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An investigation of 202 pairs of twins regarding fundamental factors in the aetiology of malocclusion

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Investigations concerning the aetiology of malocclusion have, in recent years, taken up still greater space in the orthodontic literature. Much of this work has been devoted to the effect of different environmental factors and an endeavour has been made to analyse the effect of such factors as birth injuries, finger sucking and other habits, extractions of deciduous and permanent teeth, insufficient function of the jaws, nasal and throat disturbances and lack of vitamins. These investigations show clearly that none of these factors inevitably produce malocclusion. On the contrary, more exact determinations on larger quantities of material have shown rather slight connections between the occurrence of these factors and malocclusion. This seems to imply that other factors must be of importance, among which the genetic factors take first place.

The significance of heredity can be studied mainly along three lines, namely by experiments on animals, by family investigations and by twin investigations. All these methods have been used in the study of malocclusion of the teeth. Crossing-experiments on animals can give us certain indications as to the fundamental principles concerning the inheritance of malocclusion but it is, of course, not possible to know if the results of such experiments are significant for man also regarding similar malocclusions. Family investigations based on fairly large numbers are very difficult to make as it is so difficult to obtain reliable information of the occlusion, even in only two generations, on account of the high frequency of extractions in our time. It is much easier to obtain a fairly large number of twins for investigation and this method has also been used by several authors in the study of the aetiology of malocclusion.

As is well known, one can, through observation of twins, get a conception of the influence of genetic factors as compared with that of environmental factors by comparing the differences within identical and fraternal twin-pairs. It is presupposed that the differences between identical twins, who have the same genetic constitution, are caused only by environment, while corresponding differences between fraternal twins depend on hereditary as well as environmental factors.

The majority of the investigations hitherto made on twins regarding tooth position and occlusion between the jaws are not based on exact methods. It is therefore difficult to know what conclusions can be drawn from the facts presented. Only a few authors have made measurements on their cases. These measurements seem to indicate that heredity has a comparatively great influence on malocclusion. These authors have, however, not used the mathematical methods which seem to be best suited for twin investigations and they have also, as a rule, worked on comparatively small numbers giving rather uncertain results. This is the reason why I have taken up this subject for an investigation.

The material I have been able to collect includes 202 twin-pairs of the same age: 100 identical and 102 fraternal, their ages varying between 9 and 40 years. The distinction between identical and fraternal twins has been based on the mutual similarity of the twins. Besides the general similarity, the configuration of the ears and the colour of the eyes have been studied separately and specifications have also been collected as to what extent mistakes have been made by persons who know the twins intimately. Of course, this method may cause some mistakes. When such a large amount of material is concerned, occasional mistakes in diagnosis should, however, be of minor importance.

The following characteristics in the occlusion have been examined. Within the individual jaws: (1) the breadths of the teeth, (2) the space in the dental arch, (3) the width and length of the dental arch, (4) the inclination of the upper medial incisors, (5) the height of the palatal vault. The relationship between the upper and lower jaw has been studied: (6) in the sagittal plane, (7) in the vertical plane and (8) in the transversal plane.

In the examination of the breadths of the teeth, direct measurements of the easily reached incisors and the canines were made, while the premolars and the first molars were measured on models of the jaws made of hard model plaster, reproduced by casts with a hydrocolloidal impression compound, mainly Dentocoll. As an instrument, a slide gauge was employed and the reading made with an accuracy of 0.1 mm. The other characters, regarding tooth-position and occlusion, were registered on the models. The space in the dental arch was determined in six sections of each jaw for each pair of teeth from M1-M1 (Fig. 1).

Section 1 includes Ml and P2 in the left side, and as points of measurements the distal contact points of Ml and P1 respectively, were used. Section 2 includes the following pair of teeth P1 and C, etc. If a medial diastema had occurred this was then measured separately, and because of this fact the total absolute space in the dental arch consisted of six measurements of the sections and in some cases the breadth of a medial diastema. The space in relation to the tooth material was determined as the difference in millimetres between the space and the sum of the tooth breadths in the same sections. This space difference value is therefore negative in cases with crowding, and positive in cases with spaced teeth.

The size of the dental arch was determined by Pont's method with transverse measurements at P1 and Ml in the upper and lower jaw (Fig. 2). In addition to this, the length of the dental arch from a line connecting the first molars to the medial incisors was measured. The length of the dental arch was measured with a specially designed instrument (Fig. 3) which is a modification of Korkhaus' so-called three-dimensional compass. The points of the compass are adjusted to the measuring points of the first molars. From the connection between the points there runs a metal rod which is adjustable laterally at both ends. This is placed in the middle between the points of the compass. A runner on the metal rod, of the same height as the points, is placed with its posterior edge on a level with the centre of the medial incisors edge. The inclination of the teeth was only measured as to the medial incisors of the upper jaw, the teeth which seem to vary most. The same instrument that had been used in measuring the length of the dental arch was also employed in the latter case. The inclination of the incisors was determined by means of a hinged, adjustable rod 10 mm long, which is adjusted in such a way that it rests against the facial surface of the incisors (Fig. 4). The value of the inclination is obtained by measuring the distance between the horizontal table, on which the incisal edges are resting, and the upper end of the rod. Left and right sides were registered individually, and in the case of different inclinations the mean value constituted the inclination of the case. The height of the palatal vault was measured perpendicularly to the plane of occlusion at the level of the first molars, and this measurement was also made by the compass so that the rod was adjusted in the centre of the legs of the compass (Fig. 5). The level of this rod was then compared with that of the points of the compass, and the height was measured with a slide gauge.

The sagittal relationship between the molars was registered at the first molars by measuring the mesio-distal distance between the mesio-facial cusp of the first molar in the upper jaw and the fissure between the mesio- and disto-facial cusps of the same tooth in the lower jaw (Fig. 6). It was also my intention to try to determine the true relationship between

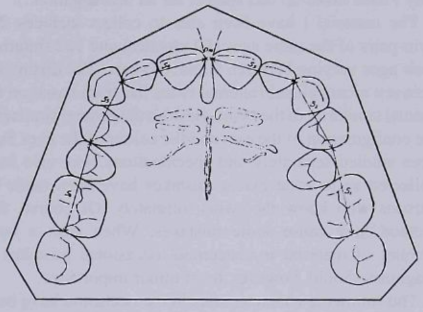

Figure 1 Measuring the space in the dental arch. The total space is given as the sum of six sections of the arch and, if such occurs, of the medial diastema (D.m.).

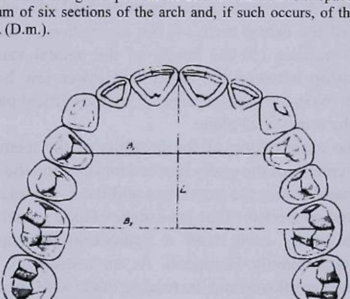

Figure 2 Measuring points for width and length of dental arches.

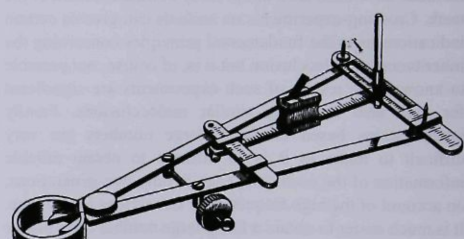

Figure 3 Instrument used for measuring the length of the dental arches, the inclination of the upper medial incisors and the height of the palatal vault.

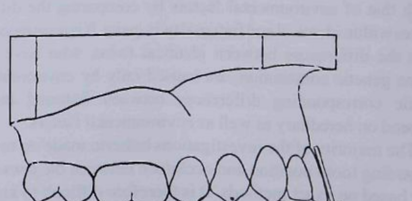

Figure 4 Measuring the inclination of the upper medial incisors.

the jaws in cases where migration of the teeth seemed to have occurred, by reconstruction of the original position of the molar. I have, however, not been able to find any objective method for this reconstruction; and was therefore obliged to give it up. The frontal sagittal relationship was determined as the horizontal overbite and measured at the medial incisors in the upper jaw. The vertical relationship between the jaws was obtained by measuring the vertical overbite at the medial incisors. Lastly, the relation between the dental arches in the transversal plane was obtained from the difference between the width of the upper and lower jaws.

It is obvious that in using measurements of this nature one has to take errors of measurements into consideration. As these may have a considerable significance for the calculation of heredity and environment, it is necessary to determine their size. This is done by means of double measurements on double models of the same individual, and was done with 40 individuals for all the characteristics examined. In order to determine the errors of measurements the standard deviation of the individual measurement was employed, and this deviation is obtained from the following formula:

$$\text{the standard deviation of the individual observation} = \sqrt{\frac{\sum d^2}{2n}}$$

in which d is the difference between the first and second determination, and n is the number of double determinations. The question as to the errors of measurement led to the statistical method which is applied in twin investigations. It is not possible in this paper to go further into the different formulas which have been used. I must, however, try to describe the general reasoning on which these formulas are based. In principle, it is presupposed that the differences which can be measured between identical twins, partly depend on errors of measurement, and partly on the twins having been influenced by different environmental factors. In the case of fraternal twins, a differentiating factor is added, namely, dissimilarities between genetic factors. Because of this, differences between fraternal twins are generally greater than between identical twins.

The variability of the differences in question is measured in the same way as for the error of measurement, i.e. by calculating the standard deviation of the differences within identical and fraternal twin pairs. For those characters which have been possible to measure on both sides of the median line I have also examined the differences between the left and right side; in order to obtain a conception of the effect of asymmetrically effective factors.

The first diagram (Fig. 7) shows the variability for the sum of the tooth-breadths from the medial incisor to the first molar. As can be expected, the variability for the differences is least between left and right sides, and greatest between the fraternal twins. As regards the tooth size, it is difficult to conceive that the differences between left and right sides are caused by actual environmental factors, because the crowns of the teeth are practically protected against external effect, and endogenic environmental factors, such as lack of vitamins, should naturally have a symmetrical effect. It is therefore most probable that these differences arise because of random influences during

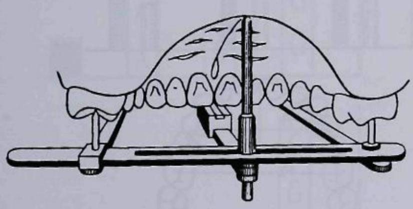

Figure 5 Measuring the height of the palatal vault.

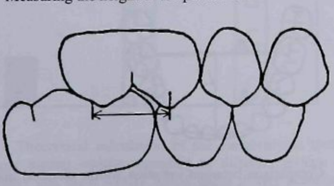

Figure 6 Measuring mesio-distal occlusion of the first molars.

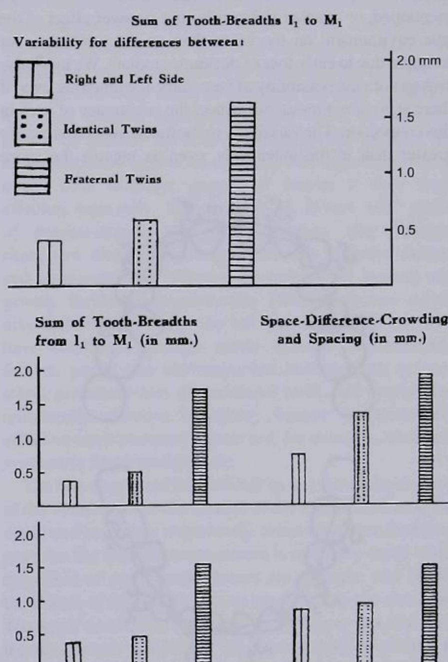

Figure 7 Comparison between left-right variation, and variation within identical and fraternal twin-pairs as regards sum of tooth-breadths (upper jaw). The variation is expressed as the standard deviation of a single observation.

early tooth development. It is conceivable, for example, that an uneven distribution of the blood vessels between the left and right sides of a tooth can give a difference between the two sides. Such factors are usually embraced under the term 'internal environment', and distinguish themselves definitely from the factors we commonly term as environmental factors. When discussing the import of twin-differences, it is therefore suitable to distinguish between non-genetic and genetic factors instead of between environmental and genetic factors. The non-genetic factors could, in their turn, be divided into true environmental factors, and internal factors randomly distributed between the left and right side. The latter factors seem, at least as regards the tooth-breadths, to be of rather great importance, greater than the importance of true environmental factors.

In the following diagram (Fig. 8) a comparison has been made between the variability in tooth-size and in the space difference which gives the space-conditions in the direction of the dental arch. The diagram shows greater variability for the space differences than for the sum of the tooth-breadths between the left and right side as well as between identical twins. Without further investigation it is impossible to determine to which degree this is connected with a stronger effect of the internal environmental factors I have just mentioned, or whether it depends on a stronger effect of the true environment on the space than on the tooth-size, for example due to early loss of deciduous molars. We must also reckon with the possibility of hereditary asymmetries, even if there is no direct reason to suspect the occurrence of such in this connection. The variability in the fraternal twins is clearly greater than in the indenticals, even as regards the space difference which indicates the significance of heredity to the origin of crowding and spacing. However, the probability should be pointed out that the dissimilarities with respect to premature losses are probably more common with fraternal than with identical twin-pairs and, because of this, it is possible that the greater variability between fraternal twins as compared with identical twins is partly dependent on this.

In the next diagram (Fig. 9) is shown the variability in identical and fraternal twins for the measurements of the width and length of the dental arch as well as the height of the palatal vault. Here again we see the typical difference between identical and fraternal twin-pairs. The slight variations which exist between the corresponding columns may in part be conditioned by random variation, i.e. because the amount of the material is too small. However, the greater variability between identical twins as regards the arch width at the first molars as compared with the first premolars in the upper jaw is significant.

In the following diagram (Fig. 10) are shown the results as regards the characteristics of the relationship between the jaws, as well as the inclination of the upper teeth. As to

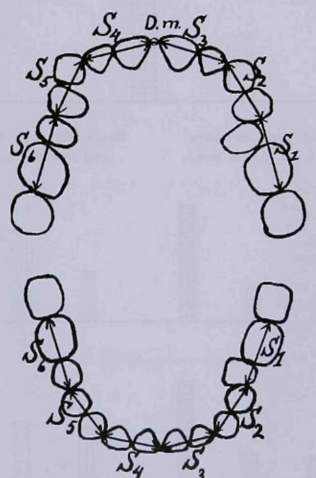

Figure 8 Comparison between left-right variation, and variation within identical and fraternal twin-pairs as regards sum of tooth-breadths and space difference (from I1 to M1, in the upper and lower jaw) cf. Fig. 7.

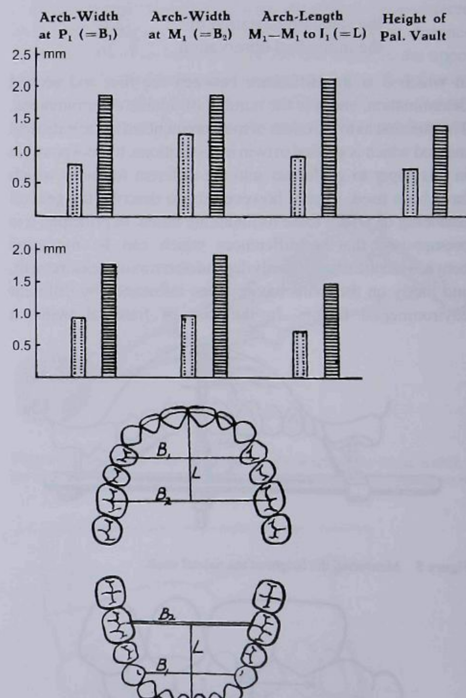

Figure 9 Comparison between variation within identical and fraternal twin-pairs as regards arch width, arch length (upper and lower jaw) and height of the palatal vault. cf. Fig. 7.

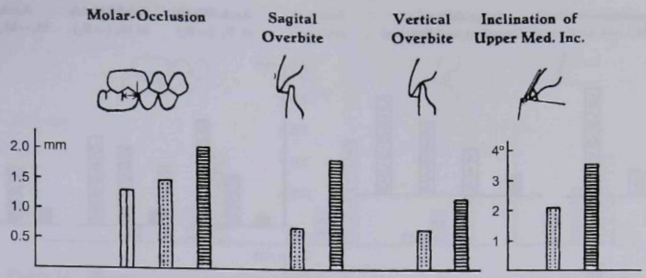

Figure 10 Comparison between left-right variation, and variation within identical and fraternal twin-pairs as regards molar occlusion, sagittal and vertical overbite and inclination of upper medial incisors. cf. Fig. 7.

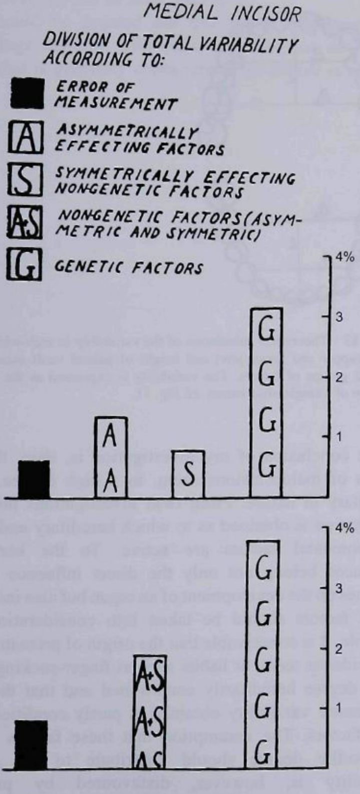

Figure 11 Theoretical calculation of the variability in tooth breadth of the upper medial incisor according to different groups of factors (the variability that these factors would cause if they acted separately). The variability is expressed as the co-efficient of variation of a single observation.

the occlusion of the molars, the variability between the left and right side is rather large and almost as large as between the twins, while the variability in the fraternal twins is somewhat larger. The difference between identical and fraternal twins as regards the sagittal overbite is particularly large, indicating a relatively strong genetic influence for this measurement. The vertical overbite and the inclination of the upper medial incisors also show distinct differences even though they are not as marked as for the sagittal overbite.

In the following series of diagrams the total variability has been divided according to the effect of different groups of factors; for it is possible, on the basis of the aforementioned figures, to calculate that variability which arises from different groups of factors if they were effective separately. The groups of factors are: errors of measurements, non-genetic factors, (for bilateral characters divided into asymmetrically effective factors and asymmetrically effective environmental factors) and genetic factors. Asymmetrically effective factors which give difference between the left and right sides are, as I have mentioned already, partly internal environmental factors, partly true environmental factors, such as one-sided, premature loss of deciduous teeth, and maybe also unilaterally effective hereditary factors. Symmetrically effective environmental factors are, for example, vitamins, symmetric finger-sucking, etc.

The first diagram of this series (Fig. 11) shows the division of the variability for the breadth of the medial incisor in the upper and lower jaw respectively. It can be seen in the lower jaw how the error of measurement is relatively small while the effect of non-genetic factors are stronger, and finally the effects of the genetic factors are distinctly the strongest. The same conditions are found in the upper jaw, but here the non-genetic variability has been divided according to asymmetrically and symmetrically effective factors; out of which the former seems to be the most active, a condition which, by the way, appears to be to a still higher degree true of the lateral tooth in the upper jaw.

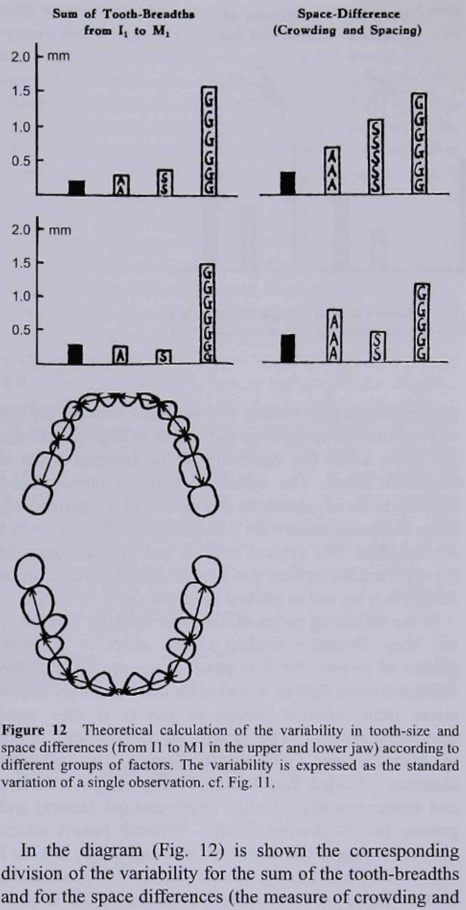

Figure 12 Theoretical calculation of the variability in tooth-size and space differences (from I1 to M1 in the upper and lower jaw) according to different groups of factors. The variability is expressed as the standard variation of a single observation. cf. Fig. 11.

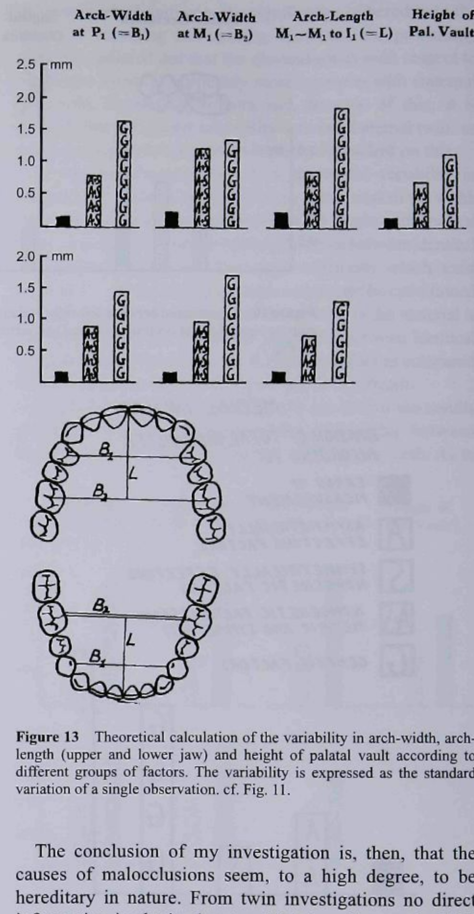

Figure 13 Theoretical calculation of the variability in arch-width, arch-length (upper and lower jaw) and height of palatal vault according to different groups of factors. The variability is expressed as the standard variation of a single observation. cf. Fig. 11.

In the diagram (Fig. 12) is shown the corresponding division of the variability for the sum of the tooth-breadths and for the space differences (the measure of crowding and spacing) within one half of the jaw. As can be expected, the effects of heredity is clearly stronger than other groups of factors as regards tooth size, but the genetic factors also seem to have a dominating significance to the origin of crowding and spacing as compared to asymmetrically and symmetrically effective, non-genetic factors.

The next diagram (Fig. 13) shows the conditions of the width and length of the dental arch and height of the palatal vault. Again the effect of heredity is, on the whole, stronger than the effet of non-genetic factors while here the error of measurement is especially small.

The last diagram (Fig. 14) shows the division of the variability for the molar occlusion, the sagittal and vertical overbite and the inclination of the medial incisor in the upper jaw. The effect of genetic factors is especially strong for the sagittal overbite.

The conclusion of my investigation is, then, that the causes of malocclusions seem, to a high degree, to be hereditary in nature. From twin investigations no direct information is obtained as to which hereditary and which environmental factors are active. To the hereditary influences belong not only the direct influence caused by genes on the development of an organ but also indirectly active factors should be taken into consideration. For example, it is conceivable that the origin of premature loss of deciduous teeth, or habits such as finger-sucking are to some degree hereditarily conditioned and that therefore the genetic variability obtained is partly conditioned by such factors. The assumption that these factors to any noteworthy degree should contribute to the genetic variability is, however, disfavoured by previous investigations, according to which the effect of these factors generally do not seem to cause permanent anomalies. However, the investigations that have been reported in this respect are not sufficient as a definite proof,

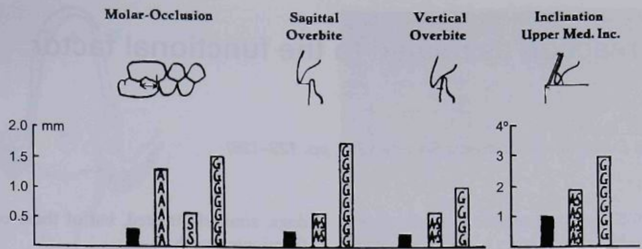

Figure 14 Theoretical calculation of the variability in molar-occlusion, sagittal and vertical overbite and inclination of upper medial incisors according to different groups of factors. The variability is expressed as the standard variation of a single observation. cf. Fig. 11.

and therefore further investigations are needed before these questions can be fully answered.

It should be pointed out that these results refer to an average material with relatively moderate deviations from what is generally characterized as normal occlusion. As regards more extreme malocclusions, one is probably justified in reckoning with still stronger influences of heredity than have appeared here, provided that special environmental factors, for example trauma or early infection of growth-centre in the condyle, cannot be proved.