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Polynesian mandibles

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INTRODUCTION

It is remarkable that in his account of the human skeletal material collected by the *Challenger* expedition of 1873–6, Sir William Turner (1884) does not mention any unusual feature of the Polynesian lower jaw. The first comment in the English literature appears to be that of Scott (1893): "The angle is occasionally sharp and easily localized, but is more frequently rounded, and this rounding is in many bones carried forwards along the under-surface of the body, curving upwards anteriorly towards the chin. Indeed in some cases the posterior margin of the ramus, the angle, and the lower border of the body form one long continuous curve, whose most dependent part is below the first molar tooth."

Subsequently Marshall & Snow (1956) introduced the term 'rocker jaw' to describe this most frequent form of Polynesian mandible, which occurs in about 80 % of Polynesians (Snow, 1974; Pietrusewsky, 1969). In this form (Fig. 1) the inferior border of the mandible continues in a convex curve around the gonial region and on to the posterior border of the ramus. There is no antegonial notch, and no distinct angular process can be defined. The bone rests by only two points on a plane surface and is unstable when touched. This is in contrast to the usual form of mandible in *Homo sapiens* which Martin (1957) describes thus: "The form of the lower border of the mandible and the manner in which the jaw rests upon a horizontal surface, depend largely upon the structure of the jaw angle, the 'angular process' of the mandible. As a rule this process is strongly marked so that there is present a deep concavity, the antegonial notch." Such mandibles, resting by three or four points, will be stable on a plane surface.

In the present study, a series of Polynesian mandibles and their associated crania from prehistoric New Zealand were analysed in an attempt to explain the rocker form.

MATERIALS AND METHODS

Mandibles in good condition from all parts of New Zealand including the Chatham Islands, were studied. Each had its associated cranium. Skulls were judged to be adult if the spheno-occipital synchrondrosis was closed, while sub-adult age was judged from tooth development.

On 197 adult mandibles (116 ♂, 81 ♀) the gonial angle was measured with the bone in the occlusal plane, and the presence or absence of the rocker trait recorded.

Twentynine (20 ♂, 9 ♀) rocker and 29 (22 ♂, 7 ♀) non-rocker adult mandibles from the full mandibular series of 197 were X-rayed with the left side of the bone flat against the film. On these X-rays the mandibular canal was traced from the mandibular foramen to a point vertically below the middle of the first molar. The curvature of the canal was then expressed by the ratio of the depth of the arc (*C–D*, Fig. 2) to the length of the chord (*A–B*, Fig. 2) for each specimen.

Fig. 1. The rocker jaw.

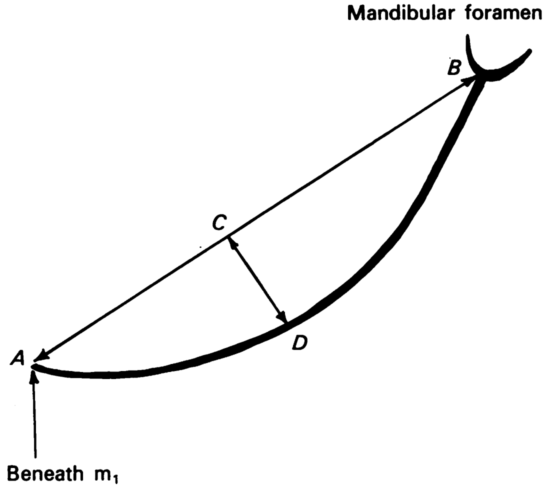

Fig. 2. Method of determining the curvature of the mandibular canal.

On the adult skulls associated with the mandibular series upper facial height (nasion–prosthion) was measured. (Two male skulls were damaged in the region of the prosthion and could not be measured).

On 60 adult (45 ♂, 15 ♀) and 12 sub-adult skulls standard lateral cephalograms were made and from these the cranial base angle (basion–sella–nasion) was measured for each specimen. The adult skulls were taken at random from those associated with the mandibular series of 197. The sub-adult skulls ranged in age from 3 to 12 years.

On the 45 male lateral cephalograms the joint angle (sella–articulare–tangent to posterior border of ramus) was measured.

RESULTS

These are set out in Table 1.

None of the mandibles belonging to children under the age of 10 years showed the rocker form.

Of the 197 adult mandibles, 72 % (69 % ♂, 77·8 % ♀) showed the rocker form.

Gonial angle was significantly less ($P < 0{\cdot}001$) in the rocker form (95° ♂, 97·8° ♀) than in the non-rocker form (101·8° ♂, 102.2° ♀).

The mean value of the ratio used to estimate the degree of curvature of the mandibular canal was 0·16 for the rocker form and 0·12 for the non-rocker. This differerce is highly significant ($P < 0{\cdot}001$) and indicates that the canal is more curved in the rccker form.

Mean upper facial height for the 114 adult males was 73·1 mm, and for the 81 females, 66·6 mm.

Mean cranial base angle for the 60 adult crania was 142°, there being no significant difference between the sexes.

Mean cranial base angle for the 12 sub-adults was 141·2°, this value not being significantly different from the adult value.

Mean value for the cephalometric joint angle in male adults was 136°.

Table 1. *Means and standard deviations for gonial angle, upper facial height, mandibular canal ratio, and cranial base and joint angle*

(For mandibular canal ratio and cranial base angle data has been combined, there being no significant difference between the sexes.)

	♂			♀			♂+♀		
	n	*x*	S.D.	*n*	*x*	S.D.	*n*	*x*	S.D.
Gonial angle (deg)									
Rocker form	80	94·95	4·13	63	97·85	4·64	—	—	—
Non-rocker form	36	101·81	3·51	18	102·20	4·05	—	—	—
Mandibular canal ratio									
Rocker form	—	—	—	—	—	—	29	0·16	0·02
Non-rocker form	—	—	—	—	—	—	29	0·12	0·02
Upper facial height (mm)	114	73·1	4·6	81	66·6	5·0	—	—	—
Cranial base angle (deg)									
Adult	—	—	—	—	—	—	60	142·0	5·7
Sub-adult	—	—	—	—	—	—	12	141·2	4·3
Joint angle (deg)	45	136·2	7·3	—	—	—	—	—	—

DISCUSSION

The rocker form cannot be entirely explained on the basis of masticatory demands. The diets of Hawaiians and New Zealanders differed vastly in prehistory, as their teeth attest, yet they have a similar incidence of the rocker form, and most populations with extreme tooth wear lack rocker jaws.

The antegonial notch determines the number of points of contact a mandible has with a plane surface, and Enlow (1975*a*) indicates that the size of this notch is determined largely by the ramus–body angle; a mandible characteristically develops a less prominent notch as the angle between body and ramus closes. If the angle closes sufficiently the notch disappears. This is borne out in the present series, where the rocker form, lacking the notch, has a lesser gonial angle than the non-rocker form where the notch is present.

The rocker form only starts to appear in late childhood, from about 11 years of age. Polynesian mandibles below this age display, like their counterparts elsewhere, distinct antegonial notches and open gonial angles. This has been observed in all juvenile material seen in New Zealand and not just in the present small juvenile series, and has also been noted by Snow (1974) in Hawaiian material. It thus appears that the growth changes during the period of maturation of individuals of this group lead to the development of this particular mandibular form.

Björk (1963, 1969) studied mandibular growth rotations by means of metal implants in the bone, and listed a number of characteristic features associated with extreme anterior growth of the condyle (termed by him 'extreme vertical growth'). These include an anterior inclination of the condylar head, a rounding of the inferior border of the mandible in its anterior part, a prominent chin, a very marked resorption of bone in the region of the angular process, a decrease in the gonial angle and an increased curvature of the mandibular canal. This could be a description of the rocker jaw – the rocker effect being merely the most obvious feature of this particular form of mandible – and indeed Björk illustrates 'extreme vertical growth' in the 1969 paper with a skull showing a rocker jaw.

Enlow (1975*b*) considers mandibular growth rotations to be of two basic types. 'Displacement' rotation involves changes in mandibular alignment at the condylar

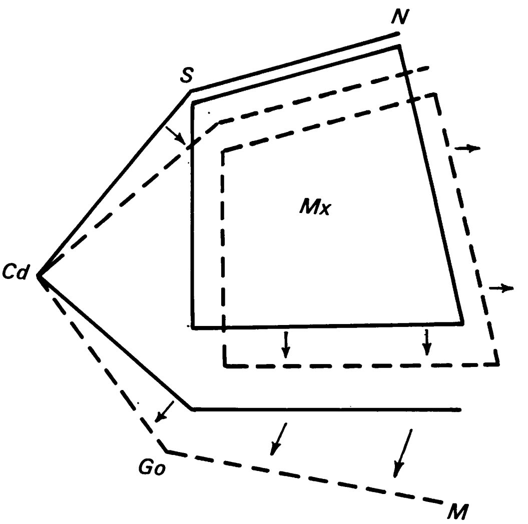

Fig. 3. Effect of opening of the cranial base angle on the splanchnocranium. The continuous lines represent the bones in the presence of a closed cranial base angle, and the interrupted lines indicate the changed position when the cranial base angle is opened. The mandible has undergone a displacement rotation down and back. (After Enlow, 1975*a*, *b*.) *N*, nasion; *S*, sella point; *Cd*, condylion; *Go*, gonion; *M*, menton; *Mx*, facio-maxillary complex.

pivot. The whole mandible rotates upward and forward to meet a short nasomaxillary complex or upright cranial base flexure, and rotates down and back to accommodate a long nasomaxillary complex or a more open cranial base flexure. The latter situation is illustrated in Figure 3.

In the second type of mandibular rotation the ramus or body independently undergoes a progressive remodelling. Such remodelling occurs particularly during puberty in the ramus, which becomes progressively more upright to accommodate a lengthening mid-face. The open gonial angle of childhood thus lessens. However, remodelling rotation also involves the body of the mandible to accommodate the effects of displacement rotation.

When displacement rotation brings the whole mandible up and forward the body rotates down to some extent to compensate; when displacement rotation brings the whole mandible down and back the body rotates upward to maintain a proper occlusal relationship. In Figure 3, illustrating a downwards and backwards displacement rotation, the compensatory remodelling rotation will bring the body segment (*Go–M*), upwards towards the horizontal pivoting at *Go*, further reducing the gonial angle.

Comparative data for cranial base angle are given in Table 2, where the Polynesian angle is seen to be the most open. The difference between the present New Zealand series and all others in the Table for which a standard deviation is given is highly significant ($P < 0{\cdot}001$).

From the literature (e.g. Howells, 1973), it can be found that the mean upper facial height for most groups lies in the range of 69–71 mm for males and 64–66 mm for females. Polynesian groups have rather large upper facial heights; Marquesas, 73·6 mm and 68·5 mm (Wagner, 1937); Hawaii, 71·9 mm and 67·5 mm (Snow, 1974). In the present series the male mean was 73·1 mm, and the female mean 66·6 mm.

The findings of the present study are interpreted thus: in the Polynesian cranium an

Table 2. *Comparative data for cranial base angle (nasion–sella–basion) in degrees*

(1–11 from Bjork (1972): (s) indicates data from non-living material.)

	n	Cranial base angle Mean	Cranial base angle S.D.
1. Easter Island (s)	1	149	—
2. Norwegian Lapp (s)	61	139	—
3. Bantu	101	136	4·9
4. Australian aboriginal (s)	100	136	5·3
5. Norwegian medieval (s)	—	135	—
6. Senegal negroes (s)	48	135	5·4
7. Bushman (s)	30	134	5·9
8. Japanese	47	133	5·0
9. Swedes	234	132	4·5
10. Danes	102	130	5·2
11. Australian aboriginals	31	130	4·2
12. Maori/Moriori (s) (present series)	60	142	5·7

open cranial base angle is associated with a rather large upper facial height, leading to a marked displacement rotation of the mandible down and back. To maintain occlusion a remodelling rotation upwards of the body occurs, further reducing the gonial angle, with elimination of the antegonial notch and development of the rocker form. Björk's 'extreme vertical growth' here represents a combination of the downward displacement rotation and the upward body remodelling rotation of Enlow, and the features noted by Björk in the mandibles showing extreme vertical growth, and effectively describing the rocker jaw, occur in association with an open cranial base angle and large upper facial height. Within the present New Zealand series a comparison of the mainland and Chatham Island material is significant in emphasizing these associations. The 34 Chatham Island skulls show a 94% incidence of the rocker form, a mean upper facial height of 75·7 mm for 27 males and 70·4 mm for 7 females and a mean cranial base angle of 146°. The mainland material has a 70% incidence of the rocker form, a mean upper facial height of 71·4 mm for males and 65·8 mm for females, and a mean cranial base angle of 140°. (The difference between the mainland mean cranial base angle of 140°, and that of all groups in Table 2 with which comparison is possible, remains highly significant ($P < 0{\cdot}001$).)

Of the cranial factors involved in the formation of the rocker form, the open cranial base angle is much the most important. The upper facial height is less significant, except in so far as, with the approach to adult facial proportions in late childhood, it compels the extreme forward growth rotation of the mandible at this time if occlusion is to be maintained.

Thus far, the rocker form of mandible has been related to the existence of a very open cranial base angle, and the necessity for extreme forward growth at the condyle if occlusion is to be maintained in the presence of such cranial morphology. It remains to be explained why, in the presence of such a pattern of mandibular growth, a distinct angular process is no longer evident.

The functional components of the mandible have been described by Symons (1951) and Washburn (1951), and this concept has subsequently been elaborated by others such as Moss & Simon (1968). The mandibular components are illustrated in Figure 4. A basal or body component has its axis represented by the mandibular canal, around whose neurovascular contents the bone originally formed. The secondary

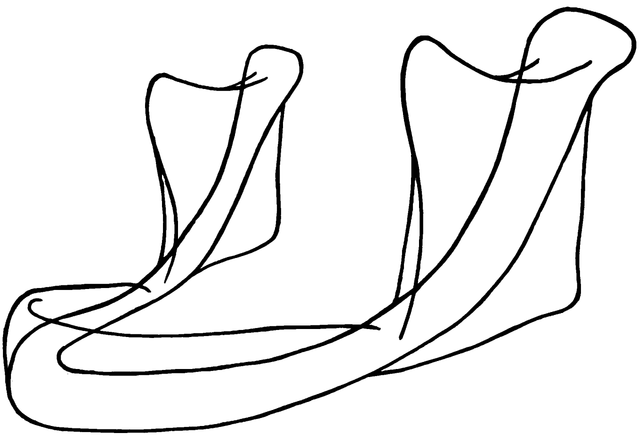

Fig. 4. Functional components of the mandible (after Symons, 1951).

components are concerned with support of the teeth, or are for muscular attachment. When the teeth are lost the alveolar component is resorbed. Many experimental studies (e.g. Avis, 1959; Moss, 1968) show that division of a masticatory muscle leads to resorption of the appropriate muscular process. However, there is no evidence to suggest that in these robust Polynesian mandibles the masseter and internal pterygoid muscles are under-developed. On the contrary, well-formed ridges at their sites of attachment indicate substantial development of these muscles.

The present data indicate that the mandibular canal, representing the central axis of the basal component, is more curved in the rocker than in the non-rocker form of jaw. It can be said that the basal component is more 'bowed'. The effect of such 'bowing' is to displace the basal component in a posterior or postero-inferior direction, into the region occupied by the angular process in a non-rocker jaw. This view is supported by the data on gonial angle, which is reduced in the rocker form. It is difficult to use comparative cephalometric data to support this view. Localization of the gonion is imprecise on a rocker jaw, neither can a consistent tangent be drawn to the single contact point on the inferior border of the body. However, the joint angle used in the present study is identical to that employed by Björk (1947). He found a mean value of 143·2° for young adult male Scandinavians. Bearing in mind the forward inclination of some 12° in the cranial base in the Polynesian (Fig. 3), and therefore of the sella point used in the joint angle, the mean value of 136·2° obtained for this joint angle in these Polynesians suggests a similar spatial position of the gonial region in both rocker and non-rocker jaws. Effectively, the relevant masticatory muscles obtain a functionally adequate spatial position for their attachment without the necessity for an angular process. There is no angular process in a rocker jaw.

This view is also supported by the morphology revealed in the mandibular X-rays. In the non-rocker form the differing trabeculation clearly separates the angular process from the body of the bone (Fig. 5). The process is 'tacked-on' to the basal component. In the rocker form the angular process is absent, and the mandibular canal lies equidistant from the margins of the basal component (Fig. 6).

Although Sir William Turner did not comment on any unusual feature of the Polynesian mandible, he did in fact make a median sagittal section of a skull from each major group that he studied. One measurement made on these sectioned skulls was the spheno-ethmoid angle. The posterior limb of this angle runs from basion to

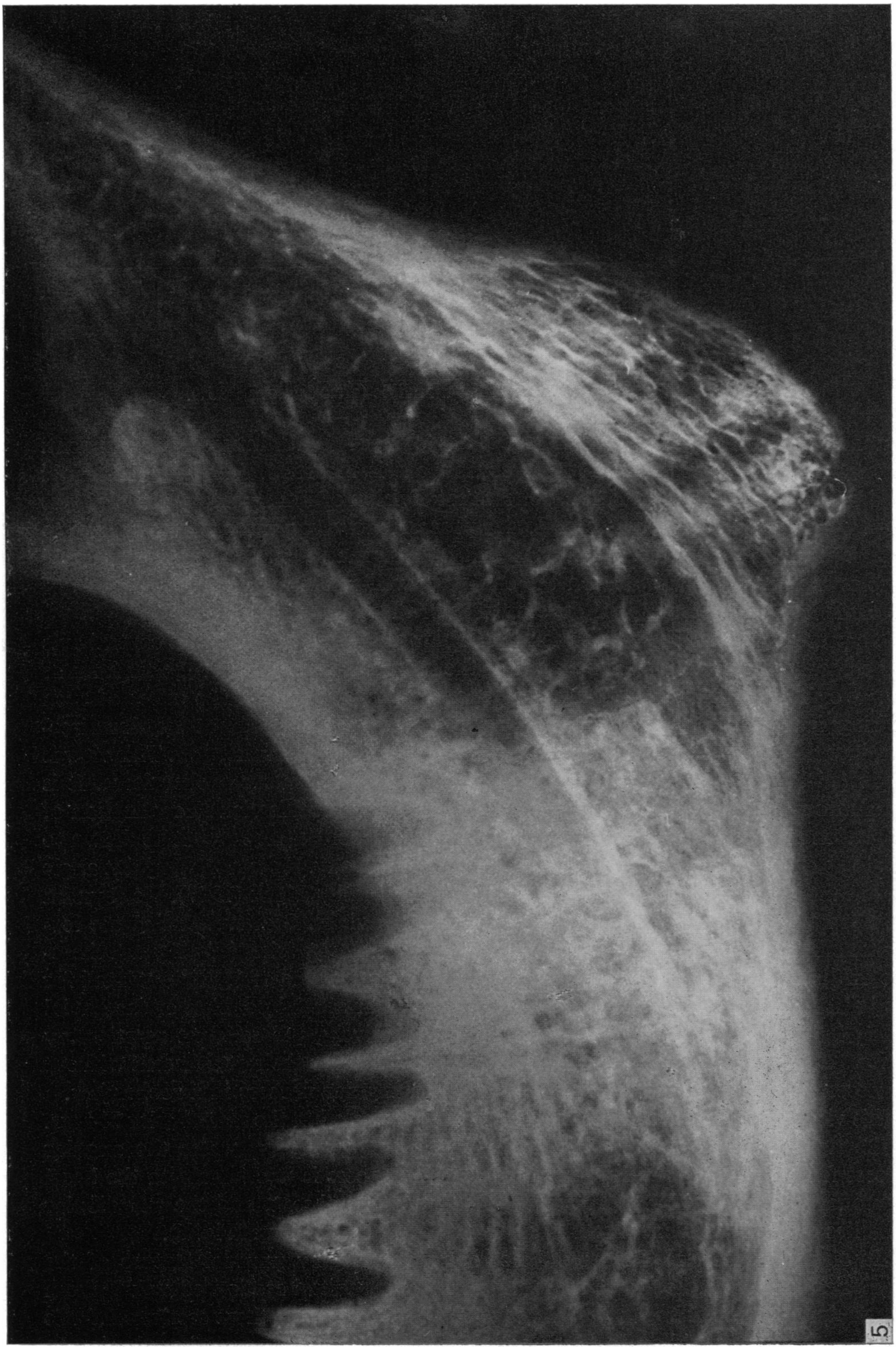

Fig. 5. X-ray of the gonial region of a non-rocker jaw. The mandibular canal is clearly visible, as is the angular process, demarcated from the basal component of the bone by trabecular lines.

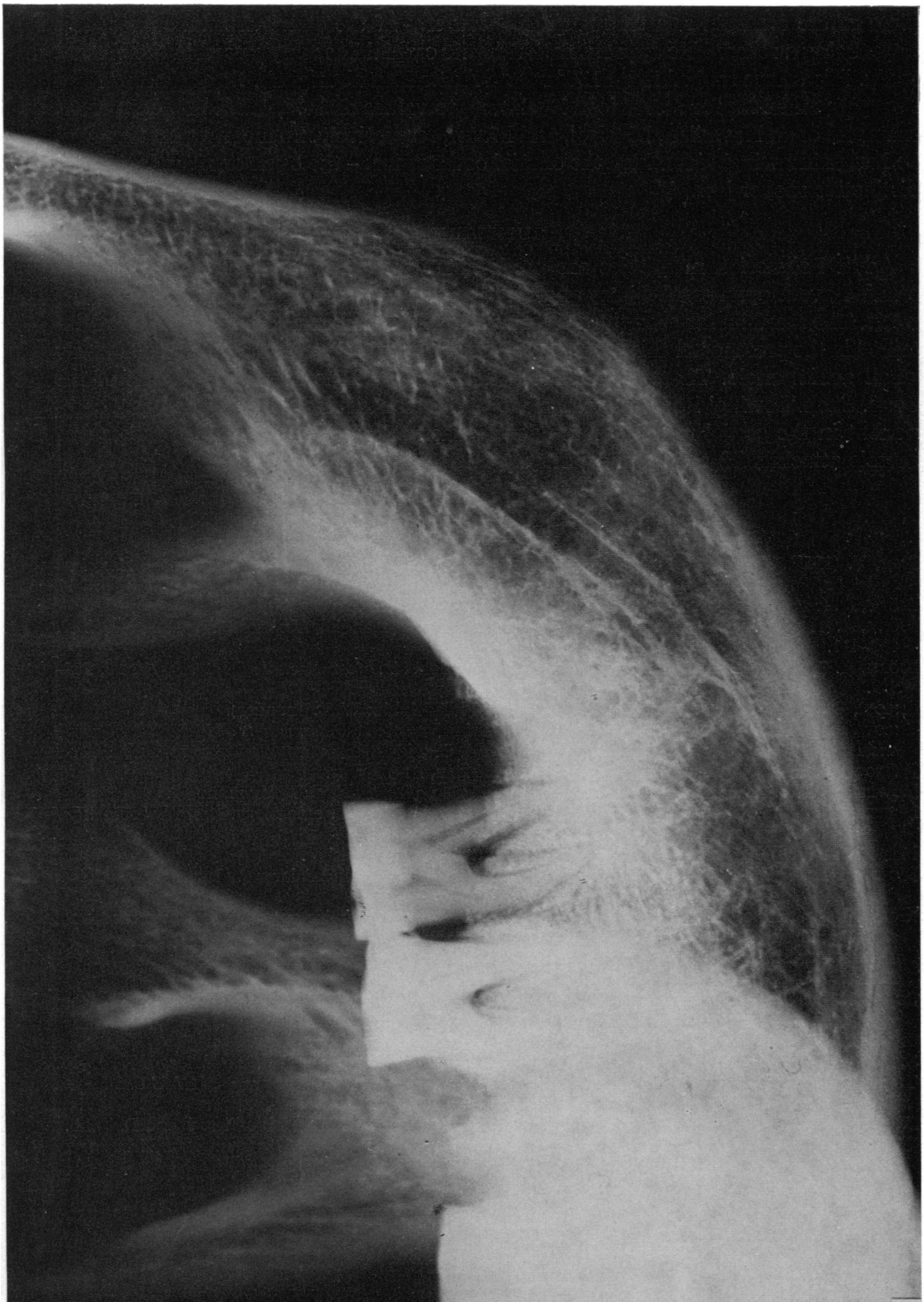

Fig. 6. X-ray of the gonial region of a rocker jaw. The mandibular canal lies approximately midway between the borders of the bone, and there is no distinct angular process.

spheno-ethmoid articulation, while the anterior limb runs parallel to the cribriform plate of the ethmoid and through the upper end of the ethmo-frontal suture; this angle being a reasonable approximation to the cranial base angle used in the present study. His values ranged from 136° for an Australian aboriginal, through 139° for a Feuegian and 142° for an African Bushman, to values of 147°, 150° and 154° for his examples of an Hawaiian, Moriori, and Maori, respectively. So, nearly a century ago, he had unknowingly identified the cranial counterpart – the open base angle – of the distinctive rocker jaw.

SUMMARY

Adult Polynesian mandibles are predominantly of the rocker form. Polynesian crania have a open cranial base angle, and a rather large upper facial height in the adult. The mandibular growth rotations necessary for normal occlusion to be maintained in the presence of this cranial morphology lead to development of a particularly small gonial angle. There is an increased 'bowing' of the basal component of the bone. Such 'bowing' leads to a sufficiently posterior displacement of the basal component in the gonial region for the development of a distinct angular process (for muscle attachment) to be unnecessary.

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