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Rocker Jaws from the Marshall Islands: Evidence for Interaction Between Eastern Micronesia and West Polynesia

Marshall I. Weisler[1] and Daris Swindler[2]

Twenty-seven mandibles from precontact sites on three Marshall Islands atolls were examined to determine the presence of post-settlement human interaction between eastern Micronesia and West Polynesia. Some 49% of our assemblage were rocker jaws; that is, they had no antegonial notch and the lower border of the mandible was convex so it rocked to and fro when placed on a flat surface. Rocker jaws are more common (50-90%) among Polynesian populations than anywhere else in the world. The relatively high incidence of rocker jaws in the precontact people living on these Micronesian atolls adds further support to the inferred interaction between eastern Micronesia and West Polynesia suggested by shared artifact styles and linguistic affinities.

Key words: skeletal biology; rocker jaws; Micronesia; Polynesia; Marshall Islands; prehistoric archaeology; interaction; radiocarbon dating.

Determining the speed, direction, antiquity, and geographic limits of the human colonization of the Pacific islands has been a major objective of archaeological research for decades (e.g. Emory and Sinoto, 1965; Finney, 1977; Irwin, 1992; Kirch, 2000: 207-245). Perhaps the most complex settlement history of any large region of the Pacific is Micronesia—a large swath of islands dispersed over about 4500 km and lying mostly between the equator and 20° north (Fig. 1). Intoh (1997: 23-24) has proposed four major movements into Micronesia, originating from the west, south, and east, based on linguistic models, the spatial and temporal distributions of stylistic artifacts, and radiocarbon age determinations. Of interest here is her "fourth movement" originating in West Polynesia (perhaps in the area of Tuvalu) and ending in central Micronesia at the Polynesian outliers of Nukuoro and Kapingamarangi atolls. Recent studies of Marshall Islands materials including artifacts (Weisler, 2000), ancient DNA from a human interment (Weisler *et al.*, 2000), and ancient teeth (Swindler and Weisler, 2000) suggests that the post-settlement history of the Marshall Islands includes significant mixing between human populations of the Marshalls with Kiribati (immediately to the south) as well as unspecified groups in West Polynesia. In this paper we examine rocker jaws (a predominantly Polynesian trait) from three atolls in the Marshall Islands and compare the frequency of their occurrence there with other Micronesian groups. We demonstrate that the Marshall Islands had significant post-settlement contact with West Polynesia, a situation suggested also by shared arti-

[1] Department of Anthropology, University of Otago, P. O. Box 56, Dunedin, New Zealand. [e-mail: marshall.weisler@stonebow.otago.ac.nz]

[2] Department of Anthropology, University of Washington, Seattle, Washington 98195 USA. [e-mail: dswindle@u.washington.edu]

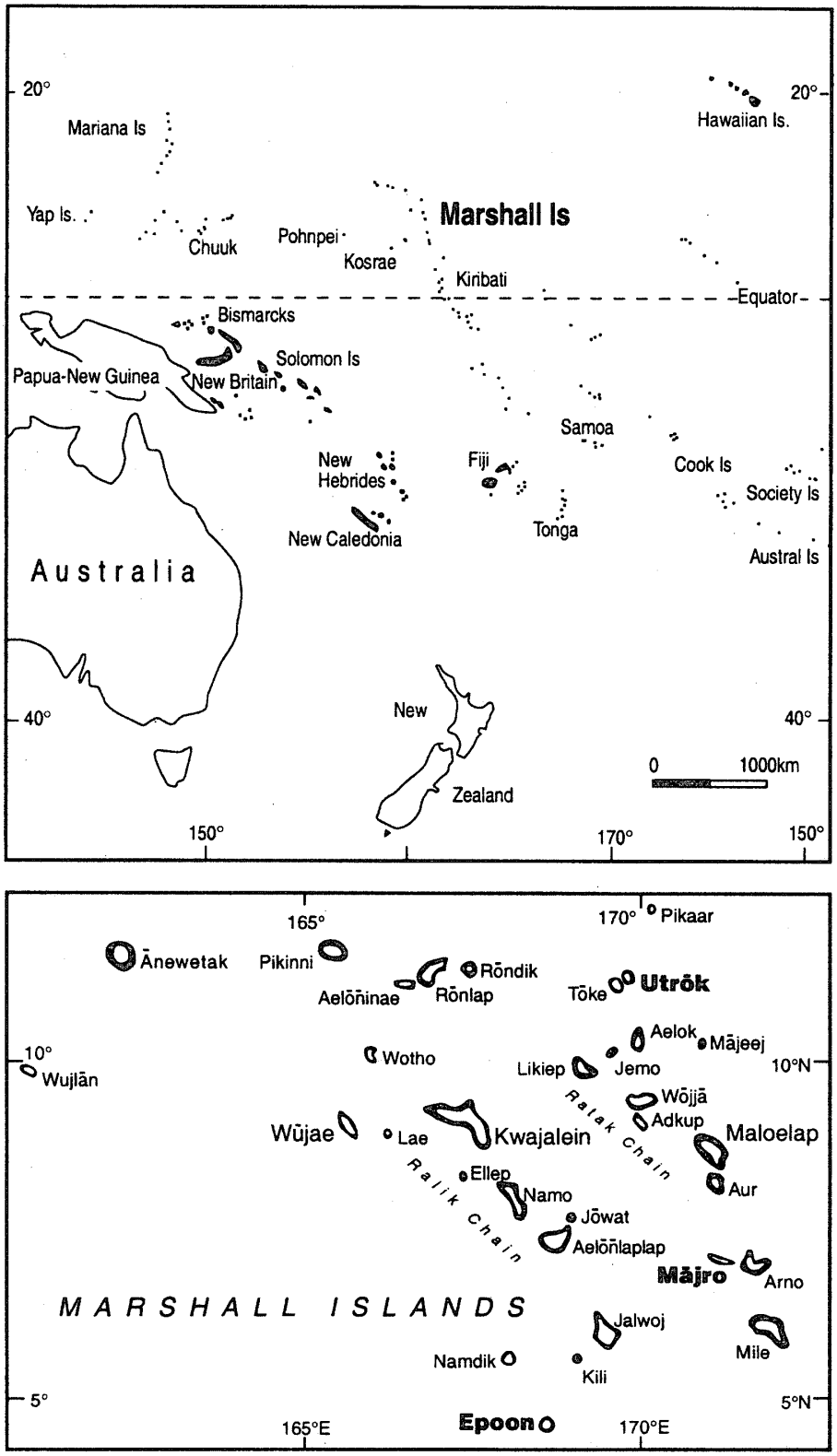

Figure 1. Map of the Pacific Showing the Location of the Marshall Islands (upper) and the Lower Illustration Shows Atolls (**Utrōk, Mājro, and Epoon**) from Where Material Has Been Analyzed for This Study.

fact styles (Weisler, 2000; Weisler *et al.*, 2000: 214) and linguistic evidence (Harrison, 1994; Lynch, 1998; Thaman, 1987; Woodroffe, 1985).

Rocker Jaws: Definition and Previous Research

The morphology of the rocker jaw has been known since Virchow in 1875 presented a picture of a German female mandible which appears to have the anatomical characteristics of a rocker jaw, although he did not use this term in his description according to Martin (1928). Martin (1928) also states that, in addition to Virchow, other authors (e.g. Zoja (1888: 169) and Toeroek (1898: 125), both cited in Martin (1928)) described the anatomy of the rocker jaw without using the term. Stahr (1906) used "Winkel ganz rund" (completely round angle) to describe mandibles with a continuous convex curve along the inferior surface of the mandibular corpus which continued posteriorly as a rounded gonial angle with no development of an antegonial notch. He found this form present in several Māori mandibles while noting that this condition rarely occurred in Europeans. As far as we know, Martin (1928: 980-981) was the first author to use the term "rocker jaw" to describe this suite of anatomical features.

According to most authorities, one of the most striking features of a Polynesian cranial sample is the "rocker jaw". It is well known that a high percentage of mandibles that have been described for both ancient and contemporary Polynesians possess several features that are not usually found in other human groups; two of these are absence of the antegonial notch, and a convex lower border of the mandible extending around the gonial region onto the posterior surface of the ascending ramus which results in a mandible making contact only at one point (below the second permanent molar) on each side when placed on a flat surface. Thus, the mandible is unstable and rocks to and fro and is known as a rocker jaw (Fig. 2, left). In contrast, the majority of mandibles from most other human populations have an antegonial notch, an angular process behind the notch, and a rather flat contour to the lower border of the mandible in front of the antegonial notch; therefore, when placed on a flat surface, the mandible rests on four contact points and does not rock (Fig. 2, right).

With the exception of the Mariana Islands (Hanson and Pietrusewsky, 1997), relatively little is known about the bioarchaeology of Micronesia. This is particularly true for information relating to skeletal biology; for example, the incidence of rocker jaw descriptive morphology is meagre throughout this large region of the western and central Pacific (Marshall and Snow, 1956; Pietrusewsky, 1984; and Douglas *et al.*, 1997). The present paper discusses the presence of the rocker jaw in precontact Marshall Islanders and examines its distribution in other Pacific islands, especially Polynesia, for a possible genetic connection with these most eastern islands of Micronesia. Similarities in some traditional artifact styles and linguistic evidence suggest that the boundary between eastern Micronesia and West Polynesia, as defined today, was less rigid in prehistory. Long-distance interaction involving the Marshall Islands seems likely given the amount of prehistoric post-colonization movement documented across vast distances within Polynesia (Weisler, 1997, 1998). Much post-colonization interaction is also supported by recent mtDNA evidence from the Marshalls (Weisler *et al.*, 2000), eastern Micronesia (Lum, 1998), and Pacific-wide studies (Lum and Cann, 1998; Lum *et al.*, 1998).

Figure 2. Marshall Island Mandibles Showing a Rocker Jaw (left) and a non-Rocker Jaw (right). The major anatomical differences between these two mandibular types are discussed in the text.

Material and Methods

The Marshall Islands mandibular material came from precontact sites on three atolls. The most northern location is Utirik (Utrōk[1)]) Atoll, while Majuro (Mājro) Atoll is in the middle of the archipelago and Ebon (Epoon) Atoll is the southernmost location (Fig. 1). There are 27 mandibles in the present study; all derive from traditional contexts suggesting prehistoric age. Although not directly dated, the Utrōk burial is from a major habitation site which dates from A.D. 20 to 1638 (Beta-103903 and 103905 in [Weisler 2001:Table 5.1, Figs 3.19 and 3.20] calibrated at 2 σ after Stuiver and Reimer, 1993; Stuiver *et al.*, 1998). The burial is clearly prehistoric, but it is not possible to assign a more specific age within this range. All the Mājro specimens are from a prehistoric cemetery on Mājro islet where 29 densely-spaced interments were partially excavated during a water development project (Spennemann, 1999). Three of these burials were directly dated to the first millennium A.D. by documenting use of the cemetery (Weisler, 2000). Two burials, whose mandibles are included in our study, dated from A.D. 4 to 713 (at 2 σ; Weisler, 2001). The mandible from Epoon Atoll is from an isolated interment in a habitation site. The cultural layer immediately below the burial dated from A.D. 1042 to 1294 (Beta-92122 [Weisler, unpublished data] calibrated at 2 σ after Stuiver and Reimer, 1993).

Since conditions of the mandibles varied from almost complete to small fragments, observations were made only of mandibles permitting evaluation of their status regarding the presence or absence of a rocker jaw (Fig. 2, left and right). Sexes were combined since

we were not always certain of the sex of each mandible. Twenty-seven mandibles were examined for the rocker jaw condition.

Results and Discussion

The original definition of a rocker jaw was used in this study since we believe it more clearly represents the morphology of the rocker jaw as used by the majority of investigators. This also allows for better comparability among many of the investigators. Of the 27 mandibles in the study, 49% were rocker jaws (Fig. 2, left).

The most detailed analysis of the anatomy of the rocker jaw and its integration as part of the Polynesian craniofacial complex is that of Houghton (1996). He considers the rocker jaw, along with a flat cranial base, a spacious airway passage, and a large facial height, to be the major morphological components of the Polynesian craniofacial complex. The ascending ramus of the rocker jaw is especially high in these populations and more vertical than it is in the non-rocker jaw. The more vertical ascending ramus, as the region between the ascending ramus and the mandibular corpus becomes more closed, results in a less prominent gonial angle (Enlow, 1982; Houghton, 1977, 1996). The outcome is the more rounded gonial angle and the absence of the antegonial notch as major features of the rocker jaw (Fig. 2, left). According to Houghton (1996: 111), of all Polynesians, the Moriori of the Chatham Islands with their flat cranial bases "show the most extreme form of rocker jaw (94%)." Of course, the morphological features ascribed to the Polynesian craniofacial complex mentioned by Houghton (1996) may be found in other human groups, and it is known that a jaw that rocks may not necessarily be synonymous with Polynesian head form. It remains true, however, that rocker jaws must have some biological (genetic) component in view of their reported high incidence among Polynesians. Marshall and Snow (1956: 414) stated that the rocker jaw "is presumably a genetic characteristic or complex of the Polynesian group, for we cannot relate it to any presently-known factor of diet or environment which separates Polynesia from other Oceanic areas." As we have seen, Houghton (1996) proffered a functional explanation for its presence in Polynesians, though at the same time recognizing that a rocker jaw may be present in individuals who do not have the Polynesian head form. For example, he points out that individuals possessing a large masticatory musculature may lack any development of the antegonial notch. And as Enlow (1982) noted, the antegonial notch itself is resorptive since it passes posteriorly as the corpus lengthens into the former gonial area of the ramus. In a recent morphometric investigation of mandibular variation in the ape and human mandible (91 apes and 317 modern humans), Humphrey *et al.* (1999: 512), though not mentioning rocker jaws specifically, suggest the "considerable degree of plasticity in mandibular morphology through time," a caveat stated earlier by Hrdlicka (1940) in his extensive study of the morphology of human mandibles. Several studies have indicated that environmental factors (e.g. reduction of chewing stress) were responsible for narrowing the human mandible (Corruccini *et al.*, 1983; Lavelle, 1973). In addition, Kaifu (1997), studying temporal changes in Japanese mandibles from the Jomon to the Yayoi periods, found evidence that both environmental and genetic factors were responsible for changes in mandibular morphology.

It seems apparent from the foregoing that genetic and environmental factors influence differential growth rates, duration of growth, and bone remodeling loci during the entire

Table 1. Incidence of Rocker Jaws in the Pacific (%). Sexes Combined.

Group	None	Rocker Jaw	Anterior Rocker Jaw
Present study		(27) 49.0	
New Zealand[1)]		(150) 40.0	
Chatham Is.[1)]		(27) 55.0	
Hawai'i[1)]		(25) 75.0	
Guam[1)]	13 (100.0)		
New Zealand[2)]		(163) 70.0	
Chatham Is.[2)]		(34) 94.0	
Chamorro[3)]	(47) 91.5		(47) 8.5
Mokapu, Hawai'i[4)]		(283) 80.0	
Marquesas[5)]		(-) 90.0	
Easter Is.[5)]		(167) 48.5	
Tonga[6)]		(18) 61.1	
Society Is.[6)]		(23) 91.3	
New Zealand[6)]		(14) 86.0	
Chatham Is.[6)]		(8) 100.0	
Easter Is.[6)]		(17) 82.0	
Marquesas[6)]		(12) 100.0	
Hawai'i[6)]		(46) 87.0	
Tinian-Saipan[6)]		(10) 70.0	
Gilbert-Marshall Is.[6)]		(6) 100.0	
Vanuatu[6)]		(17) 65.0	
New Caledonia[6)]		(30) 50.0	
Loyality[6)]		(28) 29.0	
Solomon Is.[6)]		(19) 95.0	
Admiralty[6)]		(13) 69.0	
New Ireland[6)]		(18) 78.0	
New Britain[6)]		(65) 54.0	
Gulf District[6)]		(61) 97.0	
Sepik[6)]		(17) 88.0	
Fiji[6)]		(13) 77.0	
China[6)]		(37) 73.0	
Japan[6)]		(52) 67.0	
SE Asia[6)]		(67) 63.0	
Philippines[6)]		(12) 83.0	
Sulu[6)]		(17) 76.0	
S. Moluccas[6)]		(12) 67.0	
Lesser Sundas[6)]		(17) 71.0	
Borneo-Celebes[6)]		(45) 89.0	
Java[6)]		(74) 74.0	
Coast New S. Wales[7)]		(47) 87.0	
S. Queensland[7)]		(57) 79.0	
Murray River Basin[7)]		(176) 91.0	

(continued)

Swanport[7]	(40) 60.0
N. Territory[7]	(65) 80.0
Arnham Land[7]	(17) 94.0
W. Australia[7]	(19) 89.0
Coastal S. Australia[7]	(71) 93.0
Victoria[7]	(61) 95.0
N. Queensland[7]	(24) 92.0
Tasmania[7]	(20) 90.0
Broadbeach[7]	(31) 94.0
Roonka[7]	(48) 94.0
Kow Swamp[7]	(3) 100.0

Note: Numbers in parentheses are sample sizes.
1) Marshall and Snow, 1956
2) Houghton, 1977
3) Douglas, *et al.*, 1997
4) Snow, 1974
5) Gill, 1990
6) Pietrusewsky, 1989a (males only)
7) Pietrusewsky, 1984

growth period of the mandible (Enlow, 1982; Humphrey *et al.*, 1999). At present it is difficult to separate and identify the operative kinetic forces when attempting to attribute the various morphological configurations of the mandible to specific human groups. And in many cases, bone may respond to both genetic and environmental factors.

The frequency of the rocker jaw varies among different Polynesian groups, as does the degree of rocking of the mandible itself within a particular group. That the rocker form is more common in Polynesia than outside this region is suggested by a number of investigations. Marshall and Snow (1956: 414) stated that the "most striking peculiarity of Polynesian cranial samples is the characteristic 'rocker jaw'—occurring in some 50% of all Polynesia crania." Snow (1974) stated that 80% of the precontact Mōkapu sample from Hawai'i possessed rocker jaws. In his study of mandibles from New Zealand and the Chatham Islands, Houghton (1977) identified 94% of the Chatham Island skulls with rocker jaws, while the material from mainland New Zealand had 70% rocker jaws. Gill (1990a) found an incidence of 90% rocker jaws in the Marquesas islanders, while his study of the mandibles from Easter Island, the most eastern of the Polynesian islands, reported a frequency of 48.5%. Indeed, Gill (1990b: 21), in discussing the high frequency of rocker jaws in Polynesia, stated that "this trait is considered by physical anthropologists to be virtually 'diagnostic' of Polynesian ancestry."

An exception to the above findings may be found in Pietrusewsky (1984, 1989a). In these studies, Pietrusewsky defines a partial rocker jaw as a mandible which rests squarely on a level surface posteriorly, while anteriorly the chin is elevated "warranting the designation partial rocker jaw" (1989a: 301 and Fig. 5). There is no mention of an antegonial notch in his description, but in his Figure 5, the partial rocker jaw from the 3,000 year old Lapita site of Natunuku, Fiji, has an antegonial notch. Pietrusewsky (1984, 1989b) reports

a very high incidence of rocker jaws for many non-Polynesian populations, for example, from Australia (100-60%), Melanesia (97-29%), China (73%), and Japan (67%) (Table 1). We assume he includes partial and complete rocker jaws in the same tabulations, which may explain the very marked differences between his results and those of other investigators.

In their study of Precontact Chamorro skeletons from Guam, Douglas *et al.* (1997: 297) stated, "None of the mandibles has a full rocker morphology, a Polynesian characteristic (Houghton, 1980), but the anterior rocker variation observed in four females is statistically significant." Thus, in their Table 2 (Douglas *et al.*, 1997: 299), they separate rocker jaws statistically into two categories, none and anterior, since the full rocker jaw morphology is not present in this Guam sample (Table 1). Also, Marshall and Snow (1956) did not report rocker jaw morphology in their study of Guam mandibles (Table 1).

Conclusions

The importance of defining the type of rocker jaw being discussed and tabulated in research papers is critical, otherwise rocker jaw morphology loses its "diagnostic" value as an indicator of Polynesian ancestry. Using the original definition of a rocker jaw, we found that 49% of the precontact mandibles from the Marshall Islands possessed this common Polynesian trait. This percentage, although not high for Polynesia, is apparently high for Micronesia and suggests that genetic contact may have taken place between the Marshall Islands and West Polynesia prior to European contact (see, for example, Lum *et al.*, 1998: 617). Eastern Micronesian and West Polynesian prehistoric interaction is also suggested by shared artifact styles such as *Spondylus* beads, *Conus* arm rings, polished black-lipped pearl shell (*Pinctada* sp.) breast ornaments, and pearl shell trolling lures (Weisler, 2000: 128; Weisler *et al.*, 2000: 213-214). Linguistic evidence, including shared words (lexical cognates) and phonological evidence for borrowing, is documented for eastern Micronesian and West Polynesian languages (Bender, 1981; Harrison, 1994; Lynch, 1998: 50; Thaman, 1987; Woodroffe, 1985). Historically recorded voyages between the Marshall Islands and distant island groups is also well attested (Riesenberg, 1965-1966), but it is uncertain whether small groups would have had significant influence on language change.

Additionally, the founding populations of the Marshall Islands may have included a high proportion of people of Polynesian ancestry, thus providing some empirical support to settlement models based on linguistics and the inferred voyaging routes of ancient mariners originating from archipelagoes to the south (Irwin, 2000: 400) and east. It is also necessary to extend Intoh's notion that Polynesian mixing within Micronesia was limited to Nukuoro and Kapingamarangi (1997: 25 and Fig. 8).

Although only three of the Marshall Island interments were directly dated, other spatially associated radiocarbon age determinations suggest that inter-archipelago contact may have taken place over much of the two thousand year culture-historical sequence known for the Marshall Islands. Further multi-disciplinary studies may identify periods within this long time span when interaction was more common.

Notes

1) The commonly-used spellings of Marshall Islands atolls are given, while the names in parentheses are after Abo *et al.* (1976).

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