 of the 30 rugae where there was a difference between the examiners.

Origin of the rugae

I: 1/I: 2 Agreement: 24 subjects (196 rugae).
For one subject a difference for one ruga.
I: 1/II Agreement: 16 subjects (131 rugae).
Disagreement: 9 subjects; distribution:

No. of subjects	No. differences per subject			
	one	two	three	total
No. of subjects	5	3	1	9
No. of differences	5	6	3	14

Branched rugae

I: 1/I: 2 Agreement: 24 subjects (20 branches).
Disagreement: 1 subject, where one branch was recorded only on the second run.
I: 1/II Agreement: 24 subjects (17 branches).
Disagreement: 1 subject, where I recorded three and II two branches.

United rugae

I: 1/I: 2 and Agreement: 25 subjects (5 united rugae).
I: 1/II

Broken rugae

I: 1/I: 2 Agreement: 25 subjects, of which 3 with one broken ruga (1 break each).
I: 1/II Agreement: 21 subjects (same distribution of breaks as above).
Disagreement: 4 subjects; distribution:

	No. subjects		No. broken rug.	
	I: 1	II	I: 1	II
more than II	-	-	-	-
I: 1 recorded				
fewer than II	4	0	4	

For these 4 subjects the first examiner had recorded secondary rugae in 3 cases and a fragmentary ruga in the fourth.

Papillate rugae (one examiner)

I: 1/I: 2 Agreement: 22 subjects (43 papillate rugae).
Disagreement: 3 subjects; distribution:

	No. subjects		No. papillate rug.	
	I: 1	I: 2	I: 1	I: 2
more than I: 2	-	-	-	-
I: 1 recorded				
fewer than I: 2	3	7	10	

Uncommon details

I: 1/I: 2 Agreement: 23 subjects of which 9 had 16 uncommon details.
Disagreement: 2 subjects; distribution:

	No. subjects		No. details	
	I: 1	I: 2	I: 1	I: 2
more than I: 2	1	1	0	
I: 1 recorded				
fewer than I: 2	1	0	1	

I: 1/II Agreement: 22 subjects of which 9 had 15 uncommon details.
Disagreement: 3 subjects; distribution:

	No. subjects	No. details	
		I: 1	II
I: 1 recorded	1	2	1
more than II	1	2	1
fewer than II	2	0	2

Posterior limit (one examiner)

I: 1/I: 2 Agreement: 20 subjects with 57 registrations.
In 5 subjects one difference each.

Instances where no comparison was made because the casts were included on one run only are counted as "disagreements". Normally one subject is represented by four values (left and right side) for both primary (O) rugae and the entire ruga zone. On account of loss of teeth and similar conditions it was not always possible to obtain all the values; herein lies the reason that the above-mentioned 20 subjects represent only 57 values.

Shape of incisive papilla (Comparison of 24 subjects)

I: 1/I: 2 Agreement: 21 subjects.
Disagreement: 3 subjects; distribution:

Subject no.	6D	18C	521A
I: 1 recorded	P	F	L
I: 2 ,,	T	T	P

I: 1/II Agreement: 17 subjects.
Disagreement: 7 subjects; distribution:

Subject no.	3C	6D	506A	511A	521B	526A	526B
I: 1 recorded	T	P	T	T	T	P	S
II ,,	P	F	F	F	F	F	F

There is a systematic difference between the examiners. While the first found the F form fairly uncommon (see p. 62) the other examiner found it rather often. In 6 of the 7 differences the second examiner recorded the F shape.

TABLE 3 The random error σ_i expressed as a percentage of the mean (\bar{x}), in determination of the ruga length, the length and width of the incisive papilla, the palatal width and the direction of the rugae.

	No.	σ_i	σ_i as a per cent of \bar{x}
Ruga length	36	0.13 mm	1.0
Incisive papilla			
length	24	0.11	1.5
width	24	0.10	3.0
Palatal width			
at 1st premolars	19	0.14	0.4
at 2nd premolars	14	0.16	0.4
at 1st molars	15	0.26	0.6
Ruga direction	204	1.61°	

The random error has been calculated from the expression $\sigma_i = \sqrt{\frac{\sum d^2}{2n}}$, where σ_i is the standard error of a single determination, d the difference between two measurements of the same detail, and n the number of differences.

QUANTITATIVE MEASUREMENTS

For the determination of the error incurred in measuring the length of the rugae, the length and width of the incisive papilla, and the direction of the rugae the following procedure was followed. The length and width measurements were made with calipers to an accuracy of 0.1 mm. Measurement of the angle between the rugae and the normal to the palatine raphe was made with a protractor to an accuracy of 0.5°. The results of these determinations are shown in Table 3.

Summary

The most important sources of error in the method followed in this investigation were

- (a) impression-taking and preparation of the casts,
- (b) drawing the pattern on the casts, and
- (c) measurement and estimation of a given ruga pattern.

(a) Systematic and random errors in impression-taking and preparation of the casts appear to be small. (The standard error of the single determination was 0.12, 0.15 and 0.16 mm for one measurement of

First
measurement
millimetres

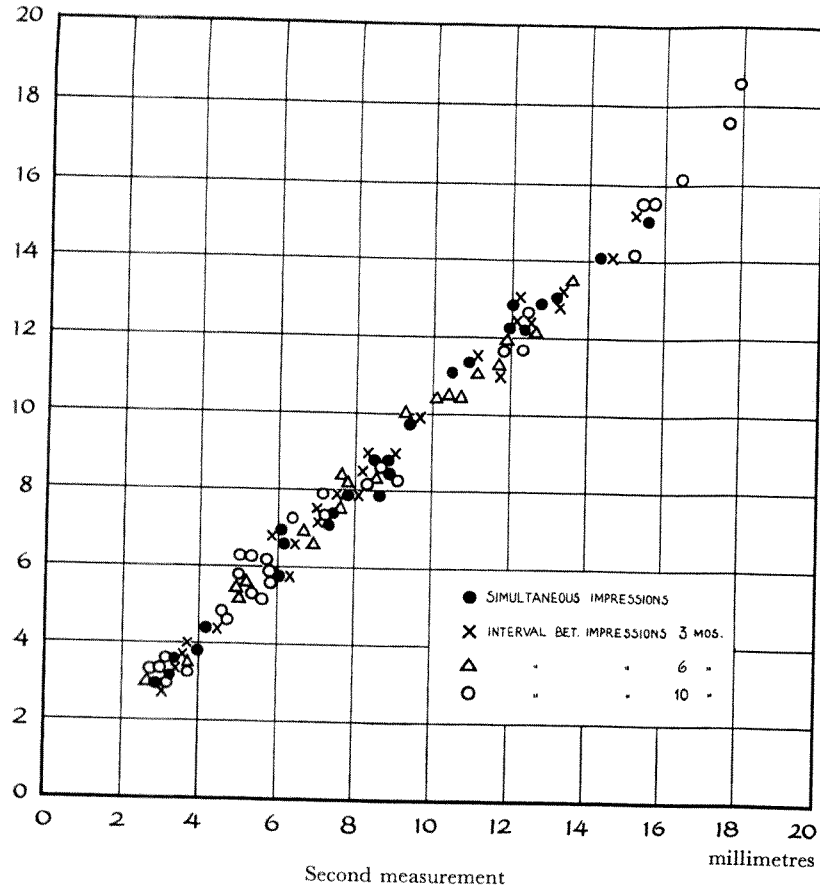


FIG. 6. Measurements of length of rugae and length and width of the incisive papilla at two examinations, made on different casts for the intervals 0, 3, 6 and 10 months. Number of subjects for the respective intervals 5, 4, 5, 6.

the height and two of the width of the upper jaw; that is, as a percentage of the means, 0.4, 0.5 and 0.9 respectively.)

In (b) error may have been incurred as a consequence of dissimilar interpretation of details and of the fact that the same detail may have been given different dimensions. Differences in interpretation were generally in respect of breaks in the continuity of the ruga. Disagreements were few, however.

In (c) both qualitative and quantitative errors may have been incurred and, as would be expected, a smaller error was observed on repeated runs by the same person, and a larger error when two persons performed the same evaluation.

Some of these disagreements (the shape of the ruga and the incisive papilla) are conceivably of a tendential nature.

The error found for the quantitative measurements was small (0.4–3.0 per cent).

Besides these technical errors conditions such as an inflamed mucosa may be taken into consideration.

An examination, repeated after 3, 6 or 10 months, showed no greater variations than those obtained from the simultaneous double determinations. (Fig. 6.)

THE VARIABILITY OF THE RUGA PATTERN IN AN ADULT GROUP

The study group consisted of 100 students and personnel at the Royal School of Dentistry, Stockholm, the sexes being equally represented. Their ages ranged from 21 to 24 years. See p. 66 for age distribution.

These ages were chosen because the study group was required to be representative in respect of the fully developed jaw, before any atrophic changes had occurred. As none of the subjects wore dentures the possibility of atrophy due to pressure need not be considered.

Results

PRIMARY RUGAE

NUMBER

There is evidence of bilateral and sex differences in the number of primary rugae (Table 4 A), the tendency being clearest for *All primary rugae* (Table 4 B). The male value appears to be higher ($t = 2.85^{**}$). There is some evidence of a larger number of rugae on the left than on the right ($t = 2.58^*$).¹

Comparison with the figures of other investigators is best made with the values for *All primary rugae*.

If the figures given by Locchi (1930) are excluded, the divergence of which is probably ascribable to differences between his method and those of other investigators, the results are found to be in fair agreement. There is no manifest racial difference in spite of the fact that such diverse groups as Europeans (Northern and Central), North Americans, Negroes, Japanese and South American mixed populations are represented (Table 5).

¹ The results are illustrated in diagrams and tables but in some instances they have been supplemented by χ^2 and t tests. The probability

P \leq 0.05 is denoted by *
 P \leq 0.01 " " **
 P \leq 0.001 " " ***

TABLE 4 23 year group. Frequency of various numbers of primary rugae in left and right palatal halves of 50 males and 50 females, with the mean (\bar{x}).

A. Primary (O) rugae

No. primary (O) rugae	Left side			Right side		
	♂	♀	♂+♀	♂	♀	♂+♀
2	1	2	3	2	5	7
3	12	15	27	19	20	39
4	29	26	55	20	20	40
5	6	7	13	6	5	11
6	2	0	2	3	0	3
\bar{x}	3.92	3.76	3.84	3.78	3.50	3.64

B. All primary rugae

No. primary rugae	Left side			Right side		
	♂	♀	♂+♀	♂	♀	♂+♀
2	1	0	1	0	3	3
3	5	9	14	10	12	22
4	17	20	37	22	24	46
5	21	19	40	10	11	21
6	5	2	7	7	0	7
7	1	0	1	1	0	1
\bar{x}	4.54	4.28	4.41	4.34	3.86	4.10

The agreement is perhaps surprising in view of the difficulty that Murakami, Locchi, Weldt, Schultz and Nilles found in defining a ruga. Schultz goes so far as to say that "the ridges are often so ramified and discontinuous that their number can be given only approximately, even with a very consistent interpretation of each pattern".

The number of rugae in the present study group varies from 2 to 7, a range that has been reported only by Schultz. The evidence of a greater number of rugae on the left than the right and in the males than the females accords with Weldt's results. Murakami found evidence of a similar difference in respect of the sexes.

TABLE 5 Number of rugae per palatal half for various racial groups.

Author	Year	No. subjects	Sex	Racial group	Age	Number of rugae			
						Left	Right	Mean	Variation
Murakami, K.	1928	50	♂	Japanese	*	4.68	4.64	4.66	3-7
"	"	50	♀	"	*	4.34	4.62	4.48	3-6
Locchi, R.	1930	32	♂+♀	white South Americans	*	3.41	3.41	3.41	3-4
"	"	47	♂+♀	Negroes	*	3.70	3.72	3.71	3-6
"	"	24	♂+♀	Mestizos	*	3.67	3.67	3.67	3-5
Weldt, J.	1935	50	♂	mixed races (Chile)	24 (18-42)	4.30	4.22	4.26	3-6
"	"	50	♀	"	19 (18-28)	4.28	3.82	4.05	3-6
Schultz, A. H.	1949	240	♂+♀	whites	juven & adults			4.28	2-7
"	"	11	♂	Negroes	adults			4.18	3-7
Nilles, K.	1950	50	♂	Central Europeans	10-50	4.34	4.16	4.25	3-6
"	"	50	♀	"	10-50	4.32	4.42	4.37	3-6
Lysell, L.	1955	50	♂	Swedes	21-24	4.54	4.34	4.44	2-7
"	"	50	♀	"	21-24	4.28	3.86	4.07	2-6

* Age not given.

Symmetry

Earlier investigators with few exceptions, Locchi among them, found that the human rugae presented bilateral asymmetry in respect of number.

In the present study symmetry is evident in 30 per cent of the subjects (Fig. 7). Weldt and Nilles give 47 and 42 per cent, respectively. A difference of more than one ruga is found in 21 per cent, compared with 8 and 10 per cent for the other studies.

SHAPE

The shape of the primary ruga is illustrated in Fig. 8.

The straight ruga is very uncommon while some two thirds of the rugae are curved.

Most descriptions of the rugae include straight, curved, wavy, and angular forms but no figures have been given on the distribution of these variants.

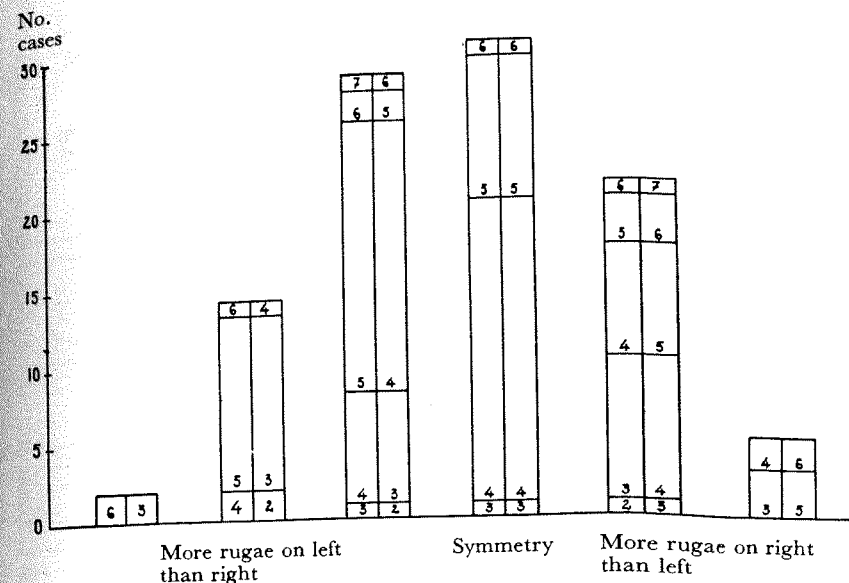


FIG. 7. The bilateral distribution of primary rugae.

ORIGIN

The first ruga originates almost invariably at the raphe. R II-IV do so with decreasing frequency, one third of these rugae originating in the medial half; rugae beginning in the lateral half are less common, although a certain increase in this respect is evident among the posterior rugae. The small number of R V-VII makes it difficult to give a general picture of the distribution of their origins.

In these calculations only the primary (O) rugae have been considered. If the primary (X) rugae are included the number with origins in the lateral half is greatly increased in virtue of the definition of the term. Their distribution is shown in Fig. 9 where the extra primaries are denoted by diagonal lines.

No clear difference between sexes or sides is observable.

No comparison with other studies is possible but the observations confirm the occasional statements that the posterior rugae often begin at a distance from the palatine raphe.

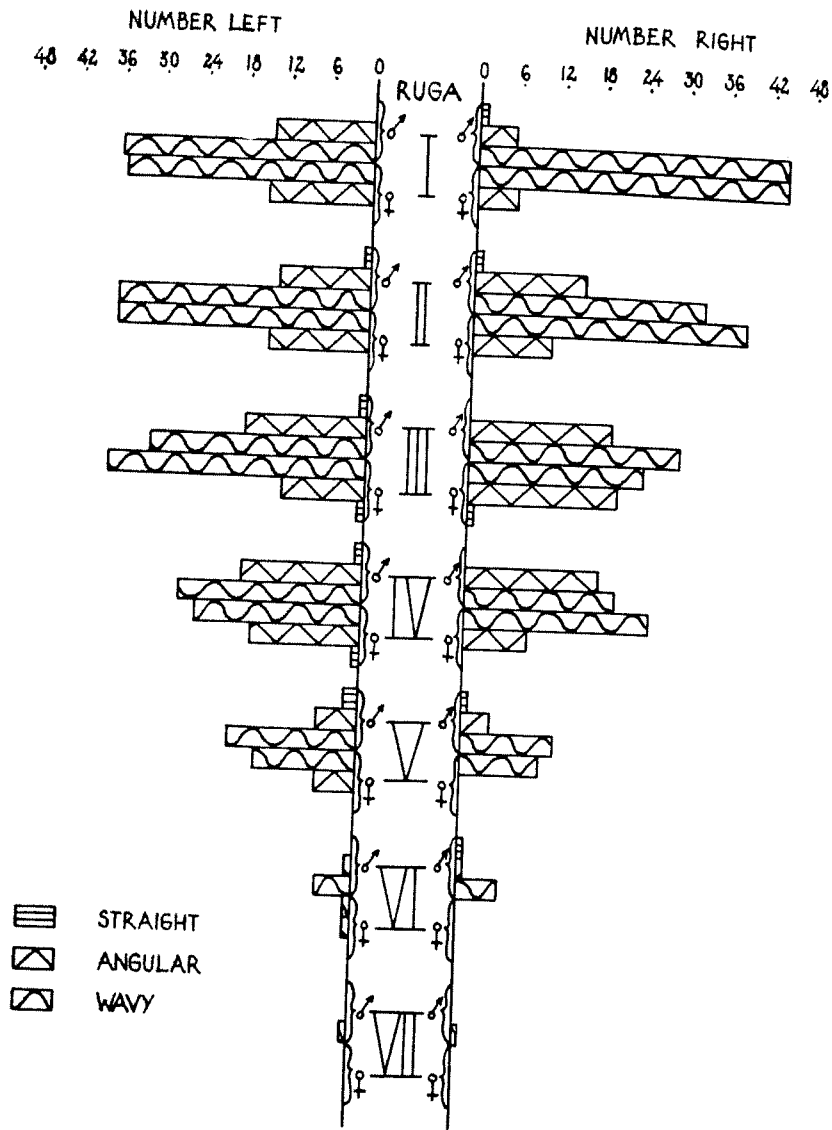
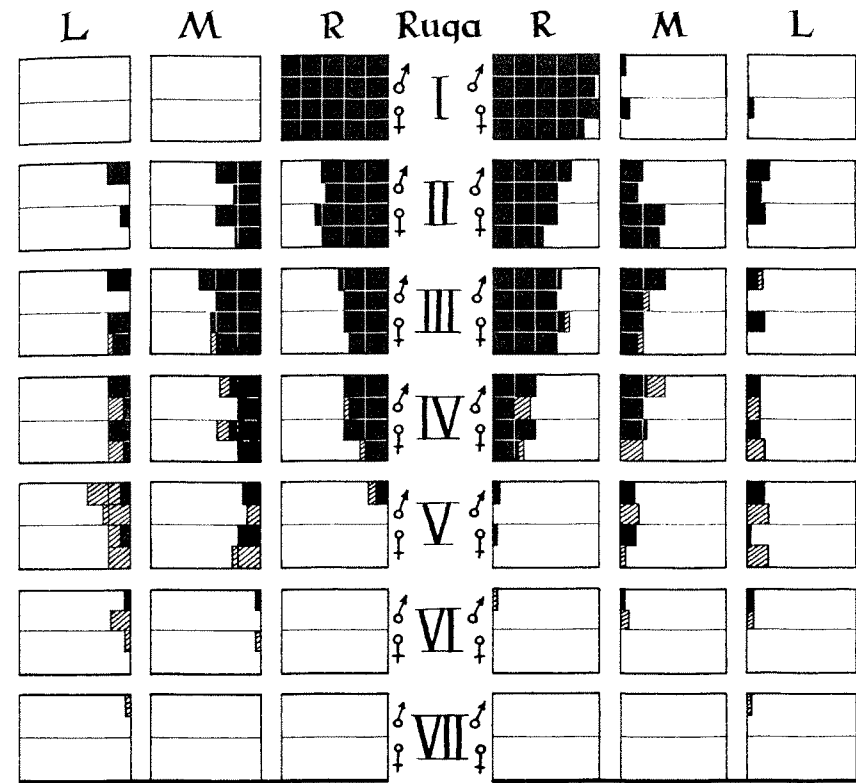


FIG. 8. The shape of the primary rugae.



R=origin in contact with the palatine raphe
 M=origin in the medial half of the ruga zone
 L=origin in the lateral half of the ruga zone

Each square represents 5 rugae
 Black squares=primary (O)
 Shaded squares=primary (X)

FIG. 9. The origin of the primary rugae.

DIRECTION

There is a manifest difference in direction between the males and females. The rugae of the former have a more forward inclination; the difference calculated on all the primaries is $6.46 \pm 1.57^\circ$ ($t = 4.11^{***}$).

Bilateral asymmetry is evident in both sexes. The rugae on the right side are more backward inclined (Table 6). This is most clearly illustrated by R II-IV, where the mean difference between the sides for the primary (O) rugae is 16 to 18°. It is also apparent that compared with the first rugae the others have a greater backward in-

TABLE 6 23 year group. The mean (\bar{x}), the standard error of the mean ($\epsilon(\bar{x})$) and the standard deviation (σ) for the direction of the rugae (50 ♂ + 50 ♀).

Ruga	Left			Right		
	$\bar{x} \pm \epsilon(\bar{x})$	σ	No. rugae	$\bar{x} \pm \epsilon(\bar{x})$	σ	No. rugae
Primary (O) rugae						
I	+ 5.65 ± 1.36	13.60	100	- 3.55 ± 1.37	13.72	100
II	- 0.15 ± 1.60	15.95	100	- 18.55 ± 1.51	15.14	100
III	- 4.90 ± 2.34	23.01	97	- 20.83 ± 1.79	17.23	93
IV	- 5.75 ± 3.17	26.50	70	- 23.82 ± 2.92	21.48	54
V	- 14.42 ± 6.75	26.11	15	- 16.89 ± 6.73	25.13	14
Primary (X) rugae						
	+ 0.95 ± 4.26	32.13	57	- 0.18 ± 4.91	33.31	46

The direction was measured as the angle (in degrees) between the ruga and the normal to the raphe, forward and backward inclinations being denoted as positive and negative, respectively.

clination, the difference being more pronounced on the right. Comparison between R I and R III reveals differences of about 20° and 10° for the right and left sides, respectively. For the posterior and less numerous rugae the same differences are not so marked and the figures are less reliable.

No such difference could be discerned for the primary (X) rugae.

It is hardly conceivable that such marked asymmetry as is found for the primary (O) rugae is ascribable to the method; the examiner sat directly behind the cast at the extension of the palatine raphe, and when placing the points observed the rugae from directly above. It is more likely that there is in fact bilateral asymmetry of direction. It may be mentioned that Lundström (1951) found similar asymmetry in respect of the upper first molars, the left of which was situated further forward than the corresponding tooth on the right, the difference being statistically significant.

Among the other investigators who have devoted attention to the direction of the rugae are Murakami and Weldt. They divided the rugae into three groups: forward inclined, perpendicular to the raphe and backward inclined. They report only those cases that are more or less symmetrical and where the majority of the rugae had

the same direction. Murakami found that in a study group of 52 Japanese the forward inclined rugae were the commonest (37 subjects) with the perpendicular next (14), while there was only a single case of backward inclined rugae. Weldt's figures for 77 subjects were 38, 37 and 2.

There are evidently rather large differences between the figures of these investigators and those for this study. It cannot be excluded that the greatest difference is related to the orientation of the cast.

BRANCHED RUGAE

The males had together 29 branched rugae, the females 31. All but 7 are the first two on each side. There is no marked difference between right and left (26/34) or between the sexes (Table 7). Such a tendency to ramification as mentioned under *Uncommon details* is found 6 times among the males and 9 among the females; the first and second pairs of rugae are concerned in 4 and 7 cases, respectively.

UNITED RUGAE

There are two types of union between rugae: (a) where the rugae have different origins and (b) where they diverge from a common origin. Neither of these is particularly common; where it is found it is generally among the three first pairs (34 of 36 unions).

Connected rugae with separate origins occur 10 times in males and 12 in females. The feature may also occur between primaries and secondaries and between primary and fragmentary rugae (4 times each in males and females).

TABLE 7 23 year group. Frequency of branched, broken and united R I-VII listed according to palatal half and sex (50 ♂ + 50 ♀).

Ruga	Branched				Broken				Ruga	United							
	♂		♀		♂		♀			Separate origins		Common origin					
	L	R	L	R	L	R	L	R		♂	♀	♂	♀				
I	7	10	6	9	0	0	0	0	I/II	3	4	7	2	1	2	0	4
II	4	5	7	5	0	0	0	0	II/III	1	1	2	0	1	0	1	0
III	1	1	0	2	0	1	1	0	III/IV	0	0	0	1	0	0	0	0
IV	0	1	1	1	1	2	1	2	IV/V	1	0	0	0	0	0	0	0
V-VII	0	0	0	0	0	1	0	0	I/III	0	0	0	0	0	3	0	2

The second type of union is recorded 7 times in males and as many times in females. In no case does it occur between primary and secondary rugae or between primary and fragmentary. Unlike the former type, which occurs only between numerically close rugae, 3 subjects display a common origin for the first and third rugae (Table 7).

BROKEN RUGAE

Broken rugae occur infrequently (Table 7), and where they are found it is always R III-V that are involved. It is evident 5 times in males, the numbers of breaks being 1, 1, 1, 3 and 4, and 4 times in females—with 1, 2, 2, and 3 breaks.

Branched, broken and united rugae do not appear to occur more frequently in some persons than others. Among the males two branched rugae occurred only three times, and two united and two broken rugae only once each. Among the females three and two bifurcated rugae each occurred twice. Two united rugae were found in two subjects. No case of more than one broken ruga was found.

Comparison with other studies of branched, united and broken rugae is difficult to make.

Murakami, Weldt and Nilles report higher percentages for branched rugae (Table 8). A contributory reason for the differences is that branches less than three millimetres in length were recorded as *Uncommon details*. They are 15 in number, 11 of them on the first two rugae.

A possible explanation is that the other authors counted as branched those rugae that in this study were recorded as secondary

TABLE 8 Percentage frequency of 0, 1 and 2 branched rugae per palatal half listed according to various authors. (Each study group comprised 200 palatal halves.

Author	Number of branched rugae		
	0	1	2
Murakami	46	45	9
Weldt	38,5	49	12,5
Nilles	47	45	8
Lysell	72	26	2

TABLE 9 Frequency of branched rugae involving R I-V reported by various authors (200 palatal halves each).

Author	R I	R II	R III	R IV	R V
Murakami	71	25	23	5	2
Weldt	42	43	45	17	1
Nilles	42	31	39	9	1
Lysell	32	21	4	3	0

or fragmentary. If this supposition is correct, the concentration of the ramifications to the first two rugae—more marked in the present study group—may be ascribed to the fact that secondary and fragmentary rugae are fewer around the first than the other pairs. If a certain percentage of these in the author's material were transferred to the branch group the values would possibly accord better (Table 9).

The term *united rugae* does not seem to have been used, so that it is conceivable that this feature is generally recorded under the heading *Branched*. As, however, no definition of this term can be found it is impossible to decide if this is the case.

The three above-mentioned authors found an average of 2-3 broken rugae per subject while in the author's group they were rare exceptions. These large discrepancies are probably a result of different bases of recording. It is conceivable that what the other investigators call broken rugae have been termed secondary and fragmentary rugae by the author.

PAPILLATE RUGAE

A little more than one third of the rugae are papillate, possibly somewhat more for males than females. This feature is most commonly found in the third and fourth rugae (Fig. 21, p. 80).

Comparison with other study groups is a hazardous procedure as it is difficult to know what the other authors considered to be a papillate ruga.

Ohshima gives the figures 43 and 45 per cent for the left and right sides, respectively.

UNCOMMON DETAILS

In addition to the remarks under the headings *Branched* and *United rugae* ring formations were observed twice in the male group,

TABLE 10 23 year group. Frequency of various numbers of secondary rugae in left and right palatal halves of 50 males and 50 females, with the mean (\bar{x}).

No. secondary rugae	Left			Right		
	♂	♀	♂+♀	♂	♀	♂+♀
0	8	9	17	11	9	20
1	18	16	34	15	18	33
2	12	14	26	10	11	21
3	10	6	16	11	8	19
4	1	4	5	2	4	6
5	1	1	2	1	0	1
\bar{x}	1.62	1.66	1.64	1.62	1.60	1.61

Number of secondary rugae associated with primary rugae I-VII.

Primary ruga	Left			Right		
	♂	♀	♂+♀	♂	♀	♂+♀
I	10	15	25	13	18	31
II	20	22	42	19	18	37
III	20	16	36	24	22	46
IV	19	20	39	19	19	38
V	9	10	19	3	3	6
VI	3	0	3	3	—*	3
VII	0	—*	0	0	—*	0

* No primary rugae of this type present.

and in one case there was a semi-circular termination to a ruga. The females presented 5 ring formations (or round swellings).

In all instances these details occurred on R I.

SECONDARY RUGAE

NUMBER

The number of secondary rugae is a little less than 2 per side. They occur in roughly 4 out of 5 palatal halves. No decided difference between the sexes or the two sides can be detected (Table 10).

Although the presence of small rugae has been pointed out by Sappey (1857-64) nowhere in the accessible literature has there been found any report giving attention to such rugae, so that no comparison is possible.

TABLE 11 23 year group. Frequency of various numbers of fragmentary rugae of 50 males and 50 females, with the mean (\bar{x}).

No. fragmentary rugae	Left			Right		
	♂	♀	♂+♀	♂	♀	♂+♀
0	25	21	46	24	18	42
1	15	20	35	14	24	38
2	6	6	12	9	7	16
3	3	2	5	3	0	3
4	1	1	2	0	1	1
\bar{x}	0.80	0.84	0.82	0.82	0.84	0.83

Number of fragmentary rugae associated with primary rugae I-VIII.

Primary ruga	Left			Right		
	♂	♀	♂+♀	♂	♀	♂+♀
I	5	3	8	8	5	13
II	7	11	18	9	11	20
III	16	14	30	12	16	28
IV	5	8	13	7	8	15
V	6	6	12	3	2	5
VI	1	0	1	0	—*	0
VII	0	—*	0	2	—*	2

* No primary rugae of this type present.

The only fairly accurate details on secondary rugae seem to be given by Aufiero & Cesati and Carrea; the former use the term *pieghe secondarie* (as distinct from *pieghe principali*), the expression denoting rugae of unusual shape. The term *Nebenruga* (= secondary ruga) is used by Carrea (1955). No figures are given in either case.

DISTRIBUTION AMONG PRIMARY RUGAE

Secondary rugae occur in association with all primaries, but the greatest proportions are found around R IV (see Table 10).

FRAGMENTARY RUGAE

NUMBER

The number of fragmentary rugae per side is a little less than one, on an average (see Table 11); they occur in one half of the palatal

TABLE 12 23 year group. Frequency of the various posterior limits of the ruga zone, listed according to palatal half and sex.

Tooth zone	Primary (O) ruga zone						Ruga zone (whole)						
	Left			Right			Left			Right			
	♂	♀	♂+♀	♂	♀	♂+♀	♂	♀	♂+♀	♂	♀	♂+♀	
4 mesial													
4 distal		2	2		2	2							
4/5 proximal . .		3	3		2	1							
5 mesial	13	11	24	15	11	26			1	1	1	3	4
5 distal	15	12	27	7	7	14	3	5	8	5	7	12	
5/6 proximal . .	10	8	18	9	9	18	5	12	17	10	7	17	
6 mesial	3	4	7	9	9	18	29	21	50	24	22	46	
6 distal	1		1				5		5	2		2	

halves. There is no observable difference between the sexes or sides. The only mention of fragmentary rugae appears to be made by Sappey (1857-64), Silva (1938) and Aufiero & Cesati (1940). In the last two systems the type is referred to as *linha simples ponto* and *pieghe secundarie puntiformi*.

DISTRIBUTION AMONG PRIMARY RUGAE

Fragmentary rugae occur in the proximity of all primary rugae although most commonly around the third (Table 11).

POSTERIOR LIMIT OF THE RUGA ZONE

IN RELATION TO THE TEETH

The primary (O) rugae reach on an average to the distal part of the second premolar, while the whole ruga zone extends almost to the mesial part of the first molar; there is no evident difference between sexes or sides (Table 12).

A direct comparison with the values of Murakami, Weldt and Nilles cannot be made as it is not known how they oriented their casts. If no mechanical aid was used the values can hardly be very reliable.

The general opinion is that the rugae never extend further back than the first molar.

TABLE 13 Bilateral comparison of posterior limit of ruga zone. The position of the right limit is given in relation to the left (difference in mm).

	R anterior to L							Level	R posterior to L								
	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8
Primary (O), No. subjects . . .	1			1		7	1	4	8	4	6	3	3	2	1	2	
All rugae No. subjects . . .				1		2	4	4	20	3	5	1		1			

BILATERAL SYMMETRY

In connection with the question of the extent of the ruga zone a study was made of the bilateral symmetry of the posterior limit (Table 13).

The subjects included were those concerned in the study of the extent of the ruga zone in relation to the dental arch; that is, persons with dentitions complete as far as the posterior limit, with no evident crowding or over-spacing. (As persons with these anomalies and extractions were excluded no account need be taken of their local influence on the positional relationship between the rugae and the teeth.)

The measurement was performed by drawing the normals from the points indicating the extent of the zone to the line representing the palatine raphe. The distance (in millimetres) between the points of intersection of the normals and the raphe gives a measure of the asymmetry (Fig. 1).

Neglecting differences of less than 2 mm and thus considering such instances as symmetrical, it is found that in the great majority of cases the posterior limit of the ruga zone is bilaterally symmetrical. On the other hand, for the primary (O) rugae, only, symmetry in this respect is not so common.

THE INCISIVE PAPILLA

SHAPE

In most cases the incisive papilla is pear-shaped. The somewhat similar triangular form is relatively common, as is the long, narrow type (Table 14).

Comparison with the reported data is very hazardous. The subject

TABLE 14 23 year group. Frequency of various shapes of the incisive papilla in the sexes (50 ♂ + 50 ♀).

Shape	♂	♀	♂ + ♀
Flame-shaped	1	1	2
Long, narrow	6	10	16
Oval	2	8	10
Pear-shaped	30	26	56
Round	0	0	0
Spool-shaped	0	1	1
Triangular	11	4	15

tive element is often great—as is borne out by the random error in determination of the form of the papilla—and it is not known how the various authors define the term.

MURAKAMI, WELDT and NILLES found that spool-shaped, oval and pear-shaped are the commonest types in their study groups with rather similar numbers of each in Weldt's and Nilles' materials; Murakami found that the spool-shaped papilla dominated. The long, narrow type in the present study is presumably similar to the needle-shaped type of the other authors, who however find it rather uncommon.

LENGTH AND WIDTH

The results show no difference between males and females in respect of length, although the incisive papilla may be wider in the man than in the woman ($t = 2.47^*$); this is also evident in the greater W/L index of the former—53.4 against 48.6 (Table 15).

TABLE 15 23 year group. The mean (\bar{x}), the standard error of the mean ($\epsilon(\bar{x})$) and the standard deviation (σ) for the length and width of the incisive papilla and W/L index (50 ♂ + 50 ♀).

	$\bar{x} \pm \epsilon(\bar{x})$		σ
	♂	♀	
Length	♂	7.41 ± 0.19	1.34
	♀	7.43 ± 0.20	1.40
Width	♂	3.93 ± 0.13	0.89
	♀	3.51 ± 0.11	0.75
W/L index	♂	53.4 ± 1.3	9.4
	♀	48.6 ± 1.5	10.9

Nilles found that both length and width were less in the males, while Weldt reached the opposite conclusion. (Murakami made no division into sex.)

The W/L index was given by Nilles as 49.3 for males and 48.7 for females, while the corresponding figures for Weldt were 56.9 and 56.1. Murakami reports 67.7 with no sex division.

Summary

1. There are about four primary rugae per palatal half, generally somewhat more in males than females and on the left than the right.
2. There is generally no bilateral symmetry in number, the difference between the sides being frequently one ruga.
3. There are generally one or two secondary rugae on each side, with no evident bilateral or sex difference. In most subjects the secondaries occur in the proximity of the fourth primary.
4. Fragmentary rugae have an average of a little less than one per side. They occur in most palates around the third primary. There is no sex or bilateral difference.
5. About two thirds of the rugae are curved; the rest, with the exception of a few straight ones, are angular.
6. The origin of the first ruga is invariably in contact with the raphe, this being progressively less frequent for the second, third and so on. No sex or bilateral difference is evident.
7. Both sexes evidence a marked bilateral difference in the inclination. The right rugae are more backward inclined than the left, this feature being more pronounced for the rugae behind the first; there is no sex difference. In general, the backward inclination is more marked in female palates than male.
8. Branched rugae are rare (60 of 851) and generally occur as the first or second (all but 7). No sex or bilateral difference.
9. United primaries with separate and common origins are seldom found (36 of 851); it is almost invariably the three first pairs that are united. No sex difference.
10. Broken rugae are extremely rare (9 of 851) and are found only in the third, fourth and fifth.
11. Roughly one third of the rugae are papillate, generally the third and fourth; somewhat more common among males.

12. The posterior limit of the ruga zone (ordinary rugae) is on an average at the distal part of the second premolar. The limit for the zone of all rugae is a little short of the mesial part of the first molar. No sex or bilateral difference.

13. The posterior limit of the ruga zone in most cases presents bilateral symmetry but not the limit for the ordinary rugae.

14. The incisive papilla is generally pear-shaped.

15. Its length is the same in both sexes but the width is possibly greater among the males, giving a higher width-length index.

THE POST-NATAL ONTOGENIC DEVELOPMENT

To what extent do the rugae change during the period of development and growth of the jaws and thereafter?

Opinions differ in this question. Carrea (1937, 1940, 1955) and Silva (1938) maintain that the ruga pattern is absolutely constant and unchanging throughout life, while Gegenbaur (1878), Retzius (1906) and Gorla (1911) are among those who consider that atrophic changes, at least, occur.

The study reported here is concerned with the changes taking place during various post-natal periods.

The problem was studied in a population of various ages (Cross-sectional study) and on individual subjects over a long period (Longitudinal study).

Cross-sectional study

Study group

Group 1 consisted of impressions taken of practically all the children 4-5 years of age who visited the Dental School over certain periods until 50 good samples had been collected.

Group 2. Children registered at the Royal School of Dentistry who, during a certain period, attained the age of 10 years were summoned for impression-taking. There was an 85 per cent response and good impressions were obtained from all.

Group 3. Impressions were taken on all pupils (with the exception of the extremely young and old) in ten classes from three Elementary Schools situated near the Dental School. Fifty satisfactory impressions were taken at random for the material.

Group 4. The same group of students and personnel of the Royal School of Dentistry as used in the study of the variability of the rugae (p. 48).

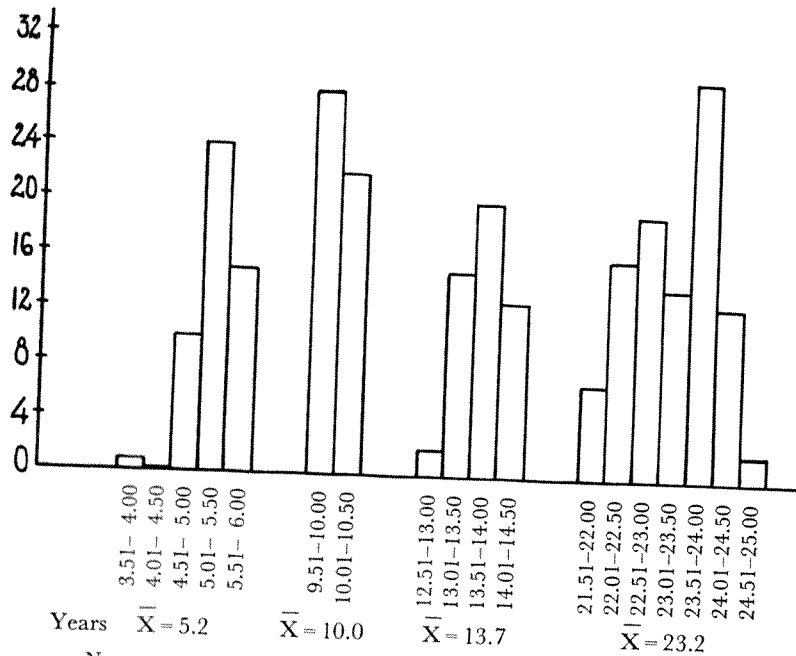
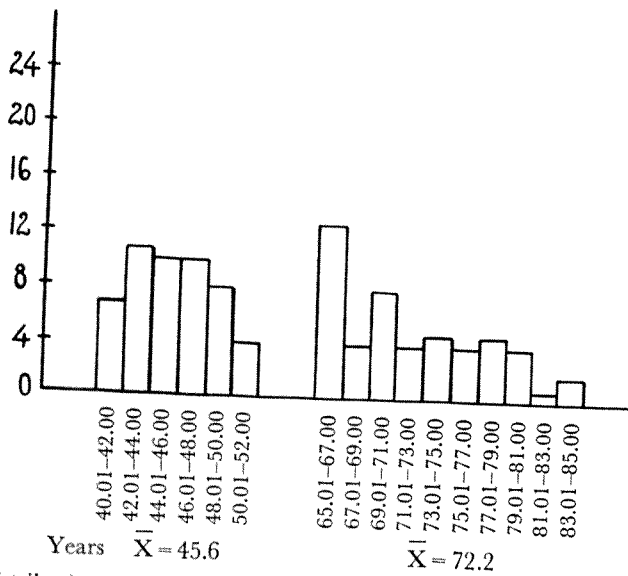
No.
casesNo.
cases

FIG. 10. Distribution of subjects according to age groups.

Group 5 consisted of adults aged 40-50 years who were the parents of the children of a given group. They had never worn upper dentures. The response to the summons was 90 per cent.

Group 6 were patients above 65 years of age who had attended the Dental School or private dentists. None had ever worn upper dentures.

No. subjects

	♂	♀
0) fully developed foetuses (p. 85)	8	12
1) infantile dentition a (deciduous)	25	25
2) » » b (mixed)	25	25
3) » » c (permanent)	25	25
4) adult dentition	50	50
5) mature dentition	25	25
6) senile dentition	25	25

The ages within the groups are given in Fig. 10.

In virtue of the great increase in the population of Stockholm over recent decades through immigration from the provinces, the study group of this investigation may be considered to be representative of the Swedish population from the aspect of hereditary biology.

On the other hand, such a factor as the dental status that is easily influenced by the environment is probably better in the material than in the population as a whole. This may be of significance to the direction of the rugae and the shape of the incisive papilla and has therefore been dealt with separately.

Results

1. NUMBER AND DISTRIBUTION OF RUGAE

Primary rugae

The number of rugae for males and females combined is somewhat more than 4 per palatal half (Fig. 11), with no great difference between the age groups except for the oldest which has a lower average than the others (difference between 23 and 72 year groups = 0.73 ± 0.11 ; $t = 6.64^{***}$). No definite sex difference was established except for the 23 year group. The distribution curves show the frequency of R I-VII (Fig. 12). The curves are similar for all age groups except the oldest, where the frequency is clearly lower for R III-V.

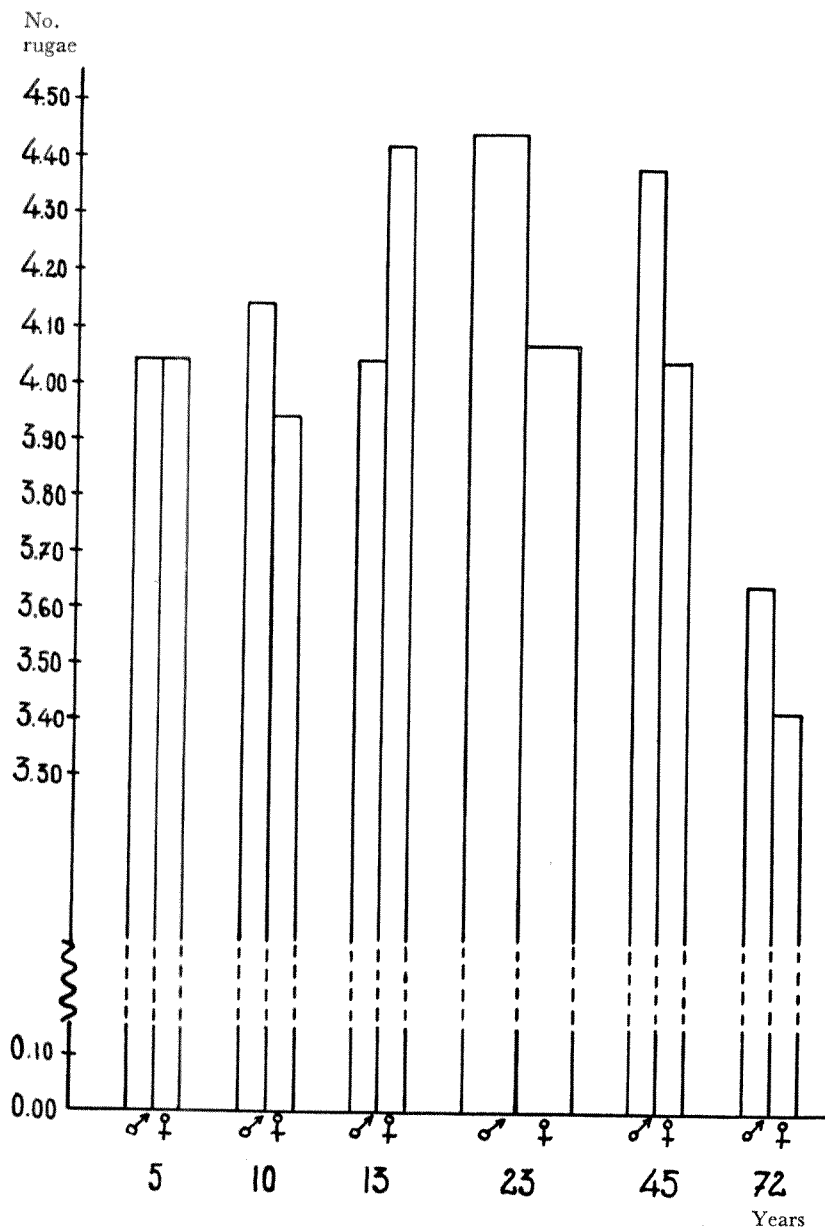


FIG. 11. Mean number of primary rugae per side in the various age groups.

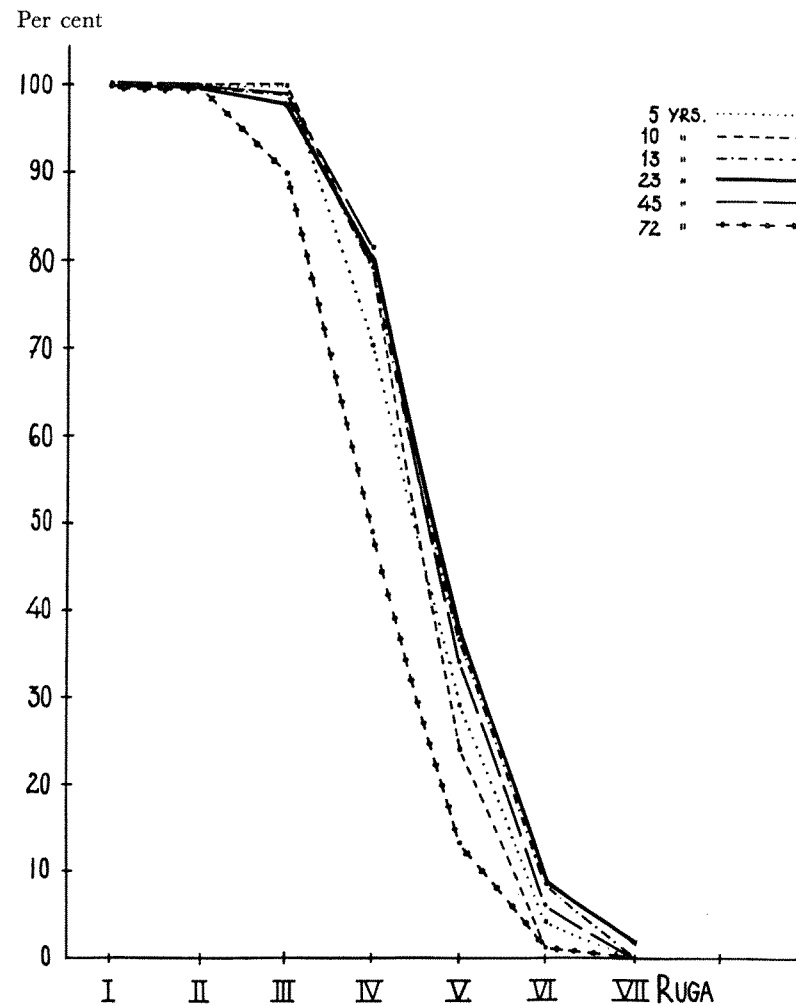


FIG. 12. Percentage distribution of R I-VII in the various age groups.

Secondary rugae

Table 16 shows the number of secondary rugae in the age groups. The four younger groups have a little more than one and one half rugae per side, while for the two older groups the figures are lower ($\chi^2 = 23.2^{**}$, D.F. = 8).

In the three youngest groups it is the R III that most frequently has adjacent secondary rugae while in the other groups it is the R IV (see Fig. 13).

TABLE 16 Mean number of secondary rugae per palatal half in the various age groups.

Age group (yrs.)	Left			Right			Both sides		
	♂	♀	♂+♀	♂	♀	♂+♀	♂	♀	♂+♀
5	1.16	1.12	1.14	1.20	1.24	1.22	1.18	1.18	1.18
10	1.12	0.52	0.82	1.12	0.92	1.02	1.12	0.72	0.92
13	0.64	0.60	0.62	0.88	0.76	0.82	0.76	0.68	0.72
23	0.80	0.84	0.82	0.82	0.84	0.83	0.81	0.84	0.83
45	0.24	0.36	0.30	0.36	0.40	0.38	0.30	0.38	0.34
72	0.08	0.44	0.26	0.40	0.44	0.42	0.24	0.44	0.34

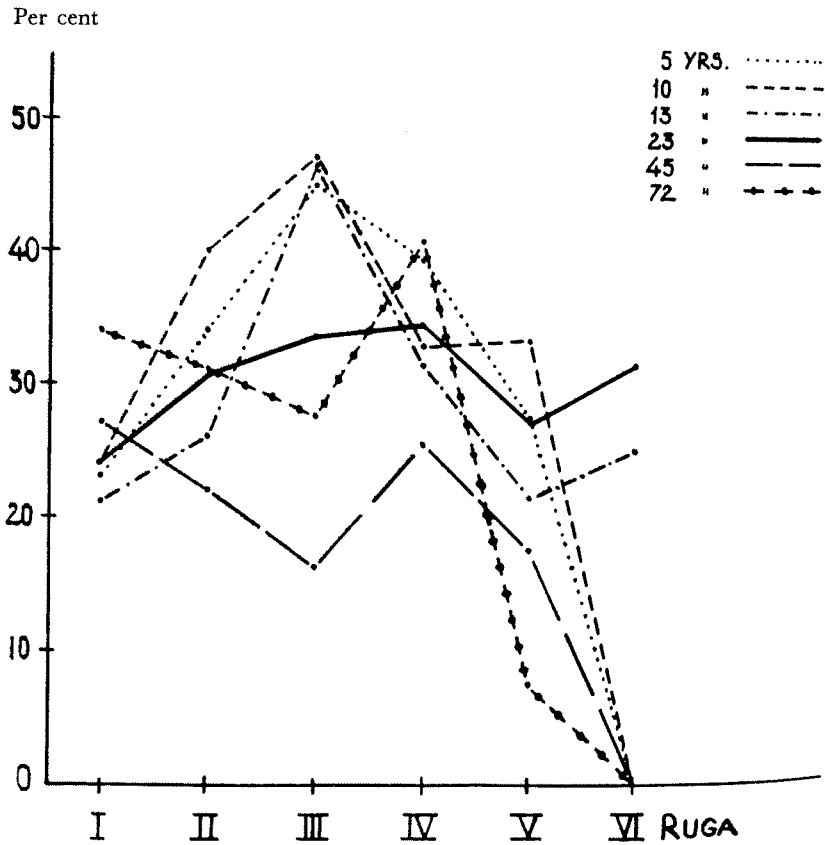


FIG. 13. Percentage of R I-VI having one or more secondary rugae.

TABLE 17 Mean number of fragmentary rugae per palatal half in the various age groups.

Age group (yrs.)	Left			Right			Both sides		
	♂	♀	♂+♀	♂	♀	♂+♀	♂	♀	♂+♀
5	1.80	1.28	1.54	1.84	1.56	1.70	1.82	1.42	1.62
10	2.16	1.68	1.92	1.80	1.76	1.78	1.98	1.72	1.85
13	1.96	1.44	1.70	1.56	1.44	1.50	1.76	1.44	1.60
23	1.62	1.66	1.64	1.62	1.60	1.61	1.62	1.63	1.63
45	1.08	1.08	1.08	1.08	1.36	1.22	1.08	1.22	1.15
72	1.12	1.44	1.28	1.56	1.28	1.42	1.34	1.36	1.35

Fragmentary rugae

The number of fragmentary rugae is on an average one per side in the younger groups. The figure generally falls with age ($\chi^2 = 62.0^{***}$, D.F. = 6) and in the two oldest groups it is roughly one third per side (Table 17). It is R III-V which most frequently have adjacent fragmentary rugae. No disparity in the different age groups can be detected ($\chi^2 = 4.2$, D.F. = 11) (Fig. 14).

The total ruga frequency (primary + secondary + fragmentary)

The curves and tables show a largely even distribution of the average number of rugae among the younger groups. There is a tendency towards an increase with age but it is indefinite and small.

A lower figure at higher ages can be established for the primary rugae, however, only in the highest group, while in respect of the secondary and fragmentary rugae an appreciable difference is evident in the two oldest groups.

2. SHAPE OF PRIMARY RUGAE

A common feature of all the age groups is that curved rugae are by far the most common, while the straight type occurs extremely seldom. In all groups except the oldest one quarter or one third of the rugae are angular while for the oldest group it is nearer one eighth (Fig. 15).

It would seem as if the rugae in this group were not well-defined.

Per cent

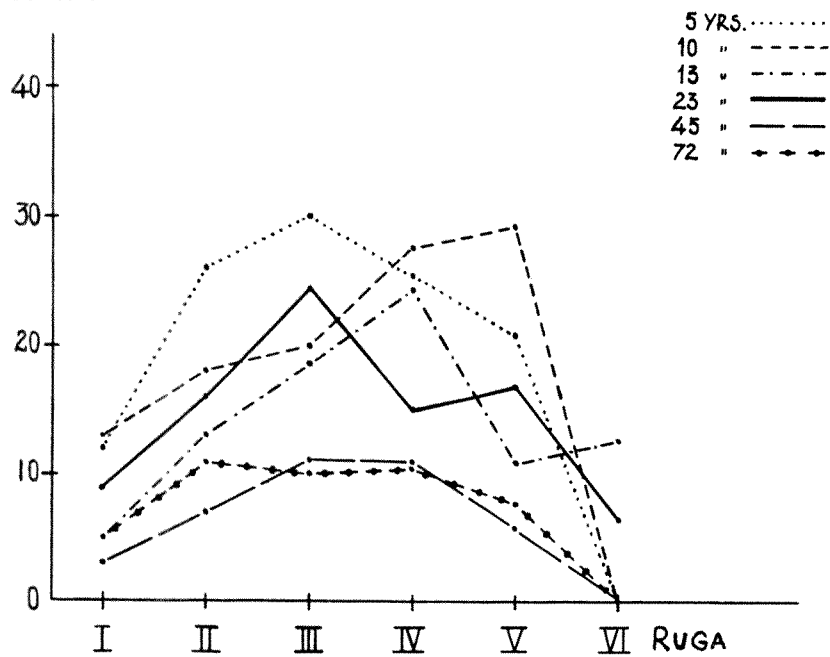


FIG. 14. Percentage of R I-VI having one or more fragmentary rugae.

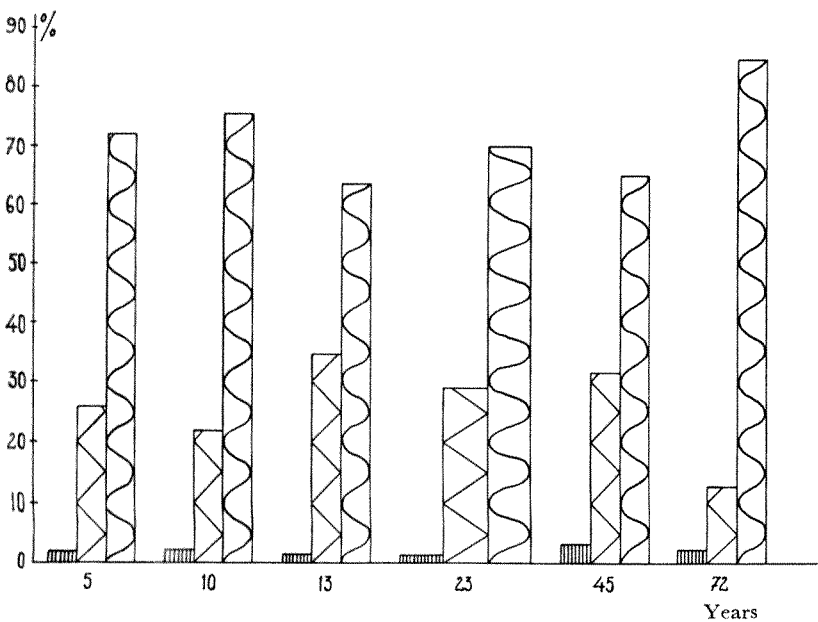


FIG. 15. Percentage distribution of straight, angular and curved rugae in the various age groups

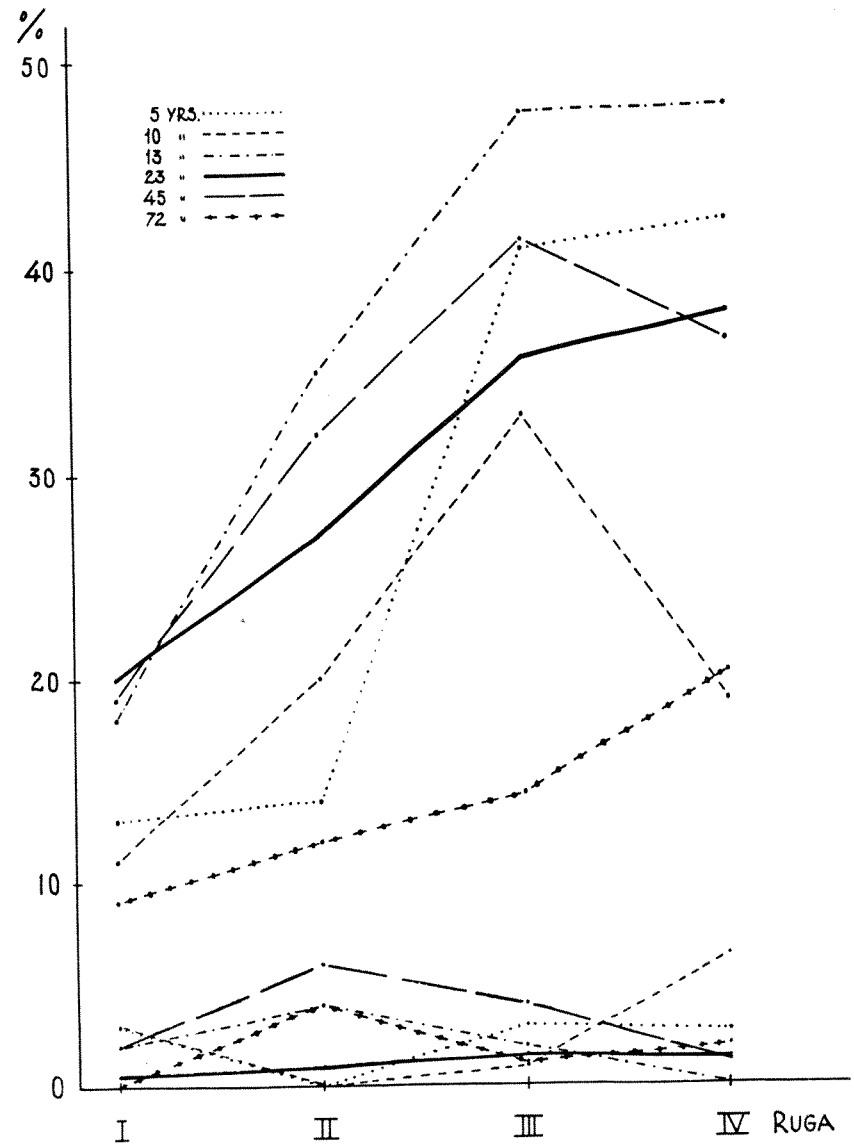


FIG. 16. Percentage distribution of angular and straight R I-IV in the various age groups. Upper curves—angular rugae; lower curves—straight rugae.

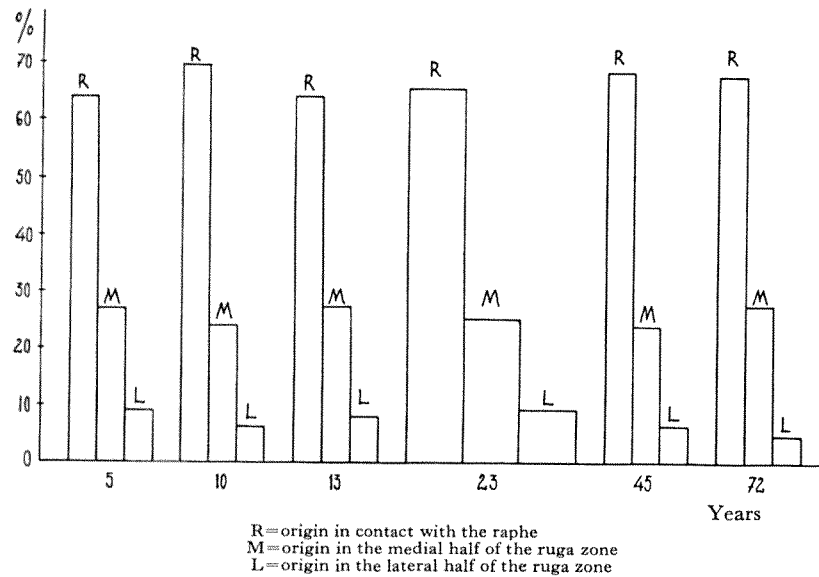


FIG. 17. Percentage distribution of the origin of the rugae in the various age groups.

An angular outline is rather uncommon for the first ruga, but increases in frequency in a backward direction in all age groups (though less marked in the oldest), at the same time as the curved ruga becomes less common (see Fig. 16).

3. ORIGIN OF PRIMARY RUGAE

The position of the origin for the various age groups is shown in Fig. 17. No age variations are apparent ($\chi^2 = 6.1$, D.F. = 4), neither does the distribution of the origins of the individual rugae seem to vary with age. This is apparent from the Fig. 18 for the four first primary (O) rugae in the various groups.

4. DIRECTION OF PRIMARY RUGAE

As pointed out in the previous chapter in all age groups the right rugae are more backward inclined than the left, the angle increasing from the first to at least the third ruga, this increase being more pronounced for the right than the left side. The backward slope

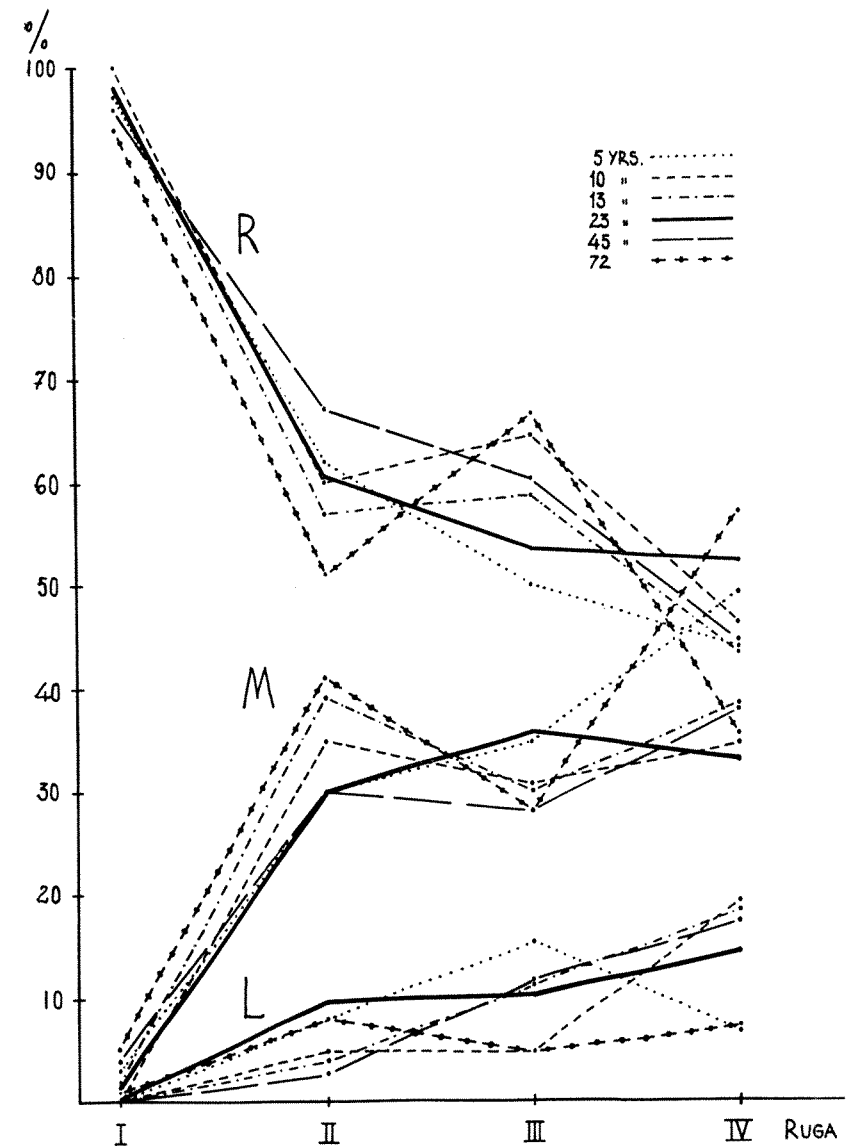


FIG. 18. Percentage distribution of the origin of R I-IV excluding the primary (X) for the various age groups. (For keys see Fig. 17.)

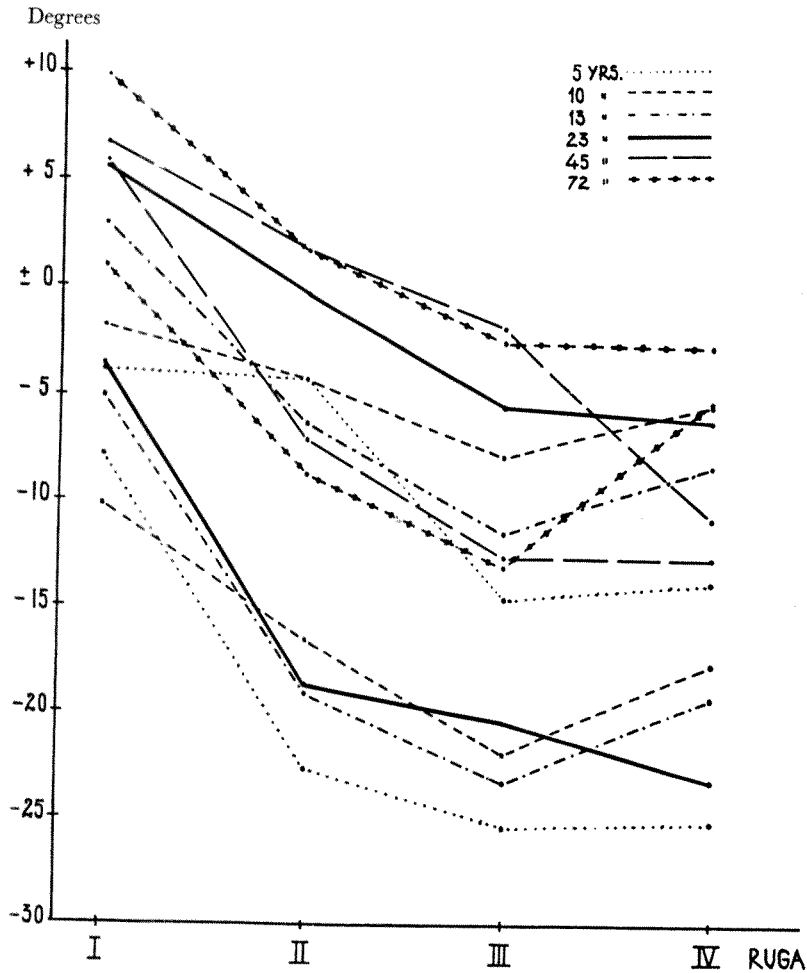


FIG. 19. Mean direction, measured in degrees, of R I-IV on the left and right sides in the various age groups. Forward-inclined rugae are denoted as positive and backward as negative. The upper line in each age group is for the left side.

falls off with age (Fig. 19), especially for the right side in the two oldest groups, with the result that the difference between the sides becomes less pronounced. For instance, the differences between the 23 and 45 year group for R III and R IV on the right are $7.61 \pm 3.49^\circ$ ($t = 2.18^*$) and $10.34 \pm 4.38^\circ$ ($t = 2.36^*$).

TABLE 18 Frequency of branched rugae R I-VII in the various age groups (100 palatal halves).

Ruga	Age group (yrs.)											
	5		10		13		23		45		72	
	L	R	L	R	L	R	L	R	L	R	L	R
I . . .	8	13	8	9	9	10	6.5	9.5	9	8	3	6
II . . .	3	7	9	9	7	7	5.5	5	4	5	4	5
III . . .	1	1	2	2	2	1	0.5	1.5	3	1	1	1
IV . . .	1	0	0	2	2	0	0.5	1	1	1	0	0
V-VII . .	0	0	0	0	0	1	0	0	0	0	0	0
Total	13	21	19	22	20	19	13	17	17	15	8	12

5. BRANCHED RUGAE

There is no appreciable difference between the various age groups, but a somewhat lower number is evident in the three oldest groups and especially the oldest. Branched rugae are consistently rather uncommon and occur mainly as R I and R II (Table 18). Minor branches included in *Uncommon details* occur rarely; they are fewest in the oldest group (Table 19).

6. UNITED RUGAE

Both types of union are rare in all age groups, and occur mainly between R I and R II. The age distribution is uneven. (Table 20.) The same is true of connections between primary rugae and both secondary and fragmentary rugae (Table 21).

TABLE 19 Frequency of minor branches on R I-VII in the various age groups (100 palatal halves).

Ruga	Age group (yrs.)					
	5	10	13	23	45	72
I	6	5	5	3.5	9	2
II	0	1	3	2	3	0
III	1	3	1	1.5	4	0
IV	1	1	0	0.5	1	0
Total	8	10	9	7.5	17	2

TABLE 20 Frequency of united rugae R I-VII in the various age groups (100 palatal halves).

Ruga	Separate origins					
	Age group (yrs.)					
	5	10	13	23	45	72
I/II	3	17	2	8	8	3
II/III	0	2	2	2	2	1
III/IV	0	3	0	0.5	1	0
IV/V	0	0	0	0.5	0	0
II/IV	0	0	0	0	1	0

Ruga	Common origin					
	Age group (yrs.)					
	5	10	13	23	45	72
I/II	5	2	11	3.5	8	1
II/III	0	0	1	1	0	0
III/IV	1	0	0	0	0	0
I/III	0	0	0	2.5	0	0

TABLE 21 Frequency of unions between R I-VI and secondary or fragmentary rugae in the various age groups (100 palatal halves).

Ruga	Separate origins					
	Age group (yrs.)					
	5	10	13	23	45	72
I	6	3	4	2	3	3
II	2	0	1	1	2	0
III	1	4	2	0.5	0	1
IV	0	0	1	0	1	0
V	0	0	0	0.5	0	0
VI	0	0	1	0	0	0

Ruga	Common origin					
	Age group (yrs.)					
	5	10	13	23	45	72
I	0	2	2	0	0	0
II	0	0	0	0	0	0
III	0	0	1	0	0	0

TABLE 22 Frequency of broken rugae R I-VII in the various age groups (100 palatal halves).

Ruga	Age group (yrs.)					
	5	10	13	23	45	72
II	1	0	0	0	0	0
III	3	3	2	1	0	0
IV	3	4	0	3	3	0
V	0	0	0	0.5	1	0

7. BROKEN RUGAE

As broken rugae are always few in number it is difficult to compare the groups (Table 22).

8. PAPILLATE RUGAE

In the four youngest groups roughly one quarter or one third of the rugae are papillate; the type is much less common in the two oldest groups ($\chi^2 = 144.8^{***}$, D.F. = 2). In all the age groups there is

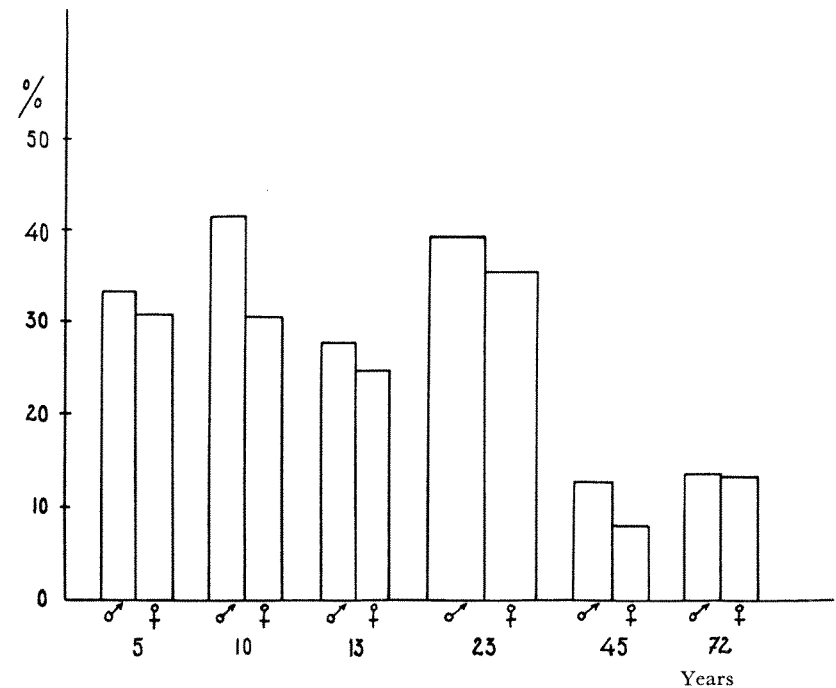


FIG. 20. Percentage of papillate rugae in the various age groups.

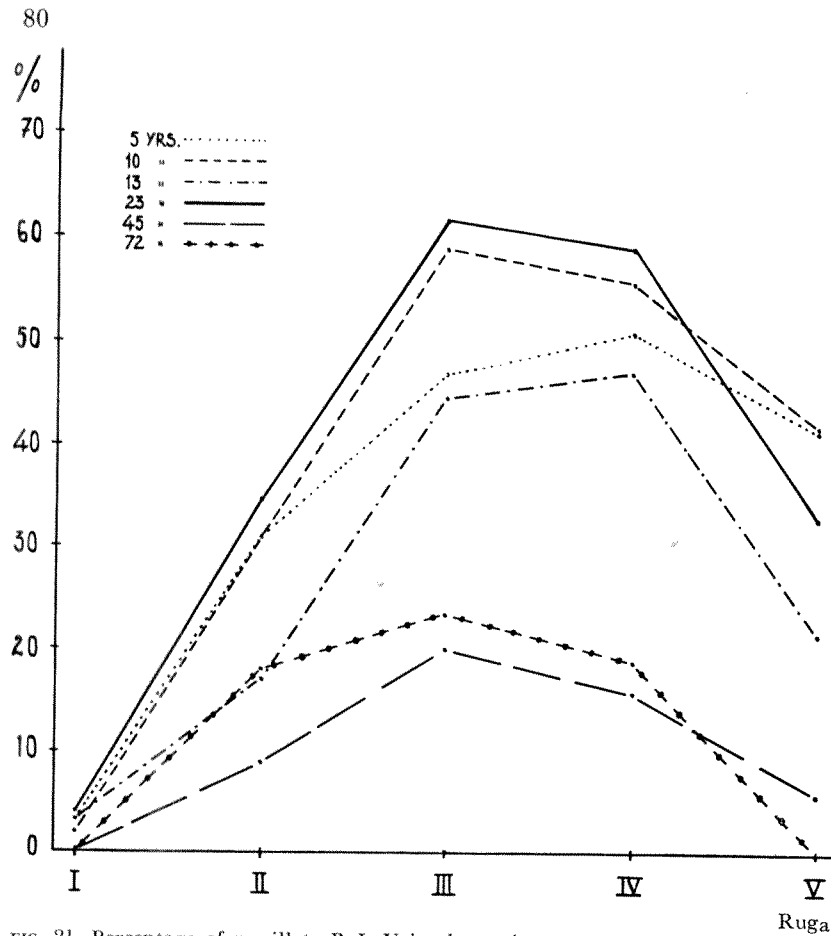


FIG. 21. Percentage of papillate R I-V in the various age groups.

a somewhat higher value for males than females ($\chi^2 = 6.8^*$, D.F. = 1). (Fig. 20.) R III and R IV are the ones most often papillate (Fig. 21). The first ruga is rarely papillate.

9. UNCOMMON DETAILS

In addition to those mentioned under *Branched* and *United rugae*, a further 24 uncommon details, were recorded, 11 in males and 13 in the females. In two casts they consisted of semicircular terminations of a ruga, and in the other cases they were annular or round swellings on the ruga. In all but two subjects they were on R I. The distribution in the age groups of the number of these details was, from the youngest to the oldest group, 3, 4, 1, 8, 6 and 2.

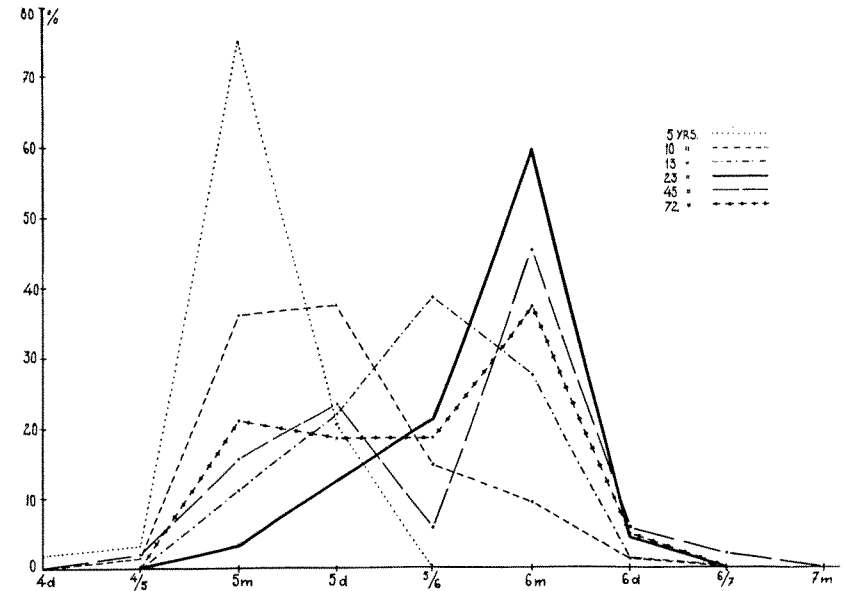


FIG. 22. Percentage distribution of the posterior limits on the tooth zones for the various age groups. All rugae. (Each palatal half recorded separately.)

10. THE POSTERIOR LIMIT OF THE RUGAE IN RELATION TO THE TEETH

Total ruga zone

The posterior limit of the ruga zone in relation to the teeth shows for the youngest group a very marked maximum around the mesial zone of the second deciduous molars. There is a tendency for the limit to move backwards in the dental arch with age up to 20 years. For the 23 year group and for the two oldest the rugae generally reached the mesial part of the first molar (Fig. 22).

Primary (O) rugae

Some tendency to move back with age is observed also in the primary (O) rugae. The maximum for all groups being near 5 m (for the 5 year group it is 04/05-05 m). (Fig. 23).

For the two oldest groups the values are uncertain. These groups are represented by fewer palatal halves than the others, mainly on account of loss of teeth. For example, for the total ruga zone the values for these two groups are based on only 51 per cent and 43

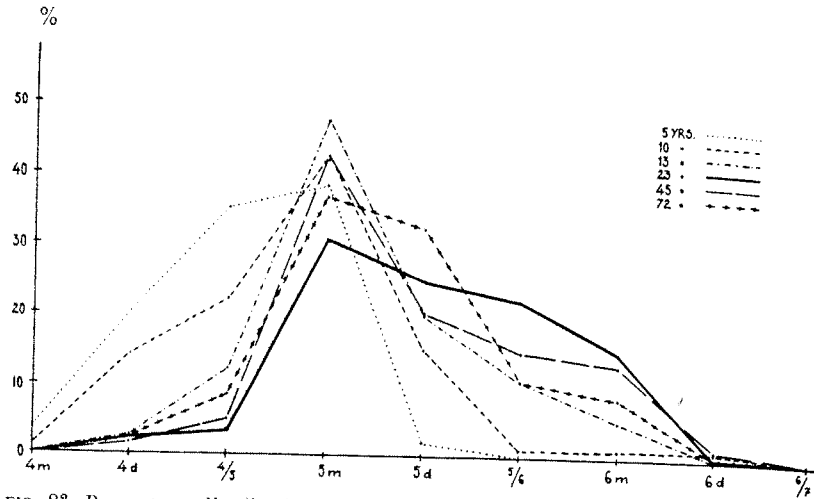


FIG. 23. Percentage distribution of the posterior limits on the tooth zones for the various age groups. Primary (O). (Each palatal half recorded separately.)

per cent of the total number of palatal halves, against 98-73 per cent for the four youngest groups. The difference may in part be ascribed to the fact that the posterior teeth are generally lost before the anterior; the number of subjects with rugae extending further posteriorly being under-represented.

11. INCISIVE PAPILLA

Shape

In the four youngest groups the pear-shaped incisive papilla is by far the commonest. The long, narrow form also occurs fairly often in these groups, as does the oval and the triangular, the latter resembling the pear-shaped papilla (Fig. 24).

In the two oldest groups the oval and the pear-shaped papilla are almost equally common and occur in the majority of the palates and with approximately the same frequency. In these two groups there are also 5 subjects with round papillae, but there are none of these in the four youngest groups. Four of these were edentulous persons.

The greatest difference between the higher and lower age groups is found in respect of the greater number of oval and the smaller number of pear-shaped papillae in the former group. The sums of these two types for the various groups are roughly equal. The ex-

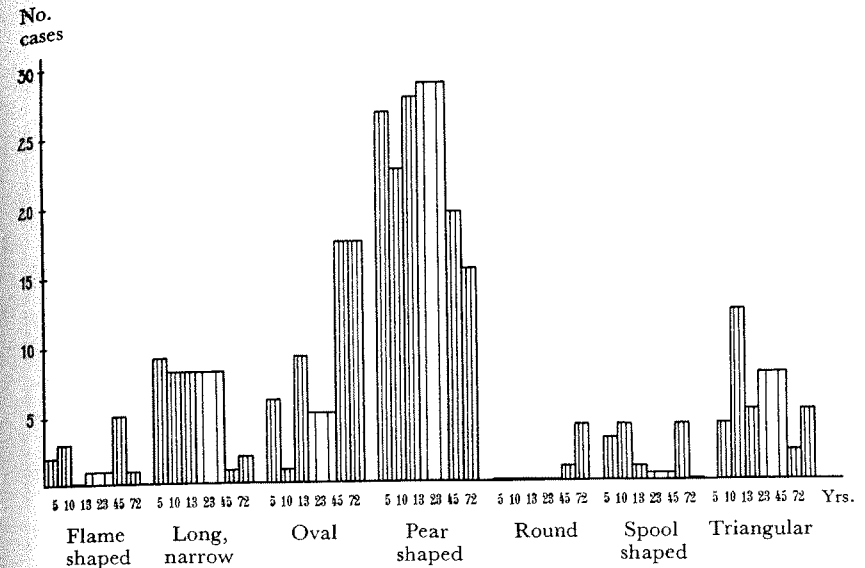


FIG. 24. Occurrence of the types of incisive papilla in the various age groups.

planation may be that the pear-shaped papilla, that has a fairly detailed configuration, may at advanced ages be considered as changing to the simpler contoured oval form. This may also explain why the simple round form occurs only in the oldest groups.

Length

Among the males, the youngest and oldest groups have shorter incisive papillae than the others, between which there are no obvious differences. Among the females, the value for the 23 year group differs from the others; there is evidently a similar tendency in the oldest group to that found for the males (Table 23).

For the 23 year group no sex difference could be established but in three of the other groups the females have definitely lower figures.

Width

Among the males the width of the incisive papilla is much the same in all age groups with the possible exception of the oldest which has a lower value.

TABLE 23 The mean (\bar{x}), standard error of the mean ($\epsilon(\bar{x})$) and the standard deviation (σ) for the length and breadth of the incisive papilla in the various age groups.

Age group (yrs.)	Males			Females		
	$\bar{x} \pm \epsilon(\bar{x})$	σ	No.	$\bar{x} \pm \epsilon(\bar{x})$	σ	No.
Length (mm)						
5	6.36 ± 0.30	1.49	24	6.76 ± 0.17	0.83	25
10	7.44 ± 0.26	1.31	25	6.42 ± 0.21	1.07	25
13	7.26 ± 0.28	1.41	25	6.40 ± 0.27	1.37	25
23	7.41 ± 0.19	1.34	50	7.43 ± 0.20	1.40	50
45	7.80 ± 0.36	1.75	24	6.45 ± 0.22	1.10	24
72	5.62 ± 0.24	1.11	22	5.66 ± 0.34	1.57	21
Width (mm)						
5	3.58 ± 0.17	0.84	24	3.51 ± 0.11	0.53	25
10	3.68 ± 0.16	0.81	25	3.23 ± 0.15	0.74	25
13	3.65 ± 0.18	0.91	25	3.31 ± 0.14	0.68	25
23	3.93 ± 0.13	0.89	50	3.51 ± 0.11	0.75	50
45	3.62 ± 0.13	0.63	24	3.43 ± 0.13	0.62	24
72	3.23 ± 0.12	0.58	23	3.80 ± 0.19	0.90	22

The females evidence no difference in any groups.

Comparison between sexes shows consistently higher values for all male groups except the oldest.

Width/length index

There is no evident difference between the sexes or between the age groups in respect of the W/L index (Table 24).

TABLE 24 The mean (\bar{x}), standard error of the mean ($\epsilon(\bar{x})$) and the standard deviation (σ) for the W/L index of the incisive papilla for the various age groups.

Age group (yrs.)	Males			Females		
	$\bar{x} \pm \epsilon(\bar{x})$	σ	No.	$\bar{x} \pm \epsilon(\bar{x})$	σ	No.
5	59.2 ± 3.5	17.1	24	52.6 ± 2.1	10.4	25
10	50.2 ± 2.2	11.0	25	51.5 ± 2.9	14.5	25
13	51.1 ± 2.3	11.3	25	53.2 ± 2.9	14.6	25
23	53.4 ± 1.3	9.4	50	48.6 ± 1.5	10.9	50
45	48.2 ± 2.1	10.1	24	53.8 ± 1.9	9.2	24
72	59.2 ± 2.3	10.9	22	71.4 ± 4.9	22.3	21

TABLE 25 The mean (\bar{x}), standard error of the mean ($\epsilon(\bar{x})$) and the standard deviation (σ) for the length, width and W/L index for various types of incisive papilla.

Shape	Length (mm)			Width (mm)			W/L index	
	$\bar{x} \pm \epsilon(\bar{x})$	σ	No.	$\bar{x} \pm \epsilon(\bar{x})$	σ	No.	$\bar{x} \pm \epsilon(\bar{x})$	No.
F	6.92 ± 0.35	1.26	13	3.70 ± 0.13	0.48	13	54.6 ± 2.3	13
L	6.82 ± 0.17	1.11	44	2.64 ± 0.06	0.41	44	39.3 ± 1.1	44
O	5.90 ± 0.20	1.54	60	3.26 ± 0.08	0.64	60	57.5 ± 1.7	60
P	7.23 ± 0.11	1.39	163	3.86 ± 0.05	0.69	164	54.7 ± 0.9	163
R	4.80		4	5.10		4	103.6	4
S	7.65 ± 0.30	1.09	13	3.18 ± 0.12	1.42	13	42.2 ± 1.9	13
T	6.85 ± 0.23	1.49	43	3.74 ± 0.11	0.69	43	56.3 ± 1.6	43

F = flame shaped, L = long and narrow. O = oval, P = pear shaped, R = round, S = spool shaped, T = triangular.

A study was made of the differences between length, width and W/L index for various types of papilla (Table 25).

The age variations in the length and width are possibly related to the difference in the frequency of the various forms in the age groups. Thus, the pear-shaped papilla is by far the commonest in the four youngest groups, while in the two oldest groups the oval and pear-shaped papillae are almost equally common.

The differences in the size and shape of the incisive papilla observed in the various age groups and sexes may be due to loss of teeth. On distributing the papilla widths according to cases with and without teeth in the oldest female group a significant difference ($n = 17$ and 5) is obtained for both categories.

For the subjects with teeth the width is 3.42 ± 0.09 mm while the corresponding figures for the edentulous cases are 5.00 ± 0.29 mm (difference 1.58 ± 0.30 mm: $t = 5.27^{***}$).

Foetus group

(Case material and results)

The foetus group consisted of 20 foetuses (8 ♂ and 12 ♀). They were obtained from the Caroline Institute in Stockholm and were stillborn, mostly full term foetuses with total length of 42 to 62 centimetres. As far as could be ascertained they were without visible

TABLE 26 Foetus group. Mean number of primary, secondary and fragmentary rugae per palatal half (♂=8, ♀=12).

Ruga type	♂		♀		♂+♀
	L	R	L	R	L+R
Primary	4.00	3.88	4.00	3.75	3.90
Secondary	0.88	0.63	0.75	0.67	0.73
Fragmentary	1.00	0.50	0.17	0.25	0.43

deformities. By reason of the fact that they were stillborn they cannot be considered as representative of the population of the ages specified.

Where convenient the study followed the same observation scheme as the other groups. The length of the ruga was not measured, however. Experience gained from the earlier groups was the basis for

TABLE 27 Foetus group. Shapes of rugae (number of straight, angular and curved rugae), site of origin (number of R, M and L) and number of branched, united, broken and papillate rugae.

	♂		♀		Total	Per cent
	L	R	L	R		
<i>Shape of ruga</i>						
straight	1	2	0	1	4	2.6
angular	5	3	4	10	22	14.1
curved	26	26	44	34	130	83.3
<i>Origin of ruga</i>						
R	19	18	28	32	97	62.2
M	9	9	14	9	41	26.3
L	4	4	6	4	18	11.5
Branched	3	2	5	5	15	
Branched, R 1, R 2	2	2	4	5	13	
<i>United</i>						
with common origin	0	1	1	2	4	
with separate origins	0	0	0	0	0	
Broken	3	0	0	0	3	
Papillate	3	5	4	5	17	

R = origin in contact with the raphe.
 M = " " medial half of ruga zone.
 L = " " lateral " " "

TABLE 28 Foetus group. Mean direction of rugae (8 ♂+12 ♀).

		Direction	No. rugae
L+R	♂	-10.23 ± 2.01	63
L+R	♀	-11.15 ± 1.81	93
Left	♂+♀	-3.25 ± 1.67	80
Right	♂+♀	-18.70 ± 1.89	76
R I	L/R ♂+♀	+0.25/-10.75	20/20
R II	" "	-3.75/-19.75	20/20
R III	" "	-4.75/-20.75	20/20
R IV	" "	-9.08/-25.40	15/14
R V	" "	+8.25/-19.75	5/2

The direction was measured as the angle (in degrees) between the ruga and the normal to the raphe, forward and backward inclinations being denoted as positive and negative, respectively.

the evaluation of the proliferations. The foetal rugae were evaluated as primary, secondary or fragmentary on the basis of a mental comparison with the rugae of all the other groups. Such a recording must be to some degree subjective.

For the sake of brevity all the values are given in tabular form (Tables 26-29). The number of primary rugae is about four per palatal half; that is, roughly the same number as in the other groups. The total number of rugae—primary, secondary and fragmentary—is, possibly, lower for this group (the difference between the fetuses and, for example, the 5 year group = 3.58 ± 0.56). This is hardly ascribable to differences in procedure, since practically all proliferations, irrespective of size, were recorded in the foetus group.

TABLE 29. Foetus group. Shape, length, width and W/L index of incisive papilla.

Shape	♂	♀	♂+♀
Long, narrow	1	2	3
Pear-shaped	3	7	10
Triangular	2	3	5

Mean length, width and W/L index.

	♂	No.	♀	No.
Length	5.20 mm	6	4.98 mm	12
Width	2.28 mm	6	2.35 mm	12
W/L-index	43.8	6	48.0	12

It is also found that

(1) the distribution between straight, angular and curved rugae is largely similar to that in the other groups; the angular rugae are, however, possibly, somewhat fewer and the curved somewhat more numerous;

(2) the percentage distribution of the origins of the rugae is in accord with that of the other groups;

(3) the rugae of the left side are more forward inclined than those on the right;

(4) the branched rugae occur roughly as frequently as in the other younger groups, and are as often found in the two first pairs;

(5) united and broken rugae are rare;

(6) papillate rugae are fewer than in the other groups;

(7) the incisive papilla is generally pear-shaped and shorter and narrower than in the younger groups.

By way of summarizing it may be said that the foetus group—with the reservation for the value of the results—accords in the main with the other age groups.

Longitudinal study

Any study of changes due to age is best conducted by making a series of observations on one subject, covering all relevant periods. The long period of observation necessary in this procedure involves greater difficulties than a comparison between different groups of subjects of different ages. In the present investigation the series study was made on two study groups, one in which the subjects were examined at 5 and 10 years of age, and the other in which they were examined at 12 or 13 years of age and again at adult age. These groups are referred to as the *younger* and *older* groups.

Study group

The *younger group* consisted of 38 (20 ♂ + 18 ♀) of the 50 children comprising the group "infantile dentition a" in the Cross-sectional study. They were subsequently summoned for examination on reaching 10 years of age. (These subjects are not included in "infantile dentition" group b of the Cross-sectional study. Their average ages

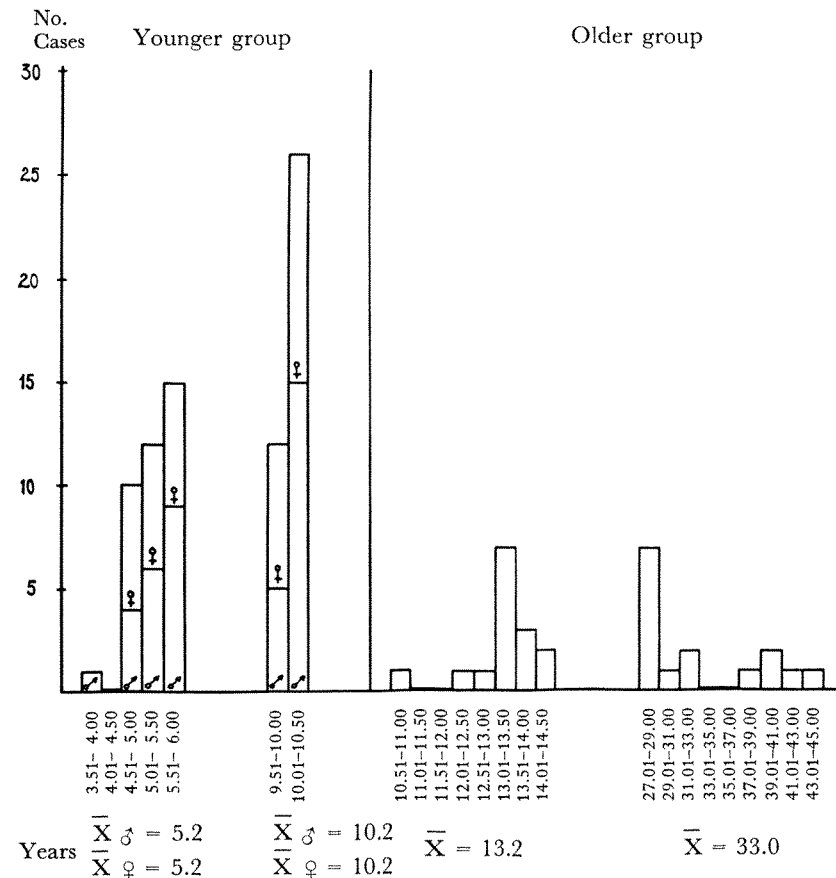


FIG. 25. Age distribution at the first and second examinations in the younger and older groups.

at both studies were 5.2 and 10.2 years. The age distribution is given in Fig. 25.) The mean interval between the two examinations was 5.0 years, with a variation of 4.0 to 6.0 years.

The *older group* comprised 15 subjects, 6 of them (4 ♂ + 2 ♀) had received orthodontic treatment while the other 9 (6 ♂ + 3 ♀) had not. Of the latter, 7 were included in the 13 year group of the Cross-sectional study.

The average ages at the both examinations were 13.2 and 33.0 years. The age distribution is given in Fig. 25. The interval between the first and second examination was on an average 19.7 years with a range of 14.0 to 30.4 years.

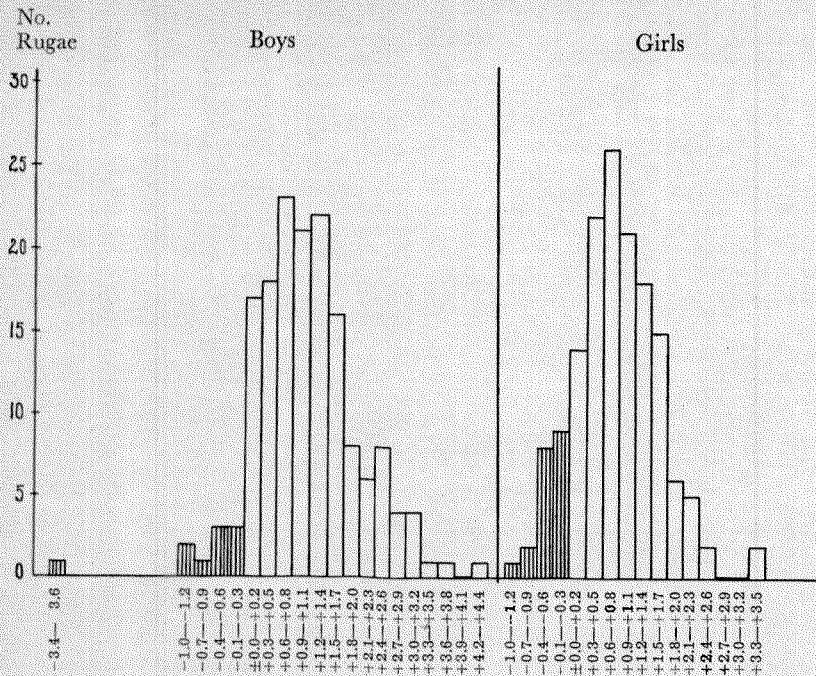


FIG. 26. Changes in length of the primary rugae between the first and second examinations. Number of rugae: boys 160, girls 151.

Results: The younger group

1. CHANGES OF THE LENGTH AND NUMBER OF RUGAE

In a comparison between the first and second examinations of all primary rugae recorded at one or both examinations (160 in boys, 151 in girls) it was found that the average increases in length were, respectively, 1.09 ± 0.08 and 0.81 ± 0.06 mm—that is, 11 and 9 per cent of the original values. The increase for boys is probably somewhat larger than for the girls ($t = 2.80^{**}$). The changes in length are given in Fig. 26 and the absolute values for all rugae at the second examination in Fig. 27.

Evidently, although there are changes in length of practically all rugae, they are rarely the cause of a change from one ruga group to another.

Such qualitative changes are given in Table 30 which is divided into three: the first part containing such rugae as do not change group; the second and the third containing rugae that increased or

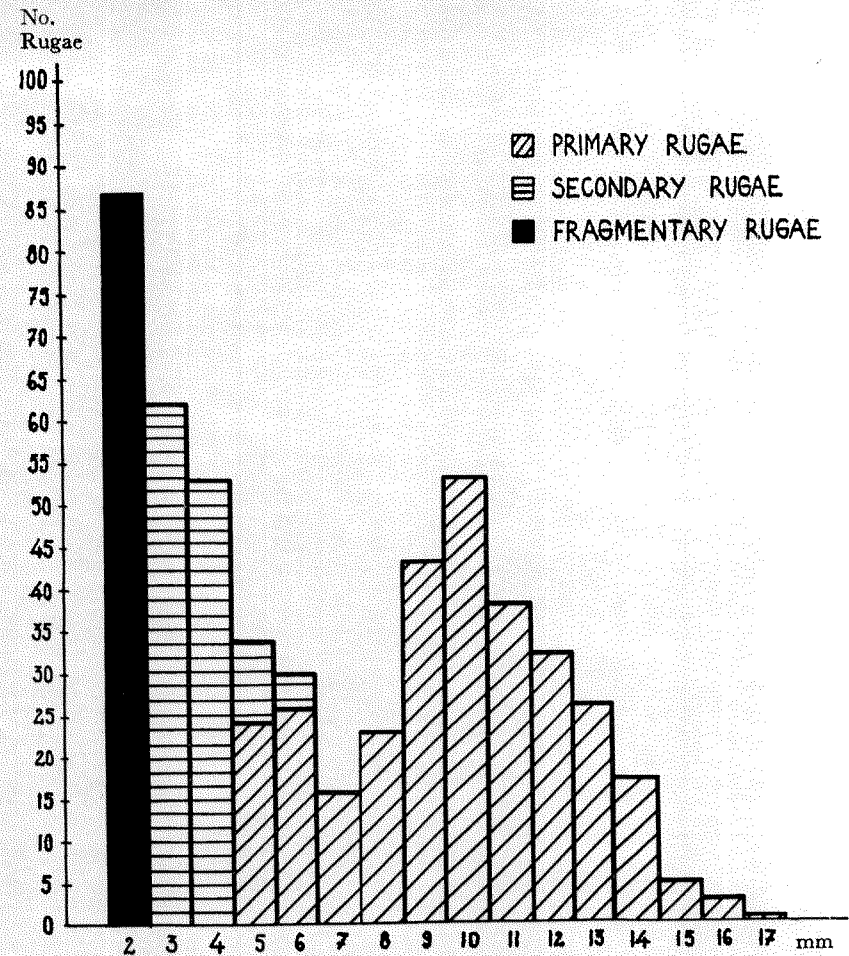


FIG. 27. Younger group: length of all rugae at second examination.

decreased in length and thus fell into another ruga group (for instance from secondary to primary rugae). Such changes are rather uncommon (58 rugae of 528) and they are more frequently due to an increase than a decrease in length (41 against 17).

2. THE SHAPE AND ORIGINS OF THE PRIMARY RUGAE

The observations refer to such primary rugae as were recorded at one or both examinations (see Table 31).

The recorded changes are small and of roughly the same magnitude

TABLE 30 Younger group. Qualitative changes in the rugae between the first and second examination (20 ♂ + 18 ♀).

	No change in type			Change in type through increase in length				Change in type through decrease in length			
	Prim.	Sec.	Frag.	Sec.	Frag.	Frag.	-	Prim.	Prim.	Sec.	Frag.
First examination	Prim.	Sec.	Frag.	Sec.	Frag.	Frag.	-	Prim.	Prim.	Sec.	Frag.
Sec. examination	Prim.	Sec.	Frag.	Prim.	Prim.	Sec.	Frag.	Sec.	Frag.	Frag.	-
Males	154	71	32	3	0	14	5	2	1	4	3
Females	143	34	36	7	0	7	5	1	0	4	2

A horizontal dash (-) indicates that the proliferation was not recorded as it was less than 2 mm in length on the occasion of that examination.

as the error of the method (4 and 1 deviations in 204 rugae). It is therefore possible that the changes are ascribable to the method. The changes in the origin are somewhat larger than the error of the method.

3. DIRECTION OF PRIMARY RUGAE

On an average both boys and girls presented a small increase in the forward direction of the rugae ($3.47 \pm 0.60^\circ$ and $2.37 \pm 0.61^\circ$).

TABLE 31 Younger group. Shape and origin of rugae. Comparisons between the first and the second examination (20 ♂ + 18 ♀).

	Shape			Origin			
	Angular	Curved	Unchanged record	Lateral displacement		Medial displacement	
R				M	L	M	
First examination	Angular	Curved	Unchanged record	R	M	L	M
Second examination	Curved	Angular	Unchanged record	M	L	M	R
Males . . .	155	3	2	156	1	1	0
Females . .	143	3	5	145	2	1	3

R = origin in contact with the raphe
 M = ,, ,, medial half of ruga zone
 L = ,, ,, lateral ,, ,, ,, ,,

The comparisons comprise all primary rugae recorded at one or both examinations.

TABLE 32 Younger group. The mean (\bar{x}), standard error of the mean ($\epsilon(\bar{x})$) and the standard deviation (σ) for changes in direction of RI-IV between first and second examination (20 ♂).

Ruga	Left		Right	
	$\bar{x} \pm \epsilon(\bar{x})$	σ	$\bar{x} \pm \epsilon(\bar{x})$	σ
I	+1.35 ± 1.11	4.97	-0.20 ± 1.61	7.19
II	+5.35 ± 1.31	5.87	+3.38 ± 1.34	5.98
III	+4.48 ± 1.72	7.69	+5.08 ± 1.49	6.65
IV	+1.94 ± 1.77	7.08	+6.55 ± 3.07	10.20

The increase for the boys was also distributed on the various rugae. The tendency appears in all rugae except the first (Table 32).

The measurement of the rugae was performed on the casts placed in a symmetrograph (p. 30) where they were oriented according to the incisal edge of the upper left central incisor and the mesiolingual cusp of the first permanent molars (deciduous dentition second deciduous molars).

It would have been desirable if in these comparisons the same point of orientation could have been used in the first and second examinations, but on account of the loss of teeth this was frequently impossible. This applies to both the anterior and the posterior points of orientation. The posterior points were, in the first examination, the upper second deciduous molars and, in the second examination, the first molars. This introduced a source of error the magnitude of which was studied in the cases in the male group (12 of 20) where it was possible to orient the cast in relation to the second deciduous molars and the first molars. In 8 cases the positioning was the same and in the 4 others, representing 34 rugae, the different adjustments introduced a mean angular change of $+0.66^\circ$.

In the same way the transition from the short and occasionally much abraded deciduous incisors to the longer permanent incisors might be considered to result in an apparent increase in the forward inclination of the rugae.

The magnitude of this change is revealed only in cases where the same orientation points (the second deciduous molars and one deciduous canine, for instance) could be employed at both recordings. This was effected in 7 cases. It was then found that in 6 of them the permanent incisors had reached 0-1 mm higher than the deciduous incisors, and in the seventh case 2 mm.

A study of the importance of the change in position in relation to the setting of the incisors was made; 5 casts were measured with a total of 40 rugae in two settings, (a) with the orientation in a horizontal plane, and (b) with the anterior reference point 2 mm below this level. The latter setting gave a mean increase in the forward inclination of the rugae of 1.16°.

It is thus possible that certain parts of the observed increase in forward inclination in the younger group is in accord with changes in orientation. This would not be sufficient, however, to explain the whole increase, for which reason it must be assumed to be at least partly real. (The increase in the older group points in the same direction when the orientation points are the same for both observations, see below.)

4. BRANCHED, UNITED AND BROKEN RUGAE

A comparison between the results from the first and second examinations shows complete agreement in respect of the branched (30) and united (5) rugae, while there was one deviation among the broken rugae (6 against 7). The break was found only at the second examination.

5. PAPILLATE RUGAE

There is a large difference between the first and second examinations. The number of papillate rugae appears to increase for both sexes (Table 33).

6. UNCOMMON DETAILS

All the uncommon details were observed equally in boys and girls (9 and 6 details) on both examinations.

TABLE 33 Younger group. Papillate rugae. Comparisons between first and second examination (20 ♂ + 18 ♀).

	First examination	Pap.	—	Pap.
	Second examination	Pap.	Pap.	—
Males		43	16	7
Females		40	20	5

A dash (-) indicates that the ruga was not recorded as papillate at that examination.

TABLE 34. Younger group. Posterior limit of ruga zone in relation to the teeth. Comparisons between the first and second examination. The numbers relate to palatal halves.

	Primary (O)		All rugae	
	♂	♀	♂	♀
Unchanged recording	9	9	10	9
Displacement to				
posterior tooth zone	16	16	16	12
beyond posterior tooth zone	2	2	1	6
Displacement to				
anterior tooth zone	1	—	—	—
beyond anterior tooth zone	—	—	—	—

7. THE POSTERIOR LIMIT OF THE RUGA ZONE

There seems generally to be a backward displacement of the posterior limit of the ruga zone for both sexes; this applies to the posterior limit of primary (O) rugae and of all rugae (Table 34).

Measurements were made to find whether this was due to an increase in the antero-posterior dimension of the ruga zone. Easily identifiable reference points were chosen in each case on the primary rugae at the anterior and posterior limits, and both medially and laterally. It was established that there was such an increase and that for the boys and girls (number of palatal halves = 38 and 28 resp.) was medially 1.13 ± 0.14 and 1.31 ± 0.13 mm, while the corresponding lateral figures were 0.58 ± 0.18 and 0.98 ± 0.13 mm. (The number of palatal halves was 40 and 36, respectively.) This may have been due to an increase in width of the rugae or in the distance between them, or to a combination of these factors.

Measurement of the increase in width was difficult because the changes were small and the easily identifiable points generally consisted of notches where it was difficult to perform a measurement of the width. It is not known, moreover, whether the increase in width for this point is representative of the increase in width of the whole ruga.

The distance between the rugae was measured and an average increase of somewhat less than one half a millimetre was found (for boys and girls the increases for 68 and 89 such distances were, respectively, 0.42 ± 0.07 and 0.26 ± 0.06 mm). The reference points used were easily identifiable medial points on the posterior edge of

TABLE 35 Younger group. Shape of incisive papilla. Comparisons between the first and second examination (20 ♂ + 18 ♀).

First examination Second examination	Unchanged recording	S T	L S	O P	F T
Males	18	—	—	1	1
Females	16	1	1	—	—

F = flame shaped, L = long and narrow, O = oval, P = pear shaped, S = spool shaped, T = triangular.

one ruga and on the anterior edge of the next ruga back, the points being chosen as far as possible so that the distance was measured on a line parallel to the palatine raphe. In 30 cases the measurements were not made between numerically adjacent rugae since one of the rugae had its origin some distance laterally. It was then omitted and the measurement made to the next but one ruga. Had this not been done comparisons would in some instances have applied equally to changes in a lateral and in an antero-posterior direction.

In connection with the study of these changes a number of measurements of the palatal width and height were made by the procedure already described. If the reference points on the first and second deciduous molars and on the first and second premolars in the mixed dentition may be considered as analogous in the two dentitions, an increase in both width and height of the palate may be considered as established. The increase in width at the first and second premolars was about 2 and 1.5 mm and the increase in height at the second premolars about 1.5 mm (for 19, 28 and 25 subjects).

A corresponding increase was found in respect of the lateral extent; for the girls it was over 1 mm (+1.37 ± 0.13 mm) and for the boys over 2 mm (+2.26 ± 0.15 mm), measured as an increase in the distance between the terminations (n = 67 and 70). The terminal distance—No. 17 in the chart (p. 28)—is that between the terminations of numerically corresponding rugae on the right and left side.

8. INCISIVE PAPILLA

Shape

In 4 of the 38 subjects there were changes in the shape of the incisive papilla (Table 35) the frequency of which was roughly the

TABLE 36 Younger group. Mean (\bar{x}), standard error of the mean ($\epsilon(\bar{x})$) and standard deviation (σ) for changes in length, width and W/L index of the incisive papilla, expressed as an increase or decrease in the values at the first examination.

		No.	$\bar{x} \pm \epsilon(\bar{x})$	σ
Change in length (mm)	+	19	+ 0.65 ± 0.22	0.97
	-	18	+ 0.27 ± 0.19	0.80
Change in width (mm)	+	19	- 0.29 ± 0.13	0.56
	-	18	- 0.14 ± 0.12	0.49
Change in W/L index	+	19	- 10.7 ± 3.0	13.1
	-	18	- 4.3 ± 2.1	9.1

same as the recording error (3 subjects of 24). In at least 2 of the 4 cases however the changes were probably real and not a consequence of the method. In one case the incisors were missing at the first examination.

Length and width

There was a change in length of the papilla for both boys and girls—statistically significant in the former case. No definite change in width was found, although there may have been some decrease. The changes are more clearly apparent from the W/L index ($= \frac{W \times 100}{L}$) a numerical increase in the length and a reduction in the width giving a lower index value (Table 36).

Results: The older group

As this group is small (n = 15) no sex distribution has been made. In most estimates a division into groups having received orthodontic treatment (OT) and others (NOT) was made.

1. CHANGES IN THE NUMBER AND LENGTH OF THE RUGAE

Alterations in the length such that the ruga changes class are as frequent here as in the younger group—18 rugae of 203 (9 per cent) (Table 37). The dimensional change of the individual ruga is different for the two groups (OT and NOT). The mean increase for

TABLE 37 Older group. Qualitative changes in the rugae between the first and second examination (15 subjects).

	No change in type			Change in type through increase in length			Change in type through decrease in length		
	Prim.	Sec.	Frag.	Sec.	Frag.	-	Prim.	Sec.	Frag.
1st examination									
2nd examination	Prim.	Sec.	Frag.	Prim.	Sec.	Frag.	Prim.	Sec.	Frag.
No orthodontic treatment . . .	77	31	9	0	7	2	0	2	1
Orthodontic treatment . . .	43	18	7	1	4	0	0	0	1

A horizontal dash (-) indicates that the proliferation was not recorded as it was less than 2 mm in length on the occasion of that examination.

the latter is 0.83 ± 0.10 mm ($n = 77$) while for the former there is no appreciable change (-0.01 ± 0.24 mm; $n = 44$).

The increase in length may have had some connection with a larger growth of the jaw for the *NOT* cases, but the smallness of the group renders comparison difficult. For these cases there is a mean increase in the palatal height at the first molar by 3.3 mm ($n = 7$) while the corresponding figure for the *OT* cases is 1.6 mm ($n = 6$). The change in width at the first and second premolar and the first molar is for the *NOT* group +1.04, +1.27, and +0.67 mm while the corresponding figures for the *OT* cases are +0.87, -0.60 and -1.56. The case series is too small for any definite conclusions; among the *NOT* cases there is a reduction of the width in only one of the 20 recorded, while the corresponding figure in the other group is 7 of 15. (An explanation of this difference may be that there had been a lateral expansion in the *OT* cases at the time of the first examination; the occurrence of some relapse would then result in a lower value at the second examination.)

2. SHAPE AND ORIGIN OF THE PRIMARY RUGAE

The changes are not great (10 and 6 per cent, resp.) although larger than in the younger group; the majority of the differences in the shape of the rugae are probably unassociated with the recording error. This is true mainly of those subjects where a ruga was recorded at one examination as curved and at the other as angular (Table 38, Fig. 28).

TABLE 38 Older group. Shape and origin of rugae. Comparisons between the first and the second examinations (15 subjects).

	Shape					Origin				
	unchanged record	straight curved	curved straight	curved angular	angular curved	unchanged record	Lateral displacement		Medial displacement	
R							M	L	M	
1st examination										
2nd examination										
No orthodontic treatment . . .	70	2	0	1	4	71	1	2	1	2
Orthodontic treatment . . .	39	0	1	3	1	43	0	1	0	0

R = origin in contact with the raphe

M = ,, ,, medial half of ruga zone

L = ,, ,, lateral ,, ,, ,, ,,

The comparisons comprise all primary rugae recorded at one or both examinations.

3. DIRECTION OF PRIMARY RUGAE

Seen as a whole, the group evidences a small increase in the forward inclination between the two examinations. For the *NOT* subjects it is significant ($+3.37 \pm 0.67^\circ$; $n = 77$) while for the *OT* subjects the change is less definite ($+1.88 \pm 1.17^\circ$; $n = 43$).

4. BRANCHED, UNITED AND BROKEN RUGAE

On the first and second examinations the same numbers were recorded (13, 4 and 4 for both *NOT* and *OT* together).



FIG. 28. The change in shape between the first and second examination. Observe R I left (on right of photo) changing from curved to angular.

TABLE 39 Older group. Papillate rugae. Comparisons between first and second examinations (15 subjects).

First examination	Pap.	Pap.	—
Second examination	Pap.	—	Pap.
No orthodontic treatment	16	1	6
Orthodontic treatment	12	3	4

5. PAPILLATE RUGAE

There is a relatively large difference between the first and second examination, but no definite trend is evident (Table 39).

6. UNCOMMON DETAILS

Among the *NOT* cases there were 5 uncommon details at both examinations (in 3 cases minor branches, in 2 connection between primary and secondary rugae). Among the *OT* cases such details were not recorded at either examination.

7. THE POSTERIOR LIMIT OF THE RUGA ZONE IN RELATION TO THE TEETH

In roughly one half of the palatal halves the posterior limit at the second examination extended further back in relation to the

TABLE 40 Older group. Posterior limit of ruga zone in relation to the teeth. Comparisons between the first and second examinations. The numbers relate to palatal halves.

	Primary (O)		All rugae	
	No orthod. treatm.	Orthod. treatm.	No orthod. treatm.	Orthod. treatm.
Unchanged recording	6	1	5	3
Displacement to				
posterior tooth zone	5	4	5	3
beyond posterior tooth zone. .	3	0	3	0
Displacement to				
anterior tooth zone	0	0	0	0
beyond anterior toth zone . . .	0	1*	0	0

* The last primary was judged once as primary (0) once as primary (x)

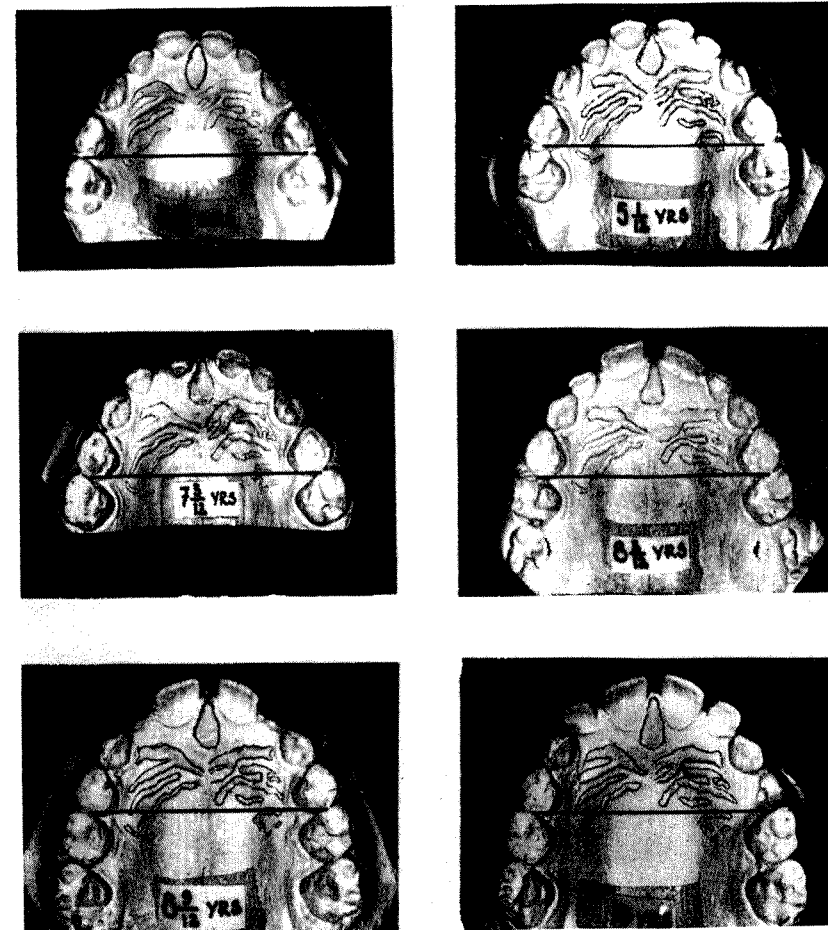


FIG. 29. Change in positional relationship between rugae and the teeth, from the age of 3 to 10 years.

dental arch (Table 40). This may have been due to (a) an absolute increase in the area of the zone in its antero-posterior direction, (b) a change in the relationship of the teeth to the palate or (c) a combination of (a) and (b). The measurement of the extent of the rugae showed for 15 subjects a mean increase medially of 1.45 mm (variation +0.4 to +3.1) and laterally 0.87 mm (variation -0.9 to +3.0), reckoned as the mean for the left and right sides. The length of the arch (measured as the perpendicular distance from the line

TABLE 41 Older group. Shape of incisive papilla. Comparisons between the first and second examination (14 subjects).

First examination Second examination	Unchanged recording	L O	L P	S P	T P
No orthodontic treatment	7	1	0	0	1
Orthodontic treatment	2	1	1	1	0

The papilla could not be observed in the fifteenth subject.

L = long and narrow, O = oval, P = pear shaped, S = spool shaped, T = triangular.

joining the deepest points of the central fossae on the first molars to the midpoint of a line between the mesial corners of the central incisors) showed a mean reduction of 1.5 mm for the 9 subjects where such a comparison was possible. It is thus not unlikely that the change in the relationship of the dental arch to the posterior limit of the rugae was due to a shortening of the arch and an increase in the absolute extent of the rugae. The study group is, however, too small for any definite conclusions. By way of comparison it may be mentioned that Friel (1949), in serial observations, observed a forward movement of the teeth in relation to the rugae in connection with jaw growth. This was confirmed by the present author in a series of six observations on a subject between the ages 3-10 years (Fig. 29).

8. THE INCISIVE PAPILLA

Shape

Changes were common (5 of 14 cases) especially in the OT group. In at least 3 subjects the changes in shape were real and not due to the method. The first observation showed all three papillae to be long and narrow, while at the second examination it was oval in 2 and pear-shaped in the third. Comparisons cover only 14 cases; in the fifteenth the papilla could not be distinguished clearly at the first examination. (Table 41.)

Width/length index

The width of the incisive papilla appeared to have increased for the 14 subjects ($+0.64 \pm 0.18$ mm). No definite change in length

was observed ($+0.09 \pm 0.21$ mm). The index shows an increase of 9.0 ± 3.1 .

The changes observed in the rugae during post-natal development may be summarized as follows.

Summary

Cross-sectional study

1. The number of rugae is largely unchanged up to the age of 23 years. Thereafter they appear to decrease.
2. Curved rugae are the commonest in all groups, while straight ones are rare. One third of the rugae are angular except in the oldest group where this type occurs once in eight.
3. The origin of the rugae is in 60 to 70 per cent in contact with the palatine raphe, in 20 to 30 per cent within the medial halves of the ruga zone and in less than 10 per cent in the lateral. This distribution appears to be without age variation.
4. The backward inclination of the rugae is more marked on the right than the left, the angle increasing from the first to at least the third ruga. The increase itself is more pronounced on the right than left side. The angle appears to decrease with age, especially on the right.
5. Branching is rather uncommon and is found mainly in R I and R II. There is no definite age variation although ramifications are probably less common in the oldest groups.
6. Unions of rugae are not common. Where connection is observed it is mainly between the first and second.
7. Broken rugae are extremely uncommon, and it is therefore difficult to compare the age groups in this respect. They appear mostly around the R III and R IV.
8. Papillate rugae constitute one third or one quarter of the total in the younger groups, while in the two oldest groups they are far less common. The males present somewhat higher values than females in all groups. It is generally the R III and R IV that are papillate.
9. The posterior limit of the whole ruga zone in the youngest group was, on an average, level with the mesial zone of the second deciduous molar. A tendency for the limit to move backwards with age is observable—up to 20 years. For the 23 year group and for the

two oldest groups the rugae generally reach the mesial zone of the first molar.

The same tendency, but less marked, is found for the limit of the ordinary primary rugae.

10. The *incisive papilla* in the younger groups is commonly pear-shaped; in the two oldest groups this shape and the oval occur equally often. In these groups but not in the four youngest the round papilla is found.

Its length for males is lower in the youngest and oldest groups. For females the 23 year group presents higher values than the others. In respect of width there appear to be no definite age variations for either sex.

The males in the 23 year group have significantly higher width values than the females, while the contrary is the case in the oldest group.

11. The *foetus* group. The figures are largely in agreement with those for the other groups but the results should be ascribed only relative value since the group is smaller than the others ($n = 20$) and no quantitative measurement of the ruga length was performed.

Longitudinal study

YOUNGER GROUP.—The first and second observations were made at the ages of 5 and 10 years.

Qualitative differences in *length* that involve change from one class to another (from secondary to primary rugae, for instance) were found in some 10 per cent of the subjects (58 of 528).

The quantitative changes in length of the primary rugae amount to an increase of 11 and 9 per cent, respectively, for boys and girls. No definite changes are observed in shape and origin of the rugae. The direction of the rugae appear to become somewhat more forward for both boys ($3.47 \pm 0.60^\circ$) and girls ($2.37 \pm 0.61^\circ$).

Branched and *united* rugae show no change; neither do the *uncommon details*.

Broken rugae present only one deviation between the two examinations.

The *posterior limit* of the ruga zone in relation to the teeth shows a tendency to recede to the next tooth zone posteriorly. In roughly one half of the palatal halves the limit moves back in relation to the teeth. Moreover, there seems to be an absolute increase also in the

antero-posterior extent of the zone and, similarly, for the distance between the rugae.

The length of the *incisive papilla* increases at least for boys and it is possible that the width is reduced for both sexes.

OLDER GROUP.—The group was composed of subjects who had already received orthodontic treatment (the *OT* subjects) and those who had received no such treatment (the *NOT* subjects). They numbered 6 and 9 respectively. The mean ages at the first and second examinations were 13.2 and 33.0 years; the mean interval between the first and second observation 19.7 years.

Qualitative changes in length that resulted in change of class (from secondary to primary ruga, for instance) occur in 18 rugae of 203 (9 per cent).

The quantitative changes appear to differ for the *OT* and *NOT* subjects. In the former no increase in growth could be observed (-0.01 ± 0.24 mm) while for the latter the increase was 0.83 ± 0.10 mm. This difference between the two groups is possibly associated with the changes in palatal width. The *NOT* subjects show higher values on the second than the first examination, while this factor varies in the *OT* group, possibly because several of them had at the time for the first examination undergone orthodontic treatment involving lateral expansion, which then decreased to some extent—through relapse.

The changes in the *shape* and *origin* of the rugae are of the same order of magnitude as the recording error. Some changes between the curved and angular rugae are so marked, however, that they could not be ascribed to the recording procedure. The direction of the rugae in the *NOT* cases shows little increase in the forward direction, while for the *OT* subjects the change is less definite.

For *branched*, *united* and *broken* rugae and *uncommon details* there is no change between the two examinations.

Papillate rugae show large differences between the two examinations but with no definite trend.

In roughly one half of the palatal halves the *posterior limit* of the ruga zone is further back in the second than in the first examination.

The shape of the *incisive papilla* shows large changes between the two investigations. Its length, width and W/L index increase from the first to the second examination.

Discussion of certain changes in the rugae and incisive papilla

The differences observed between the groups in the cross-sectional and longitudinal studies are to some extent random but there are probably systematic differences also. Up to adult age these are probably associated with the growth of the jaw. At higher ages the systematic differences are still more pronounced; the rugae are then less distinct and some of the posterior ones have disappeared.

The changes in the direction of the rugae and in the shape of the incisive papilla are probably ascribable to special causes.

There is a tendency for the backward direction of the rugae to decrease with age. At the same time there is a forward displacement of the teeth in relation to the rugae. It is uncertain whether these are true or apparent changes.

The angle between the occlusal plane and the palatal vault changes with growth. Björk (1947) found a decrease of about 3° in the angle between the plane of occlusion and the line joining the spina nasalis anterior and the spina nasalis posterior between the ages of 12 and 20 years ($11.66 \pm 0.21^\circ$ and $8.76 \pm 0.24^\circ$).

In the present study the use of the plane of occlusion as the plane of orientation gave a change in the direction of viewing and projection such that a ruga inclined backward would be still more oblique, with the result that the real change in direction would be greater than that recorded.

A constant direction of viewing is of importance in judging the posterior limit of the rugae. Here too it acts in the opposite sense to the recorded changes, which should thus be actually greater than the values indicate.

It is therefore not unlikely that the change in the direction of the ruga is real.

In the younger groups this, as other changes, may be ascribed to the active growth of the jaws. The measurements of the palatal width performed between the same points show that the values increased during the years of growth (Olow, 1954; *et al.*). Moreover, the teeth move forward in relation to the rugae during growth. To ascertain the magnitude of this change a study was made of subjects of the younger group of whom the second deciduous molars remained at the second examination. With the casts mounted in the symmetri-

graph the same easily identifiable points were marked in the dental arch and the ruga pattern on both casts. The distances were measured and in all cases (13 palatal halves in 9 subjects) the teeth were found to have shifted forward in relation to the rugae. The mean change was 2.1 mm (variation 1.1–4.2 mm).

The changes in the absolute increase in width of the palate and the forward movement of the teeth in relation to the rugae result in a ruga being in a wider, and therefore shallower, part of the palate than originally. Such a flattening of the ruga foundation would mean that in the horizontal projection the origins and terminations are further apart than before. If the points are not moved in an antero-posterior direction there would be a reduction in the backward inclination of a ruga (most of the rugae are backward inclined).

Another possible explanation for the change in direction is to be found in the forward movement of the lateral parts of the rugae in connection with the forward growth of the dental arch in relation to the rugae.

This is reminiscent of Hausser's (1950) findings on the movement of the teeth after extraction in the lateral regions: the lateral parts of the rugae moved half as far as the teeth, while the medial parts seemed not to move at all.

A similar effect was observed in the older group where the left first molar had been extracted, with the result that the premolars had moved distally in relation to the teeth anterior thereof; as a consequence there was an increase of 1.8 mm (36.7–38.5 mm) in the distance from the most distal point of the second premolar to the midpoint of a line between the mesial corners of the central incisors. The last ruga on the side of extraction increased its backward direction (from $+9.0$ to -5.0°) while the other rugae on this side assumed a more forward inclination (2.5 – 4.0°). This change may be connected with the re-shaping of the alveolar process after extraction.

Although it appears that the loss of teeth with subsequent wandering may have a local influence on the direction of the rugae the changes are probably of little importance to the value for a whole group.

In 4 *NOT* cases (39 rugae) with no loss of teeth the increase is 2.86° ; that is, not greater than the average increase of the group (cases with missing teeth included), $3.37 \pm 0.67^\circ$.

It should be pointed out in this connection that a tooth may

wander either forward or backward in the arch, so that the effect in the group as a whole would be diminished.

It is thus conceivable that extractions have a local but no general effect on the direction of the rugae. A large number of extractions would decrease the reliability of the results. A study of the 23 year group shows, however, that extraction of canines, premolars and first molars—that is, the regions where an extraction would cause the greatest change in the direction of the rugae—were not frequent. In the whole group of 100 subjects there are 5 with unilateral and 9 with bilateral loss of one premolar, and 2 subjects with both canines missing. Three subjects had one and one subject had no first molars. In the latter case the ruga zone ended mesially of the first molars. No distal wandering of the second premolars had occurred in this instance, nor in one case with the unilateral loss of a first molar.

In the older group there is a tendency to a reduction in the height of the dental arch. Measured from the first molars to the central incisors the mean reduction is 1.6 mm for 10 cases where comparison was possible.

This shortening of the dental arch may have been due to interstitial abrasion and proximal caries followed by a mesial wandering of the teeth.

The change in shape of the incisive papilla in both younger and older groups may be connected with changes in the relation between the papilla and the upper incisors. One case in the younger group with the deciduous incisors missing had on the first examination a markedly prominent papilla which, on the second examination, when the patient had all the permanent incisors, was narrow and very little raised.

In the older group there are two subjects with anterior crowding at the first examination and a long narrow papilla. At the second examination the patients had received orthodontic treatment. The papilla was then pear-shaped.

It is thus possible that the teeth are to some extent responsible for the changes of the papilla.

In the oldest female group of the Cross-sectional study there are 8 edentulous cases. In 3 of them the papilla was difficult to distinguish. Four of the remaining 5 had a round papilla (which was observed in but one other case in the whole material). The papilla lengths show no marked values while the widths appear to increase

considerably after the loss of incisors. (The average width for the 5 edentulous cases was 5.00 ± 0.29 mm, while for the 17 cases with teeth the figures were 3.42 ± 0.09 mm. Diff. 1.58 ± 0.30 mm, $t = 5.27^{***}$.)

Even if certain changes occur in the pattern they are, during the greater part of the life, so small that the pattern is still recognizable even after long periods. This circumstance may be exploited in identification if a sufficiently detailed and objective system is used. Further discussion of this is, however, outside the scope of this paper.

THE IMPORTANCE OF HEREDITARY INFLUENCE TO THE VARIABILITY OF THE RUGAE

The study of individual differences in the ruga pattern during various periods of life is closely associated with the study of genetic variation.

A pilot study has been conducted on a group of twins to get an impression of the extent to which the variations of the characteristics of the rugae and incisive papilla are influenced by hereditary and internal and external environmental factors.

The characteristics for which this study suggested the presence of a genetic influence were subjected to further examination in respect of (a) the relative importance of genetic and non-genetic factors, and (b) hereditary transmission.

In addition to these specific characteristics attention was given to the indefinable similarities in the ruga pattern in fraternal and identical twins.

The casts constituting the material for this study were already divided into identical and fraternal twins when received by the author.

Pilot study

Material and method

The study group for the preliminary survey of the influence of heredity on the rugae and the incisive papilla consisted of 50 identical pairs of twins (20 ♂♂ + 30 ♀♀) with ages ranging from 7 to 40 years.

The spotting of identical twins had been performed on the basis of their general similarity, supplemented by the shape of the ears and the colour of the eyes. In all 9 pairs in which a blood test was performed (factors: A-B-O, M-N, Rh, C-D-E, S and P) confirma-

tion of the correct selection made on the basis of general similarity was obtained (Lundström, 1954).

The subjects were arranged according to sex and age. For most of the characteristics comparisons were made within pairs and between pairs. In the latter, twin *a* of the first pair was compared with twin *a* of the second pair, and likewise for the *b* twins of each pair. The third and fourth pairs were similarly compared, and so on.

Comparison between the members of each pair gives an expression of the variation due to non-genetic factors (and the observation error), while comparison between pairs—that is, between unrelated subjects—gives an expression of the variation due to both genetic and non-genetic factors (and the observation error). It should be pointed out that a larger variation in the latter group than the former might be ascribed to a greater variation of either hereditary and environmental influences, as unrelated subjects, besides being genetically different, also grow up under more varied environment than twins (Dahlberg, 1942).

A larger variation between pairs than between the members of the pairs is thus not necessarily a direct expression of the greater influence of heredity in respect of the properties examined. On the other hand, a similar variation within the two groups would suggest that for the characteristic in question there is no reason to take into account any marked genetic variation.

The magnitude of the variation for continuously variable characteristics was calculated by determining the standard deviation for the differences within and between pairs, according to Dahlberg's

(1926) formula $\sigma_0 = \sqrt{\frac{\sum d^2}{n}}$, where *d* is the difference between two compared subjects and *n* the number of observed pairs. The standard error of the standard deviation for the differences was obtained from

the expression $\varepsilon(\sigma_0) = \frac{\sigma_0}{\sqrt{2n}}$.

The comparisons in respect of the ruga direction relate to the R I and R II (the mean for the left and right sides). A comparison of the third rugae and those posterior thereof would have introduced a high degree of uncertainty as the members of a twin pair often have different numbers of rugae and it cannot therefore be known whether, for instance, the third ruga of one twin is homologous with

the third ruga of the other. This argument applies in some measure to the R II, while in respect of the R I there can be hardly any question of homology.

For certain characteristics (number, shape, origin, and papillate rugae) comparison within and between pairs has been illustrated only graphically. Comparisons (except in respect of number) then pertain to the first three rugae.

It has been maintained that identical twins may sometimes be mirror images of one another. A comparison between the sides would then possibly give a misleading result. Comparisons were therefore performed between the sums of the values for the left and right side.

The occurrence of the rarer branched, united and broken rugae and uncommon details in both members of a pair was examined.

Results

The variation in the *number of primary rugae* is approximately the same within and between pairs; the same applies to the *sum of all recorded rugae*. For these values and for shape, origin and papillate rugae see Figs. 30-34.

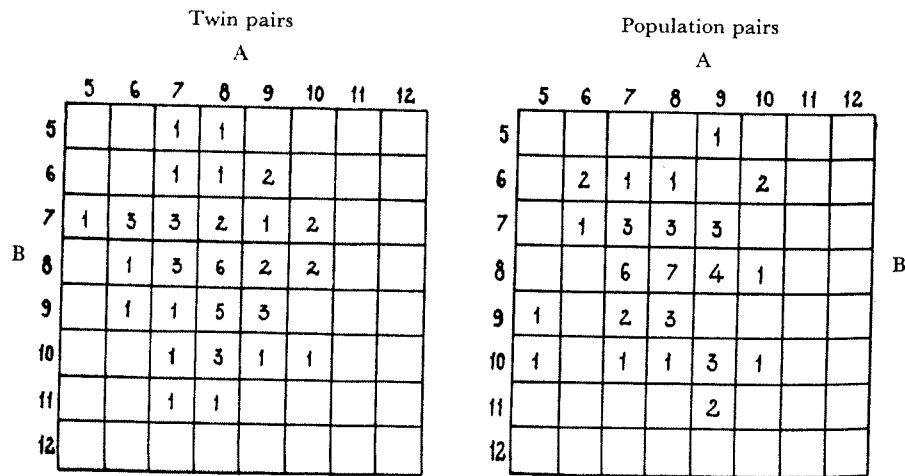


FIG. 30. Frequency of concomitance of numbers of primary rugae in identical twin pairs and population pairs. A = first and B = second member of the pair.

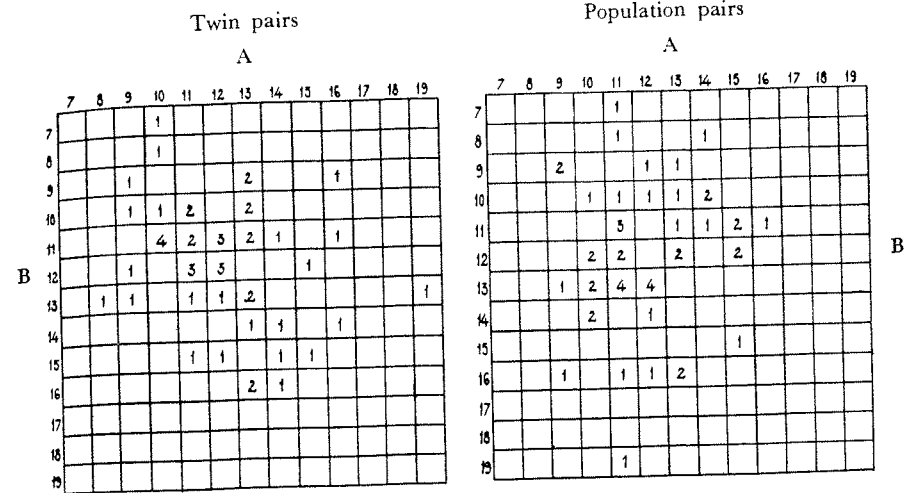


FIG. 31. Frequency of concomitance of numbers of all rugae in identical twin pairs and population pairs. A = first and B = second member of the pair.

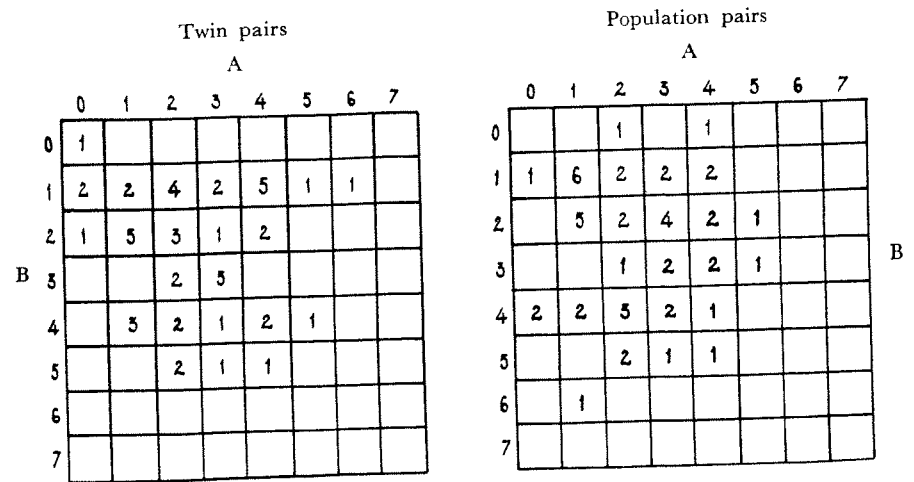


FIG. 32. Frequency of concomitance of numbers of angular rugae in identical twin pairs and population pairs. A = first and B = second member of the pair.

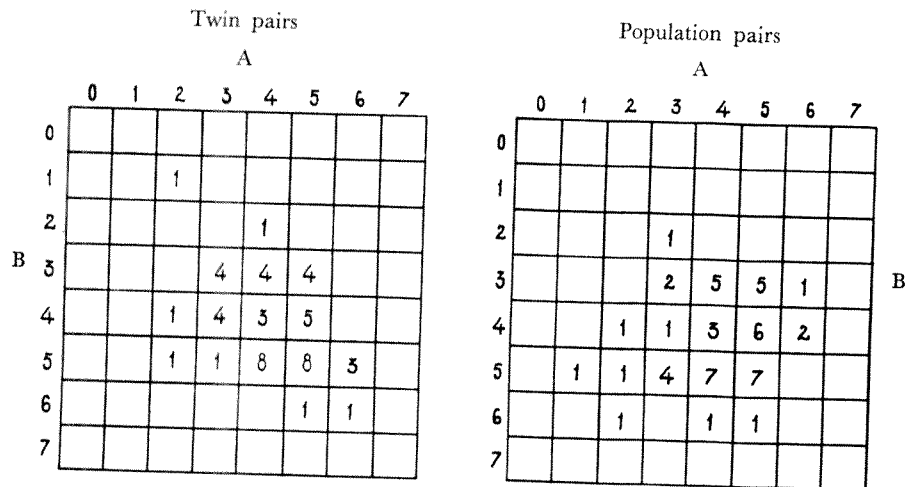


FIG. 33. Frequency of concomitance of numbers of rugae with origin in contact with the palatine raphe in identical twin pairs and population pairs. A = first and B = second member of the pair.

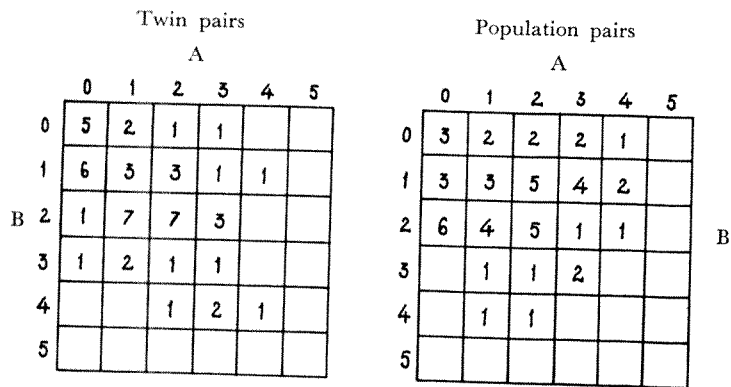


FIG. 34. Frequency of concomitance of numbers of papillate rugae in identical twin pairs and population pairs. A = first and B = second member of the pair.

For the *shape of the rugae* the comparison was made on the number of angular rugae; for the *ruga origins* the number of rugae beginning in contact with the raphe was used. In both these comparisons and for the number of papillate rugae the variation was much the same in both the compared groups. Accordingly, there is no reason

TABLE 42 Pilot study on twins. Standard deviation σ_0 in the direction (in degrees, mean for left and right palatal halves) of the rugae for differences within and between pairs.

	No. twin pairs	Within pairs $\sigma_0 \pm \epsilon (\sigma_0)$	No. pairs	Between pairs $\sigma_0 \pm \epsilon (\sigma_0)$	Difference
Ruga I					
♂	20	11.52 ± 1.82	20	12.47 ± 1.97	0.95 ± 2.68
♀	30	9.10 ± 1.17	30	14.89 ± 1.92	5.79 ± 2.25 (<i>t</i> = 2.57*)
♂ + ♀	50	10.14 ± 1.01	50	13.96 ± 1.40	3.82 ± 1.73 (<i>t</i> = 2.21*)
Ruga II					
♂	20	10.65 ± 1.68	20	15.43 ± 2.44	4.78 ± 2.96 (<i>t</i> = 1.61)
♀	30	16.97 ± 2.19	30	21.13 ± 2.73	4.16 ± 3.50 (<i>t</i> = 1.19)
♂ + ♀	50	14.77 ± 1.48	50	19.05 ± 1.91	4.28 ± 2.42 (<i>t</i> = 1.77)

to suspect that the variability between subjects is influenced by heredity.

The *direction of the rugae* is shown in Table 42. The possibility of the variability of the first ruga in female twins being influenced by heredity could not be excluded, and a closer study was therefore made.

Of the 50 pairs 39 have *branched rugae*. In 21 pairs they occur in only one member of the pair, and the number of branched is then 26, or 1.24 ± 0.10 per subject. Among the remaining 18 pairs both twins have branched rugae, the mean being 1.56 ± 0.11 per subject. It is thus possible, when the number of branches increases, to find a tendency for them to appear in both members of a pair simultaneously (*t* = 2.13*).

United rugae occur in 15 subjects (18 united rugae) and on no occasion in both twins of a set.

Broken rugae occur in 14 subjects (15 rugae). In 2 pairs both members have one broken ruga.

Uncommon details were observed in 33 persons, who together had 36 (11 instances of union between primary rugae and secondary or fragmentary rugae, 24 of minor branches, and one instance of a semi-

TABLE 43 Pilot study on twins. Standard deviation σ_0 in length, width (mm) and W/L index of the incisive papilla for differences within and between pairs.

	No. twin pairs	Within pairs $\sigma_0 \pm \varepsilon (\sigma_0)$	No. pairs	Between pairs $\sigma_0 \pm \varepsilon (\sigma_0)$	Difference
Length					
♂	18	0.85 ± 0.14	18	1.69 ± 0.28	0.84 ± 0.31 ($t = 2.71^*$)
♀	28	0.97 ± 0.13	27	2.26 ± 0.31	1.29 ± 0.34 ($t = 3.79^{***}$)
♂ + ♀	46	0.92 ± 0.10	45	2.05 ± 0.22	1.13 ± 0.24 ($t = 4.71^{***}$)
Width					
♂	18	0.63 ± 0.11	18	1.03 ± 0.17	0.40 ± 0.20 ($t = 2.00$)
♀	28	0.53 ± 0.07	27	0.89 ± 0.12	0.36 ± 0.14 ($t = 2.57^*$)
♂ + ♀	46	0.57 ± 0.06	45	0.95 ± 0.10	0.38 ± 0.12 ($t = 3.17^{**}$)
W/L index					
♂	18	4.74 ± 0.79	18	13.82 ± 2.30	9.08 ± 2.43 ($t = 3.74^{***}$)
♀	28	9.11 ± 1.22	27	14.19 ± 1.93	5.08 ± 2.28 ($t = 2.23^*$)
♂ + ♀	46	7.70 ± 0.80	45	14.04 ± 1.48	6.34 ± 1.68 ($t = 3.77^{***}$)

circular termination to a ruga). In 7 pairs the same detail was observed in both members (6 times a minor branch, and once a union of a primary and a secondary ruga).

The shape of the incisive papilla. In 24 of the 50 pairs both twins had papillae of the same shape, while comparison between pairs showed agreement in 14 cases. In 4 pairs comparison was not possible because the incisive papilla could not be observed in one or both members of the pair.

The values for the length and width of the *incisive papilla* and W/L index suggest a possible genetic influence. The case series is, however, so small that statistically significant values were obtained for the male and female groups combined but not always for them separately (Table 43).

To summarize, no hereditary influence could be traced in respect of the number of rugae, or the various characteristics of the single primary rugae, with the possible exception of direction. It was found, on the other hand, that there might be a hereditary influence in respect of the length and width of the incisive papilla, and further study was thus indicated.

The incisive papilla

A closer study was made of the incisive papilla, attention being centred on the relationship between genetic and non-genetic factors and hereditary transmission.

GENETIC AND NON-GENETIC FACTORS

Material

This study was performed in 113 identical and 121 fraternal twin pairs (40 ♂♂ + 73 ♀♀ and 59 ♂♂ + 62 ♀♀, respectively). The mean and the standard error of the mean for the ages were, for (a) identical pairs: 16.2 ± 1.0 years (range 9–40 years) for males and 17.3 ± 0.72 years (range 7–36 years) for females, (b) fraternal pairs: 14.1 ± 0.35 years (range 11–28 years) and 14.4 ± 0.34 years (variation 10–23 years).

Method

The magnitude of the variation was determined for the various characteristics using the above formula (p. 111).

In the calculation of the isolated influence of genetic and non-genetic factors the standard deviation for the individual member was used, this being obtained from the s. d. for the differences between the members of the pairs by dividing by $\sqrt{2}$. In this manner the standard deviation becomes comparable with the observation error and the s. d. for the population.

The standard deviations for genetic and non-genetic factors were calculated in the following manner. For the identical twins the s. d. (σ_{II}) is due to non-genetic factors and the error of the method (σ_1), and for the fraternal twins the s. d. (σ_{II}) is due to these two factors together with the genetic factors. The standard deviation for non-genetic factors only and genetic only are given by

$$\sigma_{\text{non-gen}} = \sqrt{\sigma_I^2 - \sigma_{II}^2}$$

$$\sigma_{\text{gen}} = \sqrt{\sigma_{II}^2 - \sigma_I^2}$$

From these expressions the ratio between genetic and non-genetic factors $\left(\frac{\sigma_{\text{gen}}}{\sigma_{\text{non-gen}}}\right)$ is obtained.

Results

Table 44 shows that the differences in the standard deviation for identical and fraternal twins in respect of the length, width of the incisive papilla and W/L index are significant.

TABLE 44 Twin study. Standard deviation σ_0 of intrageminal differences in length, width (mm) and W/L index of the incisive papilla.

	Sex	Identical twins		Fraternal twins		Difference
		No. twin pairs	$\sigma_0 \pm \epsilon (\sigma_0)$	No. twin pairs	$\sigma_0 \pm \epsilon (\sigma_0)$	
Length	♂	40	0.78 ± 0.09	59	1.56 ± 0.14	0.78 ± 0.17 mm (<i>t</i> = 4.59***)
	♀	73	0.79 ± 0.07	62	1.32 ± 0.12	0.53 ± 0.14 mm (<i>t</i> = 3.79***)
	♂ + ♀	113	0.79 ± 0.05	121	1.44 ± 0.09	0.65 ± 0.10 mm (<i>t</i> = 6.50***)
Width	♂	40	0.55 ± 0.06	59	0.95 ± 0.09	0.40 ± 0.11 mm (<i>t</i> = 3.64***)
	♀	73	0.50 ± 0.04	62	0.82 ± 0.07	0.32 ± 0.08 mm (<i>t</i> = 4.00***)
	♂ + ♀	113	0.52 ± 0.03	121	0.89 ± 0.06	0.37 ± 0.07 mm (<i>t</i> = 5.29***)
W/L index	♂	40	6.77 ± 0.76	59	15.02 ± 1.38	8.25 ± 1.58 (<i>t</i> = 5.22***)
	♀	73	8.43 ± 0.70	62	13.12 ± 1.18	4.69 ± 1.37 (<i>t</i> = 3.42***)
	♂ + ♀	113	7.88 ± 0.52	121	14.08 ± 0.91	6.20 ± 1.05 (<i>t</i> = 5.90***)

For the combined male and female groups the ratio between genetic and non-genetic factors was calculated. For length, width and W/L

TABLE 45 Comparison between genetic and non-genetic variation (expressed as the standard deviation) in length, width (mm) and W/L index of the incisive papilla.

Character	Genetic variation		Non-genetic variation		$\frac{\sigma_{\text{gen}}}{\sigma_{\text{non-gen}}}$
	No. twin pairs	σ_{gen}	No. twin pairs	$\sigma_{\text{non-gen}}$	
Length	121	0.85	113	0.55	1.6
Width	121	0.51	113	0.36	1.4
W/L index	121	8.36	113	5.41	1.6

index the ratios 1.6, 1.4 and 1.6 were obtained (Table 45). Lundström (1951) obtained a mean of about 1.4 for this ratio with a larger number of characteristics of the teeth and jaws.

HEREDITARY TRANSMISSION

Material

The case material of this study of hereditary transmission in respect of the incisive papilla comprised 39 families of parents aged 33 to 54 years ($\bar{x} = 43.7 \pm 0.6$ years) with at least two children (total 92 children, 52 boys and 40 girls aged 7–22 years; $\bar{x} = 13.1 \pm 0.3$ years).

Method and results

Large variations in respect of length, width and W/L index were revealed.

For a correct comparison between members of a family it is necessary that any difference in sex or age for the characteristic in question should be eliminated by means of a correction factor.

In respect of length and width of the incisive papilla several statistically significant differences could be established between the age groups to which the subjects were assigned. In respect of the W/L index the sex and age differences appear to be smaller.

Comparison within families were therefore made only in respect of this characteristic and as a mean the index value of 50.00 was taken, this being close to the common mean for all the age groups in question.

For each subject in these families the difference between the value of the index and the mean was found, a positive difference represent-

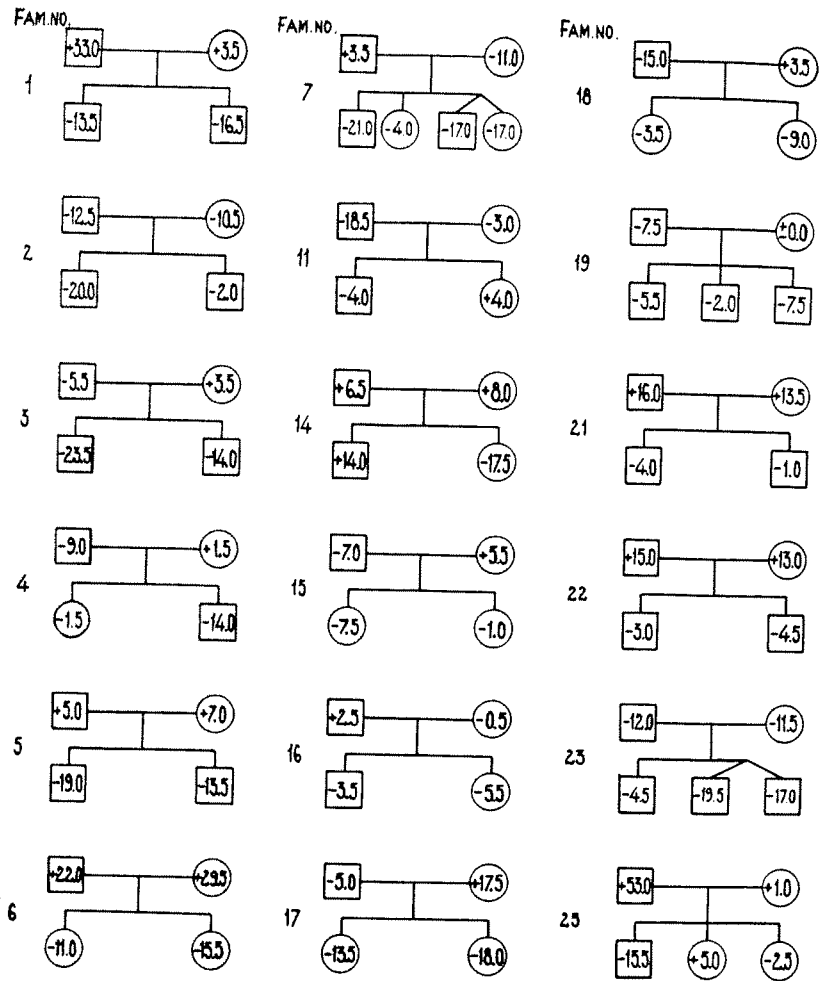


Fig. 35 a.

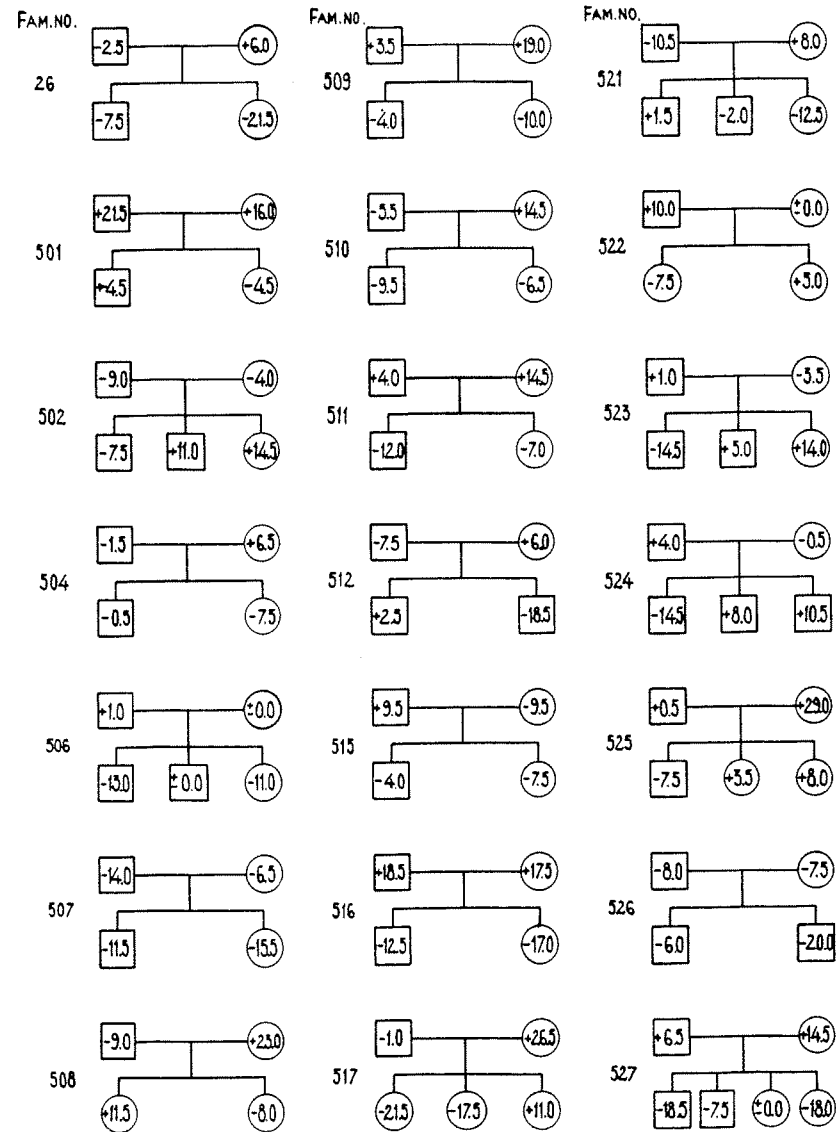


Fig. 35 b.

FIG. 35. Pedigrees for 40 families giving width/length index of the incisive papilla. The figures are differences from the assumed mean 50.00.

ing a higher index than the mean and a negative difference a lower index. These differences are included in the figure. The whole case series is represented graphically in Fig. 35.

A study of hereditary transmission is best made on families where the index values of both parents are similar and preferably show extreme deviation from the mean. The latter condition is, however, difficult to realize in so limited a case series.

There are families where all members show negative values—Nos. 23 and 507, for instance—and there are also those where the parents have both positive values and both children negative—No. 516. In most cases the positive and negative values would appear to indicate no definite tendency.

The direction of the rugae

The case series was the same as for the study of the incisive papilla. The direction was studied in the first two rugae in the same manner as in the pilot experiment. The magnitude of the variation in identical and fraternal twins is given in Table 46.

The results are largely in accord with those observed in the pilot experiment. The values for the female subjects suggest a likely influence of heredity on the direction of the first rugae. In the males no such tendency was observed. No difference in the variability for the second rugae was detected between identical and fraternal twins.

The ratio *genetic/non-genetic* for the whole series (0.72) suggests that the hereditary influence would not be of the same size as the non-genetic for the direction of the first ruga. The dissimilarity in the values between the male and female groups renders the ratio unreliable, however.

The general similarity of the ruga pattern

IDENTICAL TWINS

The comparisons of genetic factors are all in respect of some specific characteristic or detail in the ruga pattern. Nilles states, however, that the hereditary similarities in the pattern should sometimes be evident "at a glance".

If such similarities exist they would be more easily and reliably

TABLE 46 Twin study. Standard deviation σ_0 of intrageminal difference of the direction (in degrees, mean for left and right side) of first and second rugae in identical and fraternal twins.

	Identical twins		Fraternal twins		Difference
	No. twin pairs	$\sigma_0 \pm \epsilon (\sigma_0)$	No. twin pairs	$\sigma_0 \pm \epsilon (\sigma_0)$	
<i>Ruga I</i>					
♂	42	10.53 ± 1.15	58	10.19 ± 0.95	3.94 ± 1.40 (<i>t</i> = 2.81**)
♀	74	9.25 ± 0.76	63	13.19 ± 1.18	
♂ + ♀	116	9.72 ± 0.64	121	11.85 ± 0.76	2.13 ± 0.98 (<i>t</i> = 2.17*)
<i>Ruga II</i>					
♂	42	15.08 ± 1.65	57	13.31 ± 1.25	
♀	73	16.39 ± 1.36	54	15.87 ± 1.53	
♂ + ♀	115	15.92 ± 1.05	111	14.61 ± 0.98	

observed the closer the relationship between the individuals. Figs. 36 & 37 demonstrate the similarities in the ruga patterns of identical and fraternal twins.

This possibility has been tested in this investigation, in which 50 pairs of identical twins were studied. The ruga pattern and the incisive papilla were drawn on the plaster casts in the usual manner; the casts were then numbered arbitrarily. The teeth were screened so as not to be of assistance in the test and the casts photographed with the optical axis and plane of occlusion at right angles.

The similarity test involved the examination of 20 mixed photographs representing 10 identical pairs, the examiner trying to pair the photographs by inspection. The results were noted and passed to the person in possession of the correct matchings. In two tests 30 and 50 photographs (representing 15 and 25 pairs) were compared in the same way. The results were noted. After a fortnight the test was run again with all 100 photographs at once. Two weeks later the procedure was repeated in respect of the combination of 10, 15 and 25 pairs, after which a further two weeks was allowed to elapse and the 100 photographed paired a second time.

In addition to the author 4 persons performed the process of pairing. The results are given in Table 47. A consistently better result was obtained by the author than by the other examiners, the reason for which may lie in the author's greater practice in estimation.

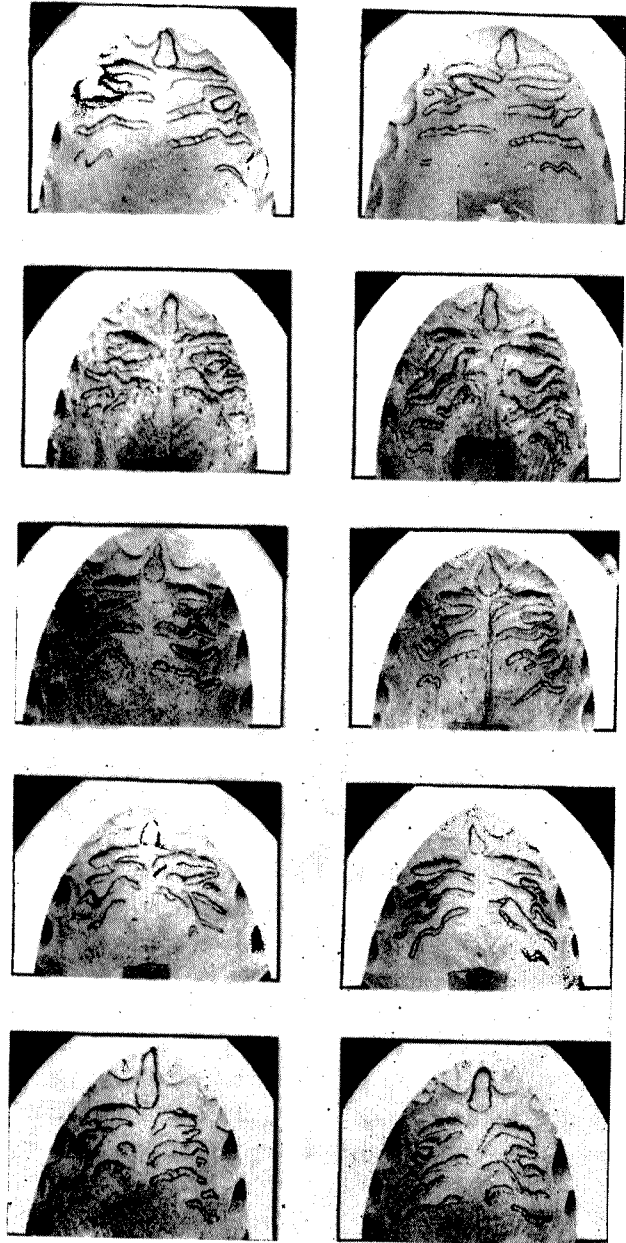


FIG. 36. Five pairs of identical twins taken at random.

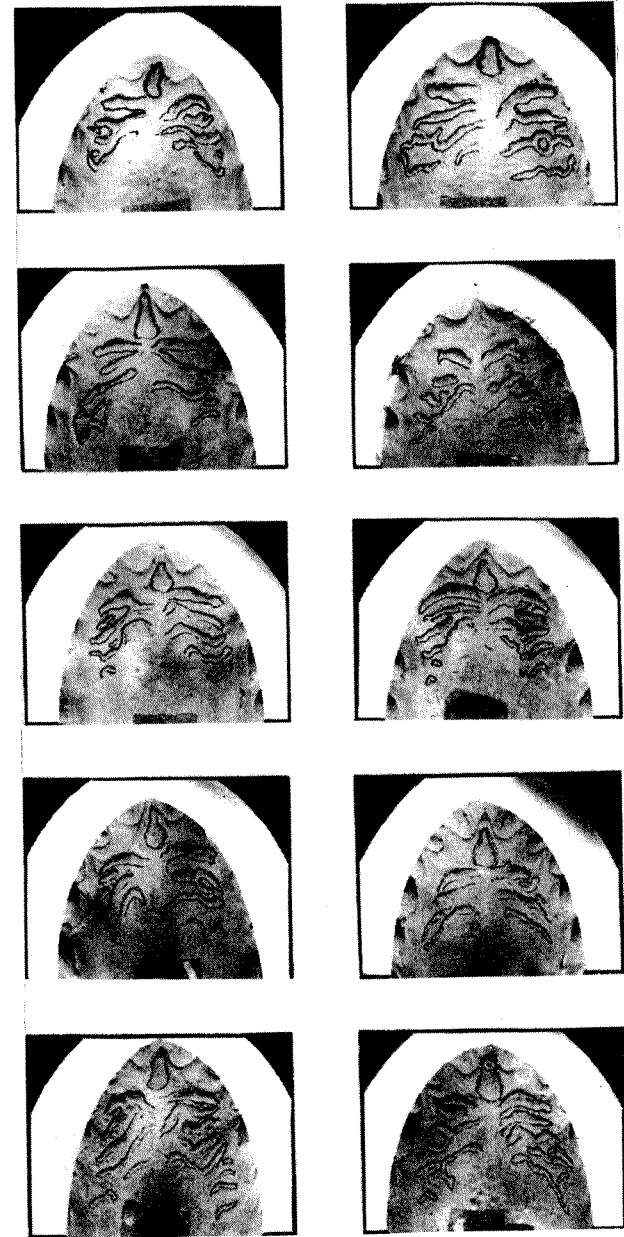


FIG. 37. Five pairs of fraternal twins taken at random.

TABLE 47 Results of pairing ruga pattern photographs of identical twins.

No. pairs	No. correct pairings					
	Examiner					
	I: 1	I: 2	II	III	IV	V
10	10	10	6	5	8	5
15	13	15	8	7	8	8
25	13	20	13	5	10	13
50	31	36		12		

I: 1 and I: 2 denote the author's first and second run, respectively,

A scrutiny of the results shows that there is, for all examiners, a number of "certainties" that are always correctly spotted; the variation between examiners then depends on the number of pairs with less evident similarities that can be correctly matched.

SELECTION OF IDENTICAL AND FRATERNAL TWINS

Comparisons between identical pairs showed that the similarities ascribable to heredity are evident in the general structure of the ruga pattern to a degree that makes it possible within limits to select identical pairs from the photographs.

It should then to some extent be possible with the guidance of the photographs of the ruga pattern and the incisive papilla to decide whether a given pair of twins is identical or fraternal.

This was further tested by comparing 25 sets of identical pairs taken at random from among the above and 25 pairs of fraternal twins of which photographs were made in the same manner as for the identical pairs.

The comparison entailed successive judgement of the pairs, the numbers being invisible. The results were given directly to the person with the correct matchings. As the examiner was not permitted to write down the numbers of pairs already judged, the likelihood of mental "compensation" in the judgement of the last pairs was reduced.

In the first run 43 of 50 pairs were correct (22 identical and 21 fraternal). Two weeks later the figures were 44 pairs (23 identical and 21 fraternal).

Summary

1. There was no clear evidence of any hereditary influence on the variation in the number of rugae and the various characteristics of the individual ruga.
2. There is evidence of a certain hereditary influence on the length and width of the incisive papilla and the W/L index, the mean ratio *genetic/non-genetic* being approximately 1.5.
3. No conclusions relating to the hereditary transmission for the characteristics of the incisive papilla could be drawn from the study.
4. Comparisons of twins suggest that there are in the ruga pattern general, indefinite similarities due to heredity.
5. These differences may serve as a guide in distinguishing identical and fraternal twins.

PATERNITY DETERMINATION

Neither the number nor the details of the primary rugae appeared to be influenced appreciably by genetic factors. On the other hand the incisive papilla did present indication of such influence in respect of length and width, as did the ruga pattern in its general structure. An examination of the width and length data in families for evidence of hereditary transmission yielded no results on which conclusions could be based. A study was then made of whether the similarity in the general structure of the ruga pattern evidenced in identical twins could be traced between parents and children.

No study of actual hereditary transmission was possible, but only of greater or smaller similarities between the various subjects.

Such similarities have assumed some practical significance in recent years. Attempts have been made to apply the rugae—considered from various aspects—to anthropologic paternity determination (Nilles, 1950; Klenke, 1951; and others).

On the basis of the results of this investigation the value of similarity of pattern in determination of paternity was tested experimentally. This similarity appeared to provide the only remaining possibility of demonstrating a relationship between persons by means of the rugae and the incisive papilla.

Material and method

The material for the tests was the same family study group as that used in the examination of hereditary transmission in respect of the incisive papilla.

Casts of the father, mother and youngest child in each family were numbered arbitrarily and photographed in the same way as the twins. As there is generally only one child involved in paternity cases only one was considered in this experiment.

The mother and child in each family were grouped with the father of the family and a father from another family taken at random. This choice was made by giving the families numbers from 1 to 40 in order of registration. From the "first thousand" in a table of random numbers (Kendall & Smith, 1946) the numbers 1 to 40 were taken in the order in the table and paired with the family numbers. Thus, the first number obtained from the table gave the family from which the father should be taken for comparison with the father of the Family No. 1. The next selected number indicated the family from which the father should be taken for pairing with the father of Family No. 2, and so on. The numbers already used were rejected the next time they appeared, as were the numbers which coincided with the number of the family with which it should be paired.

In this way the examiner compared each of the 40 families with a man taken at random from the other families and was required to indicate which of the two men was the more likely to be the father of the child.

It was not possible to exclude the chance that the family father was not the biologic father. On the other hand, it may be assumed that in no case was the man taken at random from the other families the biologic father. In as far as an evident hereditary influence might exist, combinations of this kind would therefore tend to indicate that neither of the two fathers may be considered as the probable father. Since these cases would be rare it is unlikely that they would affect any conclusions that may derive from experiment.

In order that the examiner should not be able to make use of the numbers on the casts of the fathers (as these must occur twice) the numbers were made invisible.

As it might be presumed *a priori* that in some cases similarities between the two possible fathers might render it difficult to point out only one as the possible father, it was decided that these cases should be recorded in a group where the examiner expressed no opinion on the paternity. In this way the results were made less dependent on chance than if the examiner in each case had been obliged to make a choice.

In the above comparisons the man considered to be the father was pointed out (positive paternity determination), while in another test the possibility of the man not being the father was considered

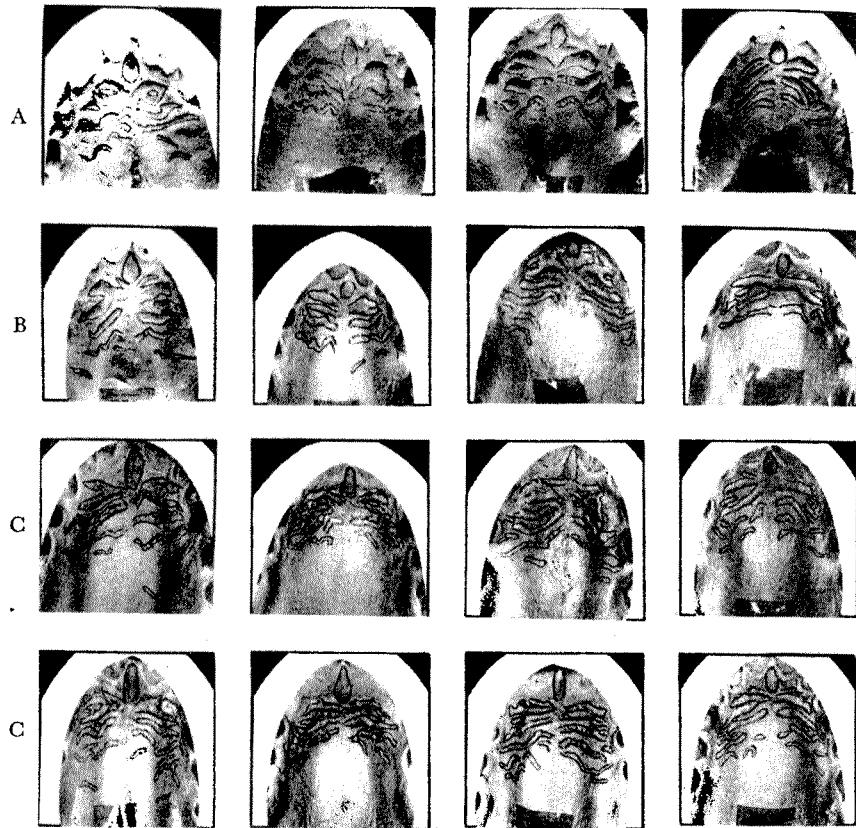


FIG. 38. Four families taken at random.
A = fathers B = mothers C = children

(negative paternity determination). This possibility was tested on the same study group. In one half of the cases the family fathers were paired with their correct families and in the remaining 20 families the fathers were paired randomly.

The examiner was given photographs of the ruga pattern of the mother, child and one man who in only one half of the cases was the family father, and was required to indicate whether the man could be excluded from the paternity or not. (It would be expected that there would be only a few cases where it was possible to exclude the man as the father.)

Results and discussion

In the first examination where the examiner had to choose between two fathers the correct one was chosen in 22 and the incorrect in 11 cases, while no decision was made in the remaining 7 cases. It is evident, however, that the results may as well be due to chance as the selection by the examiner.

In the second experiment the examiner in 3 cases excluded the family father from paternity, while the "exchange" father was considered not to be the father in 4 cases. This test shows that it is probably difficult to exclude a man from paternity with the guidance of the ruga pattern (only 4 in 40 cases). However, it was also erroneous in 3 cases (excluding the possibility of illegitimity).

To summarize, the results of these paternity experiments indicate that it is impossible to use the ruga pattern alone for determination of paternity. It is possible, however, that the analysis of the ruga pattern may be of some assistance in a general anthropologic study of paternity determination.

To illustrate the difficulty of detecting similarities in the ruga patterns, four examples from families taken at random are reproduced in Fig. 38.

GENERAL SUMMARY

(Summaries are provided at the end of most chapters)

A system of recording the rugae and the incisive papilla is presented.

The rugae are classified as primary, secondary and fragmentary. The characteristics considered are: number of all types and, for the primaries, the shape, direction, branching, union, continuity, papillate appearance, position of origin in relation to the palatine raphe, and the posterior limit of the rugae in relation to the teeth.

The incisive papilla is recorded in respect to shape, length and width.

The error of recording was calculated. For one examiner the error was fairly small for all characteristics. For two examiners it was roughly the same as for one, except for certain characteristics, the most divergent being the shape of the rugae and the incisive papilla.

The variability of the ruga pattern was studied in adults. In respect of certain essential characteristics such as the number of rugae and the size of the incisive papilla the results largely accord with those of other workers. It has been assumed that the numbers of rugae reported by other authors refer to what in this study has been called the *primary* ruga. In many respects comparisons are difficult or impossible to make on account of the lack of definitions.

Studies of the ruga pattern in various age groups and serial observations of a single subject show that in general the rugae are unchanged throughout life, although this is not true for each detail. There are evident changes in some characteristics during growth of the jaw, and particularly in connection with atrophic processes in the senile dentition; during growth, for example, the relationship between the rugae and the teeth tends to alter, the latter moving forwards in relation to the rugae, while in older subjects the most evident change is a reduction in the number of rugae.

It should be possible for the rugae to be used for identification in

spite of the changes in the pattern, provided that a set of satisfactory definitions could be found which would facilitate search in the archives. To some extent mistakes might be avoided with the aid of photographs, but the system would still tend to be cumbersome. It seems doubtful, however, whether the ruga pattern can provide a suitable basis for identification, even if a fool-proof system could be devised, in virtue of the changes that occur during life. Whatever the system, it does not approach the finger-print method in reliability where the basis is a pattern that is unchanged throughout life.

A further disadvantage of the rugae for this purpose is the complicated technique involved.

There are certain cases where the finger-prints cannot be used but where the rugae can—as in fires, where the body has been burned—, but these are extremely few and it is rare that no other means of identification exists.

Similarities due to hereditary influence have been studied in twins. The only ruga characteristic that presented evidence of such an influence was the direction of the primaries. The length, width and width/length index of the papilla exhibited a fairly definite influence, the mean *genetic/non-genetic* ratio being about 1.5. No conclusions could be drawn in respect of hereditary transmission for the papilla, which was studied in a series of families.

Comparison between twins suggest that the ruga pattern presents certain general, undefinable attributes which might offer guidance in determination of identical and fraternal twins.

Theoretical tests on the lines of legal paternity cases provided no evidence that the ruga pattern alone is a reliable guide to the determination of paternity. It is possible, however, that the analysis of the ruga pattern may be of certain value in a general anthropologic study of paternity determination.

REFERENCES

Abbreviations according to the *World List of Scientific Periodicals*. London (1952)

- ALLEN, HARRISON, 1889: The palatal rugae in man. *Proc. Acad. nat. Sci. Philad.* 1888, p. 254.
- AUFIERO, V. & GESATI, F., 1940: Le pieghe palatine e la loro importanza nella identificazione personale. *Stomat. ital.* 2: 567.
- BJÖRK, A., 1947: The face in profile. *Svensk tandläk. Tidskr.* 40, Supplement. Diss., p. 64 & 126. Lund.
- BLOMQUIST, K., 1953: Dimensionella förändringar hos olika alginatavtrycks-material. *Odont. Revy* 4: 251.
- BROMAN, I., 1936: Människokroppen. Del III, p. 92. Lund.
- BROOMELL, I. N., 1902: Anatomy. Second Edition, p. 32. London.
- CARRERA, J. U., 1937: La identificación humana por las rugosidades palatinas. *Rev. Ortodoncia* 1: 3. Buenos Aires.
- , 1940: Rugo-estenografía paladale técnica argentina de identificación humana. *Academia de Ciencias de Buenos Aires*, Tome I: 75. Buenos Aires.
- , 1955: Gaumenfalten-Fotostenogramme, ein neues Identifizierungsverfahren. *Dtsch. zahnärztl. Z.* 10: 11.
- CRUVEILHIER, J., 1837: Anatomie descriptive. Tome Premier, p. 396. Bruxelles.
- , 1843: Traité d'anatomie descriptive. Deuxième ed., Tome troisième, p. 202. Paris.
- CUVIER, G., 1845: Leçons d'anatomie comparée. Seconde Edition, Tome troisième, p. 745. Paris.
- DAHLBERG, G., 1926: Twin Births and Twins from a Hereditary Point of View. Diss. Stockholm.
- , 1942: Methodik zur Unterscheidung von Erbliehkeits- und Milieuvaiiationen mit Hilfe von Zwillingen. *Hereditas, Lund* 28: 409.
- DIEULAFÉ, L. & HERPIN, A., 1909: Anatomie de la bouche et des dents, p. 34. Paris.
- DORLAND, W. A. NEWMAN, 1944: The American Illustrated Medical Dictionary, 20th Edition. Philadelphia and London.
- DREYER JØRGENSEN, K., 1954: Investigation on the expansion properties of some dental model plasters. *Acta odont. scand.* 12: 24.
- EDWARDS, H. MILNE, 1860: Leçons sur l'anatomie comparée de l'homme et des animaux. Tome Sixième, p. 119. Paris.
- FRIEL, S., 1949: Migration of teeth. *Dent. Rec.* 69: 74.
- GEGENBAUR, C., 1878: Die Gaumenleisten des Menschen. *Morph. Jb.* Vierter Band, p. 573.
- , 1901: Vergleichende Anatomie der Wirbelthiere. Zweiter Band, p. 91. Leipzig.
- , 1903: Lehrbuch der Anatomie des Menschen. Siebente verbesserte Auflage, Zweiter Band, p. 10. Leipzig.
- GORIA, C., 1911: Le rughe del palato in speciale rapporto coll'anthropologia criminale e la psichiatria. *Arch. Anthropol. Crim.* 32 (Vol. III della serie IV), p. 72.
- HALD, A., 1948: Statistiske Metoder. København.
- HAUSSER, E., 1950: Das Verhältnis zwischen Gaumenfalten und Zähnen. *Dtsch. zahnärztl. Z.* 5: 879 and 1016.
- , 1951: Zur Bedeutung und Veränderung der Gaumenfalten des Menschen. *Stoma* 4: 3.
- HENCKEL, K. O., 1926: Die Gaumenleisten von 11 Papua and Melanesiern. *Z. Morph. Anthr.* 26: 127.
- HENLE, J., 1862: Handbuch der systematischen Anatomie des Menschen. Zweiter Band, p. 79. Braunschweig.
- HIROTA, K., 1933: The morphological and statistical studies on plicae palatinae transversae of Japanese. *J. anthrop. Soc. Tokyo.* 48, Nos. 543—554: 599. (Japanese text.)
- HÄGGQVIST, G., 1934: Lärobok i histologi och embryologi för tandläkarstuderande, p. 206. Stockholm.
- KENDALL, M. G. & SMITH, B. BARBINGTON, 1946: Tracts for Computers. No. 24. Tables of random sampling numbers. Cambridge.
- KENDRICK JR., Z. V., 1950: The physical properties of agar type hydrocolloid impression material. *J. Amer. dent. Ass.* 40: 575.
- KLENKE, W., 1951: Die Gaumenfalten im Vaterschaftsnachweis. *Homo* 2: 69.
- , 1951: Das Gaumenrelief im Vaterschaftsnachweis. *Umschau* 51: 370.
- KNISCHEWSKI, F., 1951: Materialienkunde der Zahntechnik. Teil I: Nichtmetallische Werkstoffe. München.
- KORKHAUS, G., 1939: Handbuch der Zahnheilkunde. Vierter Band, p. 78. München.
- , 1942: Über den Einfluss der Erbmasse auf das Gebiss. Befunde an Drillingen und Vierlingen. *Europ. Orthodontic Soc. Rep. of the Twenty-Third Congress*, p. 19. Leipzig.
- LAFOND, M., 1930: La surface palatine chez les mammifères et l'homme. *Rev. Stomat.* 32: 620.
- LOCCHI, R., 1930: Sur les "plicae palatinae transversae" chez diverses races humaines. *C. R. Ass. Anat.* III^e Congrès Fédératif International et XXV^e Réunion, p. 217.
- LOTH, E., 1931: Anthropologie des parties molles, p. 279. Paris and Warsaw.
- LUNDSTRÖM, A., 1948: Tooth Size and Occlusion in Twins. Diss. Basle and New York.
- , 1951: The aetiology of crowding of the teeth. *Europ. Orthodontic Soc. Rep. of the Twenty-Seventh Congress*, p. 176. The Hague.

- , 1954: The importance of genetic and non-genetic factors in the facial skeleton studied in 100 pairs of twins. *Europ. Orthodontic Soc. Rep. of the Thirtieth Congress*, p. 91. The Hague.
- VON LUSCHKA, H., 1867: Die Anatomie des Menschen in Rücksicht auf die Bedürfnisse der praktischen Heilkunde. Zweite Auflage, Dritter Band, p. 320. Tübingen.
- MERKEL, FR., 1885–90: Handbuch der topographischen Anatomie. Erster Band, p. 389. Braunschweig.
- MURAKAMI, K., 1928: Die Gaumenleisten der Japaner. *Arb. anat. Inst. Sendai* 14: 1.
- NILLES, K., 1950: Morphologische und erbbiologische Studien über das Gaumenmuster. Inaug.-Diss. Heidelberg (typescript).
- , 1952: Das Gaumenrelief als diagnostisches Hilfsmittel beim anthropologischen Vaterschaftsnachweis *Stoma* 5: 121.
- Nomina Anatomica, 1949. Vierte, durchgesehene Auflage, p. 64. Jena.
- OGAWA, H., 1940: Morphologische Untersuchung über die Gaumenleisten bei den japanischen Zwillingsfeten. *Folia anat. jap.* 19: 343.
- OHSHIMA, S., 1937: Studien am harten Gaumen der Chinesen. *J. orient. Med.* 26: 24.
- OLOW, M., 1954: A metric study of transversal size of the dental arches in children at 7, 12 and 18 years of age. *Odont. Tidskr.* 62: 266.
- ORBAN, B., 1949: Oral Histology and Embryology. Second Edition, p. 248. St. Louis.
- PAFFENBERGER, G. C., 1940: Hydrocolloidal impression materials: physical properties and a specification. *J. Amer. dent. Ass.* 27: 373.
- PETRÉN, T., 1948: Anatomi för tandläkarstudierande och tandläkare, p. 159. Trelleborg.
- PORT, G. & EULER, H., 1951: Lehrbuch der Zahnheilkunde. 6. verb. Aufl., p. 45. München.
- QUAIN, J., 1848: Elements of Anatomy. Fifth edition. Vol. II, p. 1004. London.
- , 1876: Elements of Anatomy. Eighth Edition. Vol. II, p. 333. London.
- RAUBER, A. & KOPSCH, FR., 1948: Lehrbuch und Atlas der Anatomie des Menschen. 17. Auflage, II. Teil, p. 58. Leipzig.
- RETZIUS, G., 1906: Die Gaumenleisten des Menschen und der Tiere. *Biol. Untersuch. N. F.* 13: 117.
- RITTER, R., 1943: Über die Form, den Verlauf und die Typeneinteilung der Gaumenleisten. *Z. Morph. Anthr.* 40: 367.
- ROMITI, G., 1895: Trattato die Anatomia dell'Uomo. Volume Secondo, Part V*, p. 21. Milano.
- SANDERMANN-OLSEN, TH., 1953: Karakteristik af dentale aftrykspastaer. *Tandlægebladet* 57: 333.
- SANTORINI, J. D., 1775: Septemdecim Tabulae. Parmae.
- SAPPEY, PH. C., 1857–64: Traité d'anatomie descriptive. Tome troisième, p. 28. Paris.
- SCHADE, H., 1954: Vaterschaftsbegutachtung, p. 109. Stuttgart.
- SCHOONOVER, I. C. & DICKSON, G., 1943: Preparation and characteristics of elastic

- dental impression compounds with an alginate base. *J. Amer. dent. Ass.* 30: 565.
- SCHUBERT, L., 1937: Hilfsmaterialien und Werkstoffe der zahnärztlichen Prothetik im Lichte experimentell-physikalischer Untersuchungen, sowie ihre Nutzenanwendung in der Praxis. Leipzig.
- SCHULTZ, A. H., 1949: The palatine ridges of primates. *Contr. Embryol. Carneg. Instn.* 215: 45.
- SCHWARZ, R., 1933: Individual measurements of the face and jaws before and during orthodontic treatment. *Int. J. Orthod.* 19: 22.
- SHAPIRO, H. H., 1947: Applied anatomy of the head and neck. Second Edition, p. 14. Philadelphia, London, Montreal.
- SICHER, H., 1949: Oral Anatomy, p. 186. St. Louis.
- SILVA, L., 1938: Ficha rugoscopica palatina. Systema Luiz Silva. São Paulo.
- SKINNER, E. W., 1954: The Science of Dental Materials. Fourth Edition, revised. Philadelphia and London.
- SKINNER, E. W. & KERN, W. R., 1938: Colloidal impression materials. *J. Amer. dent. Ass.* 25: 578.
- SKINNER, E. W. & POMES, C. E., 1946: Dimensional stability of alginate impression materials. *J. Amer. dent. Ass.* 33: 1253.
- , 1947: Alginate impression materials: technic for manipulation and criteria for selection. *J. Amer. dent. Ass.* 35: 245.
- SKINNER, E. W., COOPER, E. N. & BECK, F. E., 1950: Reversible and irreversible hydrocolloid impression materials. *J. Amer. dent. Ass.* 40: 196.
- SODEAU, W. H. & GIBSON, C. S., 1927: The use of plaster of Paris as an impression material. *Brit. dent. J.* 48: 1089.
- SPALTEHOLZ, W., 1920: Handatlas der Anatomie des Menschen. Neunte Auflage, p. 517. Leipzig.
- WEIKART, P., 1950: Leitfaden der zahnärztlichen Werkstoffkunde. München.
- WELDT, J., 1935: Beiträge zur Anthropologie Chiles. IV. Das Gaumenrelief von 100 Einwohnern der Stadt Concepción. *Z. Morph. Anthr.* 33: 491.
- WETZEL, G., 1920: Lehrbuch der Anatomie für Zahnärzte und Studierende der Zahnheilkunde. 2. Aufl. Teil. I, p. 361. Jena.
- , 1951: Lehrbuch der Anatomie für Zahnärzte. Sechste Auflage, p. 339. Jena.
- WINSLOW, J. B., 1732: Exposition Anatomique de la structure du corps humain. Tome IV, II^e Partie, p. 681. Paris.
- , 1743: Exposition Anatomique de la structure du corps humain. Tome quatrième, p. 355. Amsterdam.
- , 1753: Expositio Anatomica structurae corporis humani. Tomi quarti pars secunda, p. 227. Francofurti & Lipsiae.