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DENTAL PATHOLOGY AND DIET : SECOND THOUGHTS

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ABSTRACT

Dietary regimes have a strong bearing on dental pathology rates. In this paper we use data from large samples of Portuguese Mesolithic and Neolithic dentitions to show that caries rates are not, however, easy to establish. We demonstrate that while comparable methods and samples are obviously necessary, there are more important considerations which have not been discussed in the literature. Accurate observation of different types of caries will be affected by both the type of burial and depositional conditions. Furthermore, it is necessary to take into consideration factors which may bias the available sample, e.g., the demography of the population and differential preservation of tooth classes and of specific age categories. In sum, not only burial practices, but mortality rates, the nature of the burial deposits, the methods of excavation and curation, and the techniques of observing and recording caries, will all introduce variations into caries rates, as well as the immediate biological determinants of oral health. We conclude that it may be impossible to obtain accurate dental pathology rates and that variations in pathology cannot be attributed to diet alone.

INTRODUCTION

We have recently published a detailed study on dietary change from the Mesolithic into the Neolithic, based on large skeletal collections from several Portuguese sites including Moita do Sebastião, Cabeço da Arruda and Casa da Moura. Using stable isotope analyses, together with discussions on rates and types of attrition, we have been able to follow changes from 8,000 BP to 4,000 BP (calibrated years). While dental pathology is included in our discussions, we show that pathology does not give us the clear and simple picture one might expect (Lubell et al. 1994).

Yet caries rates are considered important indications of diet, and there has long been a certainty that alterations in caries rates mark dietary shifts world wide.

Part of the variability that makes the picture unexpectedly fuzzy will be the result of unknown dietary factors. But non-dietary factors also come into play. Two considerations are important here.

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a) The first depends on our ability to observe and recognize caries as the type of caries changes through time, and as burial practices change through time;

b) The second relates to problems of sample bias due to demographic and taphonomical factors.

Problem 1

Analyses of Portuguese Mesolithic dental pathology (Figure 1) demonstrate that it is difficult to identify the "real caries rate". Some of the variation can be explained by different criteria for the definition of caries, and some by different or biased samples. For example, the sample used by Frayer (1987) was less than 50% of the teeth from Cabeço da Arruda and excluded some of the oldest individuals. The only real consistency is the contrast between the two Mesolithic sites, Moita do Sebastião and Cabeço da Arruda. Although they are only 3 km apart, Moita, with a mean date 300 years earlier, has a higher caries rate than Arruda.

Errors in observation of Portuguese Mesolithic caries are to be expected and rates may vary for the simple reason that heavy matrix obscures the fossils (Figure 2). Our results are based on multiple observations (by four individuals, and with progressively more complete cleaning, over a six year period) of dentitions preserved in the Geological Survey of Portugal in Lisbon. We have also made some observations of dentitions from these sites which are housed in the Institute of Anthropology in Porto, but because the material there is not cleaned we will not use those data here.

The state of preservation and degree of cleaning becomes particularly important when interproximal caries are frequent. Complete dentitions set in their alveoli cannot be examined fully, for it is impossible to observe all interproximal surfaces, and the smallest amount of matrix compounds the problem. In such a situation rates must be reported in very specific ways. For example, we would report, not general caries rates, but specifically that Moita has a higher mandibular molar occlusal caries rate than Arruda (14% of lower molar occlusal surfaces at Moita vs. 7% for Arruda), even despite the slightly higher rate of attrition in Moita molars.

We interpret the high Mesolithic caries rates as a result of consumption of sticky fruits, for example, dried figs. However, consumption of sticky fruits might be expected to increase the rate of interproximal caries; but we find that the ratio of interproximal to occlusal caries increases through time (Figure 3). Perhaps our interpretation with regard to fruits may not be correct, or perhaps we are unable to see all interproximal caries in the Moita dentitions.

The question of interproximal caries is of increased importance in the comparison of Mesolithic and Neolithic pathology rates, and this raises the question of burial practices and depositional conditions. Mesolithic Portuguese dentitions are generally in situ in the bone, while Neolithic dentitions rarely are retained in the alveoli. This is due, in large part, to replacement of the Mesolithic pattern of individual burial by ossuary burial in the Neolithic.

Most Neolithic teeth are found loose. Our sample from Casa da Moura included about 5,000 loose teeth, and we were therefore able to do an extremely detailed study, examining every tooth surface using a 10x loup or a dissecting microscope. As a result, we can specify the number of unequivocal caries and state, with complete confidence, when toothpicks were used to relieve the discomfort of caries (Figure 4a).

However, the presence of root caries in the Casa da Moura sample prevents us from being able to state confidently the caries rate for this population. The problem relates to caries such as the one in Figure 4b at the cemento-enamel junction (CEJ) of an upper molar.

When teeth are retained into old age, root surfaces are exposed. Our data from Mesolithic and Neolithic dentitions indicate that over 3 mm of root was laid bare by the time secondary dentin was exposed. Modern clinical research shows that under such conditions one can expect root caries, especially when the diet is based on carbohydrates with little sugar consumption (Fure and Zickert 1990); and we hypothesize increased dependence on cereals and reduced dependence on dried fruits in many Portuguese Neolithic sites. Adults, and even young children, had high rates of CEJ caries from the introduction of agriculture and throughout the period before sugar was widely available in Europe (O'Sullivan et al. 1993).

Unfortunately, there is post-mortem erosion at the CEJ in many teeth; for example, at least 15% of upper molars have marked erosion. We interpret this cemento-enamel junction erosion as postmortem damage (Figure 4c, d, e). If the Casa da Moura CEJ furrowing is in vivo and pathological, there should be significant age trends in CEJ furrowing on the roots of loose teeth. We have not found a significant relationship between age indicators and the presence of CEJ erosion in any tooth class. Thus, not all the CEJ erosion can be attributed to pathology. There may be a generalized relationship between broad wear categories and CEJ erosion, indicating that teeth of older individuals are more susceptible to postmortem damage and also, perhaps, that active caries foci at time of death predispose the tooth root to postmortem damage because of demineralization of the cementum and exposure of the underlying less mineralized dentin.

Thus we have two problems: the first, that root caries may be both mimicked by and masked by postmortem destruction; and the second, that root caries at the approximal CEJ locations are likely to be common and underreported in the literature. At least a third of all Casa da Moura mandibular molar interproximal caries are, or originated as, root caries at the CEJ. This is in perfect agreeement with rates reported by O'Sullivan et al. (1993: 150) for pre-17th Century archaeological samples from Britain. Had the Casa da Moura teeth been retained in their sockets, or had matrix similar to the concreted Mesolithic midden matrix been present, the majority of these caries would not have been observed.

Problem 2

Now we would like to turn to Problem 2: the other reason why we can never be sure of the "real caries rate". Taphonomy is normally considered to be the province of palaeontologists. But it has an aspect, differential diagenesis, which although of minimal concern to faunal analysts, must be considered by the human osteologist. Given purposeful human burial, human osteologists need rarely worry about how bone accumulations came to be where they are. But we must be concerned about bone preservation and how it biases our studies - the effect of differential diagenesis on the analysis of cemetery populations.

This aspect of taphonomy has been largely ignored even though Masset (1973) urged its importance 20 years ago. Belgian work (Toussaint 1991) on bone distribution and body part representation is in the vanguard in Europe, but we have to consider, in addition to the preservation of elements, the age-at-death factor within the preserved elements. When we try to understand the interaction of the human organism with the environment and the mediation of culture in this interaction, we normally analyze age-dependent characteristics, of which dental pathology is a very important example. In order to understand the dental pathology rate we must also take into account (a) the age distribution of the dead and (b) the possibility that the bones of young adults are preferentially preserved.

We have an extremely clear example of the first possibility in a site in Ontario with extraordinarily high mortality because of epidemics, famine and warfare (Jackes 1988). Analyses of stable isotopes and trace elements have shown that the maize component in the diet was very high (see also Schwarcz et al. 1985) and Jackes (1988) suggests that the caries rates (which are about half the expected rates) are determined not only by diet but by the fact that average age at death was very young. Thus, it is worth repeating that *if dental pathology is age-dependent and we do not have a clear idea of the age distribution of our samples, it is meaningless to say that site A has 20% pathology and site B has 40% pathology.* We may really be saying that at Site A there are very few old people, while the Site B sample has relatively more old people. Our reason for maintaining that the difference between Moita and Arruda caries rates is real, despite questions of lowered attrition rates and possible differences in age-at-death distributions, is that both sites show a fairly unbiased sample across all attrition levels (Figure 5).

The second factor which may confound osteological studies is the faster decomposition of the skeletons of the elderly. A 75 year old has about 30% less bone than a young adult of 25. While endosteal resorption accounts for much bone loss in the elderly, intracortical porosity also contributes. There are more Haversian canals, the canals are bigger, there are over 200% more resorption spaces and those are filled with new bone more slowly in the old than in the young (Mazess 1983; Martin and Burr 1989). The thinner cortex and greater porosity of the compactum of the old, together with the reduction of the number of trabeculae in spongey bone, allow bones to break more easily under soil pressure and to be more subject to microbial action. Furthermore, cortical bone with more spaces is more likely to be subject to microbial action (Jackes 1990; Jackes et al. 1992 and in prep.). Thus the bones of the old are preferentially comminuted or destroyed.

As a test of the effect of this problem, we will examine whether dental pathology rates might be incorrect as a result of differential representation of parts and age classes. Our data are the more than 5000 teeth from Casa da Moura, only one third of which are still in situ in alveolar bone. We probably do not have exact figures here the material was excavated in the mid-nineteenth century (Delgado 1867) and recent re-excavation demonstrated that, although the 19th century excavator used very advanced techniques, there are still a lot of loose teeth left in his back dirt (Strauss et al. 1988).

Figure 6 shows a very specific pattern of adult tooth preservation (ignoring the question of premortem tooth loss). Since the right and left sides are almost identical, we know that a specific taphonomic factor, not chance, is at work here. It is striking how similar the curves are for the right and left sides considering when the bones were excavated and how they have been stored, let alone the enormous problems of identification of thousands of loose teeth.

Besides the comparable preservation of sides, what other evidence suggests that there is any general significance to the pattern of preservation? Analyses of Portuguese Mesolithic burials and Neolithic ossuaries by Meiklejohn and Jackes and work by Duarte (1993) on the later Neolithic ossuary of Carenque, allow us to make comparisons among sites. The two Mesolithic sites (Figure 7) show a simple pattern: mandibular dentition is better preserved than maxillary, and first, followed by second molars are the most commonly preserved teeth, while incisors and third molars are the least commonly preserved. The Neolithic sites provide a similar picture for mandibles but the maxillary dentition is more varied in its preservation.

First, there is no similarity among Neolithic sites in the percent frequency of teeth shed from alveoli (Figure 8). This could be due to depositional or cultural factors or to excavation and storage techniques. We cannot make definite statements about which teeth are always more likely to fall out of their sockets and be found loose in deposits, but we can predict that these loose teeth are likely to be maxillary teeth, especially incisors and canines, followed in some sites by mandibular incisors and maxillary premolars.

In general, mandibles are more likely than maxillae to retain teeth in the bone (Figure 8). That is to be expected. Nineteenth century French palaeontologists had already noted the differential survival of upper and lower jaws and the same observation has been made by many modern faunal analysts. Tobias (1987) has used it as a measure of severity of taphonomical effects on East African hominid samples.

We would also have expected complex multiple rooted teeth to be more secure, and generally the first molar, especially on the mandible, is retained in the bone. However, it is unexpected that 65% to 70% of all Casa da Moura mandibular teeth samples are loose: we did not expect that there is really very little difference across tooth types on Casa da Moura mandibles.

While the retention of teeth in the bone is one factor to be considered, the second factor is differential preservation of teeth (Figure 9). The ratio of observed to expected is similar for maxillae across sites. But for the mandibles the ratio of observed to expected is virtually identical in the two Neolithic ossuaries. This is surprising, considering all the factors which could bias the samples, including the difficulty of excavating and identifying thousands of loose teeth. The pattern is illustrated (Figure 10) by the Casa da Moura data, including premortem tooth loss along with surviving teeth. We can assume that we are saying something real here about preservation of mandibular dentition. Since a broadly similar pattern also occurs in the Mesolithic individual burials, which are a thousand years older, this is a justifiable assumption.

Cultural factors during life may intrude. For example, the premortem tooth loss rate for Casa da Moura right central lower incisors is 64%. This is extraordinarily high and is no doubt due to the use of anterior teeth as tools (identified in all Portuguese Mesolithic and Neolithic samples we have examined; see also Lefèvre 1973 and Fléchier et al. 1976).

Cultural practices at burial could also account for some variations in the representation of teeth. We need not go as far as the 19th century excavator of Casa da Moura who speculated on cannibalism (Delgado 1867), but the point must be made that we do not know the burial rites involved.

Cultural practices may be a factor, but it seems more likely that we can discern some general facts about the differential survival of teeth. There is no strong correlation between representation and percent retained in the bone (maxillae r = .230; mandibles r = .069: based on data from Casa da Moura, Carenque and the incompletely excavated ossuary of Feteira; Zilhão 1984), but in both cases mandibular cheek teeth are most likely to be at the high end of the scale. Those most likely to survive are mandibular first and second molars (though strong rooted upper central incisors and upper canines may also be well represented in ossuaries). The teeth most likely to be retained in alveoli are mandibular, especially mandibular cheek teeth.

If we can take this as evidence of a common pattern of differential preservation of teeth in archaeological sites, then it has a bearing on our methods of reporting rates of pathology. We have questioned our ability to provide "real, meaningful" dental pathology rates because of problems of observing and identifying caries, especially at the cemento-enamel junction. Now we want to question whether archaeological samples can ever provide accurate incidences in age-dependent characters like dental pathology.

Different tooth classes have different susceptibility to pathology. The complex topography and grinding function of molars and premolars increases the likelihood of caries over that in the simple, cutting anterior dentition (incisors and canines). If tooth type sample sizes are unequal, then the overall pathology rates will be biased. If there are more molars and fewer anterior teeth in the sample, reported pathology rates will be higher than actually occurred in the living population. And that must be the case with the Portuguese ossuaries. In fact, Casa da Moura had quite low pathology rates. If we calculate a caries rate from our preliminary work using all teeth, the overall mandibular caries rate is around 6%, but the real caries rate must have been lower, simply because the teeth which are least likely to have caries are the teeth which are least likely to be represented in the sample.

Because of this all our work on Portuguese dental pathology is based only on one tooth class - lower molars (Jackes 1988; Lubell and Jackes 1985, 1988; Jackes et al. 1991; Lubell et al. 1994). It is quite clear that our chosen method is flawed because in every site there is a bias against lower third molars, too great to be explained by slow eruption or agenesis of third molars.

The more important question is whether the age distribution of the preserved tooth types differs, and we will search for an answer using mandibular canines, premolars and second molars, all of which have more or less equivalent eruption times. The question is relevant because our analyses show that mandibular canines and premolars may be underrepresented in Neolithic samples by up to 40%, despite relatively high frequencies of retention in alveoli (nearly 40%).

In Figure 11 the four teeth are plotted as cumulative percentages of the minimum number of individuals (MNI) of 302 individuals aged about 11 and over. This MNI is derived separately from first and second molars and from right and left sides, so we can be fairly certain that it is a good estimate of adolescent and adult population size. To the samples of teeth in the older age category, we add the teeth we know were lost premortem.

Figure 11 raises the question of how second molar wear is related to wear on teeth more anterior in the jaw. It is most probable that the attrition grades of Smith (1984), which we used as the starting point for our work, lump too many molars into wear level 3. For more detailed work we use finer gradations. But leaving aside the need for a little smoothing of the M2 curve, we see that the M2 sample is least biased. The premolar and canine samples represent less than 60% of the population. Granted the deficiencies of the wear grading system, we can still say that the inequalities in the samples are most evident in middle and late adulthood. What does this inequality do to the caries rate?

In Figure 12 the premolars and second molars are grouped into three age classes :

1) adolescent and young adult from eruption to the point where no more than a pinpoint of dentin shows;

2) a very general class which includes a broad range of adults from age 30 on through middle age: canine cemental annulation analysis suggests up to 55 years;

3) a third class which, in molars, comprises all those cases in which the fissures have been completely obliterated and the dentin exposures are coalescing: in canines cemental annulation analysis suggests ages 55 to around 80.

Canines are absent from Figure 12 because lower canines were free of caries. But there is premortem canine loss, some of it probably attributable to caries for the reason that a third of Casa da Moura lower first premolar caries are mesial interproximal.

Caries rates increase into old age as expected in the second molar (M2) and the second premolar (P4). But in the first premolar (P3) caries rates actually decrease into old age. Since the two premolar teeth experience equivalent premortem tooth loss (12% in P3 vs. 15% in P4), and nearly half the lower second premolar caries are mesial, it is possible that carious first premolars in higher wear categories are underrepresented. Furthermore, first premolars in higher wear categories have higher frequencies of CEJ erosion than do second premolars (7% vs. 6% strongly marked erosion on the preliminary analysis).

Analysis of the distribution of first and second premolars over the three broad wear categories shows no significant difference (X3 P = .164), indicating that errors in coding for wear do not explain the difference between the two teeth. Nevertheless, this possibility must be controlled for. Figure 13 confirms that third premolars do indeed lack caries in older age categories, as determined by objective measurement of buccal crown height and the ratio of buccal to lingual crown height, not by subjective wear assessments. The value of these two characteristics was determined on the basis of discriminant function analysis which showed them to discriminate among the grouped wear levels. Buccal height contributes most strongly to function 1 which explains 98-99% of the variance.

The combined effects of carious first premolar underrepresentation in older age categories and the masking effect of the CEJ erosion means that we cannot know the caries rate for first premolars. The underrepresentation of lower canines, together with a rate of CEJ erosion even higher than for the lower first premolars (8% marked erosion vs. 7% for P3), again means that we have no clear idea at all of the caries rate in lower canines.

CONCLUSION

There is differential tooth preservation in archaeological sites. Since pathology is age-dependent, the combined effect of the preferential loss of older teeth in categories that suffer least dental pathology means that we are truely unable to estimate overall dental caries rates.

Combined with other considerations including the unknown age distribution of the dead and various problems of defining and observing caries which will differ among sites, our chances of correctly assessing changes in caries rates through time and correctly attributing all such changes to diet alone are not high.

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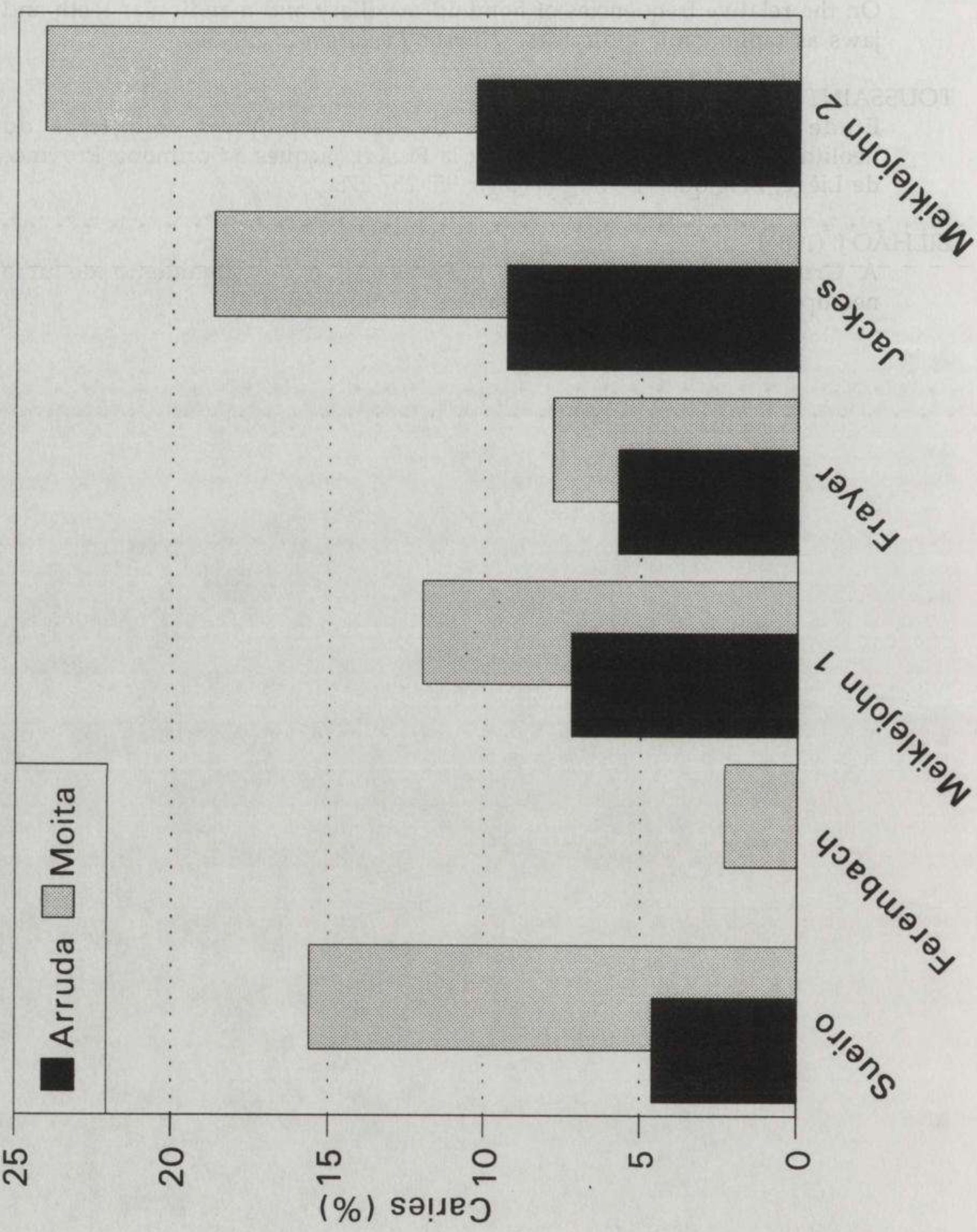

Fig. 1. : Caries rates for Mesolithic Portuguese samples from Cabeço da Arruda and Moita do Sebastião as recorded by different investigators using individuals (Sueiro), all teeth (Ferembach, Meiklejohn 1, Frayer), lower molars only (Jackes), molars and premolars (Meiklejohn 2).

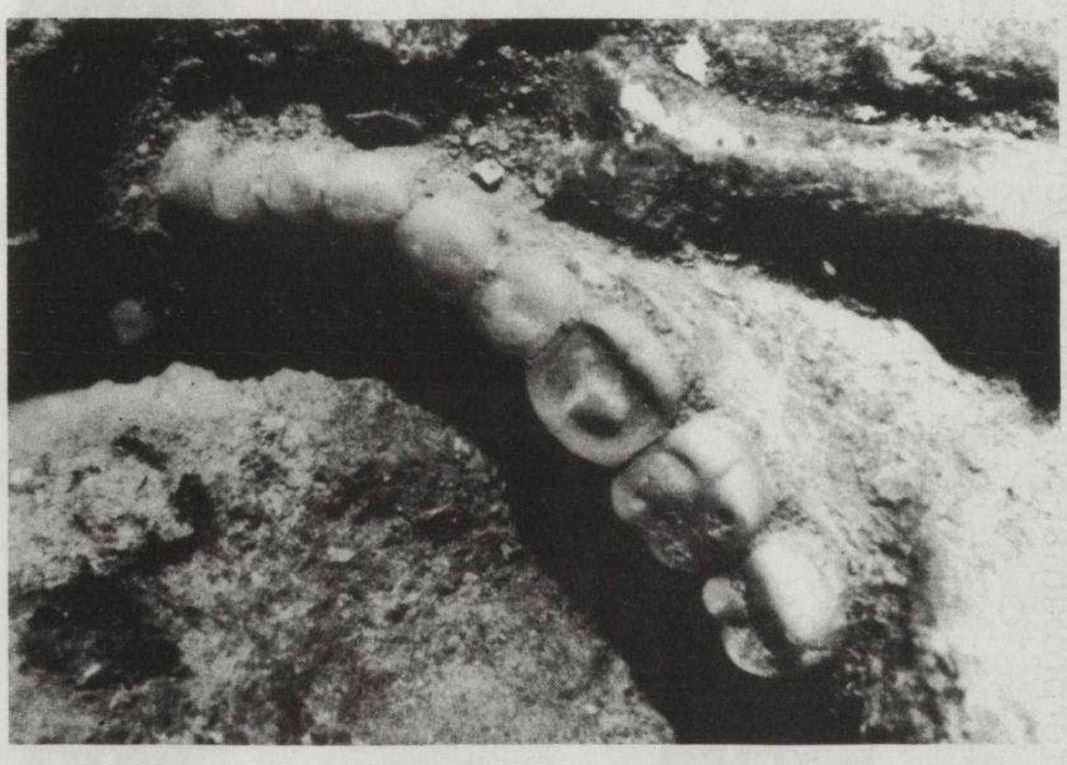

Fig. 2. : Cabeço da Amoreira 7, as preserved in the museum of the Serviços Geologicos in Lisbon, showing partially cleaned matrix obscuring interproximal surfaces.

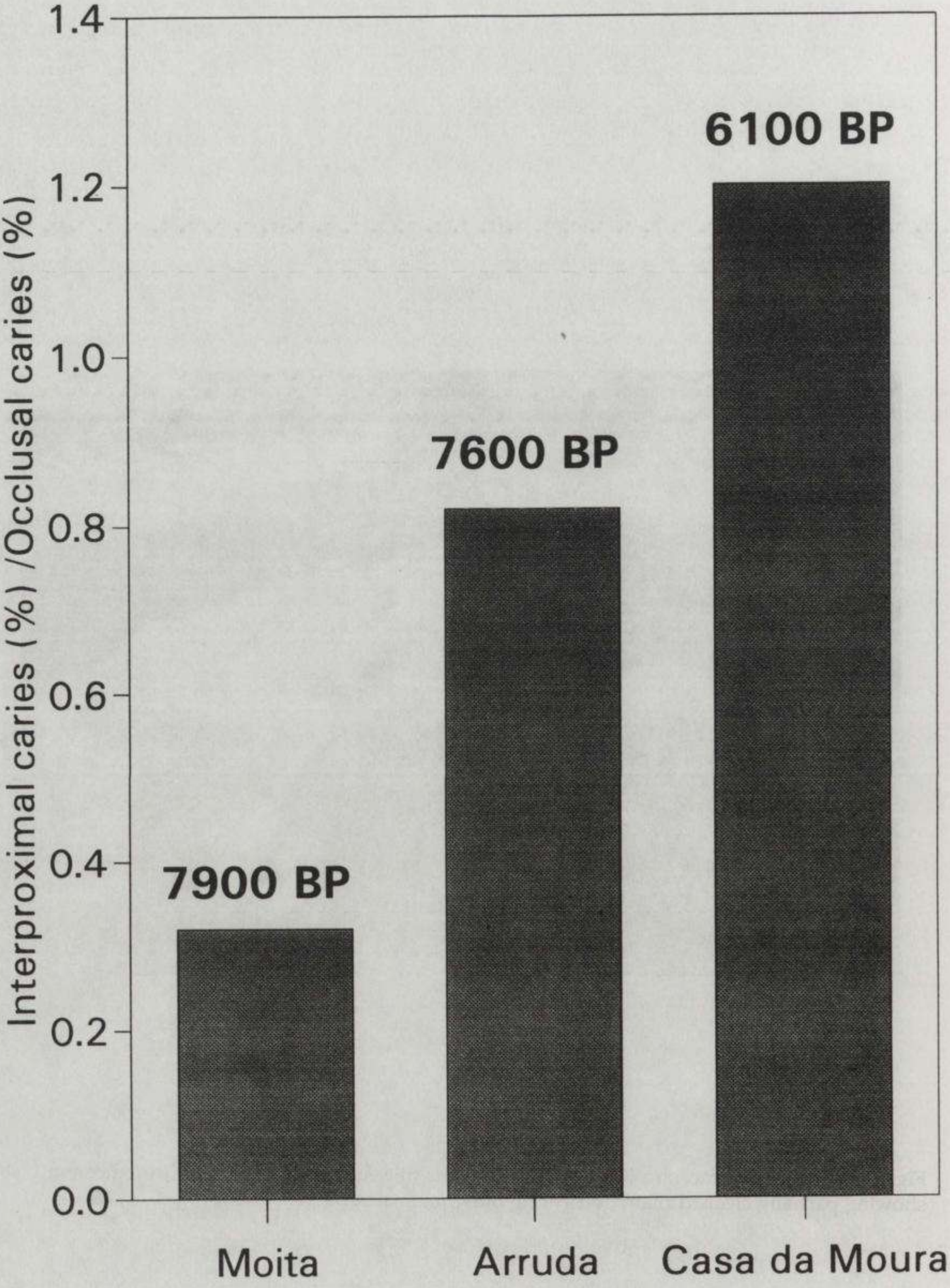

Fig. 3. : Changes through time in mandibular molar pathology in the ratio of interproximal to occlusal caries. Calibrated mean radiocarbon years are shown.

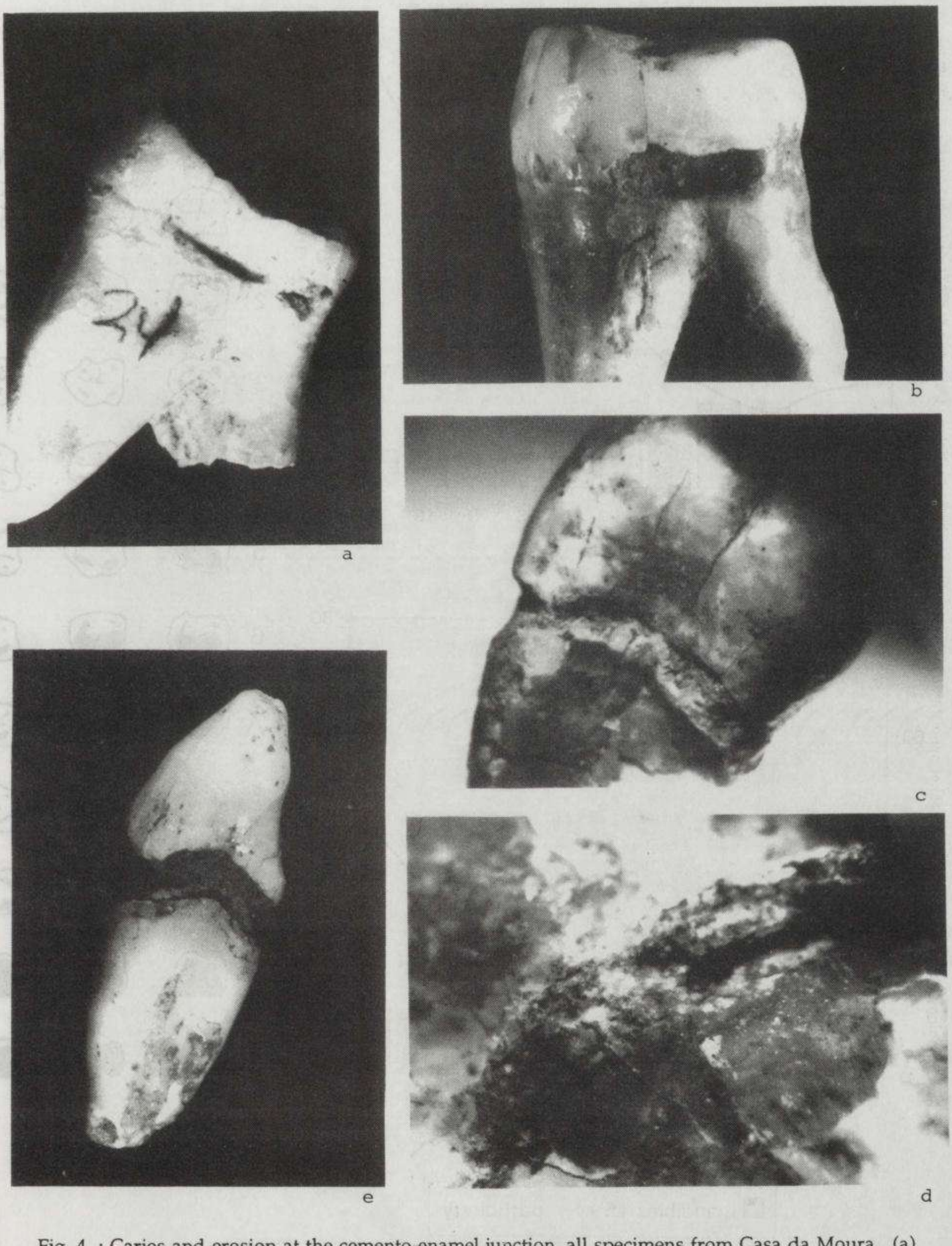

Fig. 4. : Caries and erosion at the cemento-enamel junction, all specimens from Casa da Moura. (a) toothpick groove on a non-carious upper molar; (b) caries on an upper molar, note smooth radical margin; (c) post-mortem erosion on an upper premolar at 6x; (d) same specimen at 12x, note rough floor; (e) extreme grooving on a lower canine.

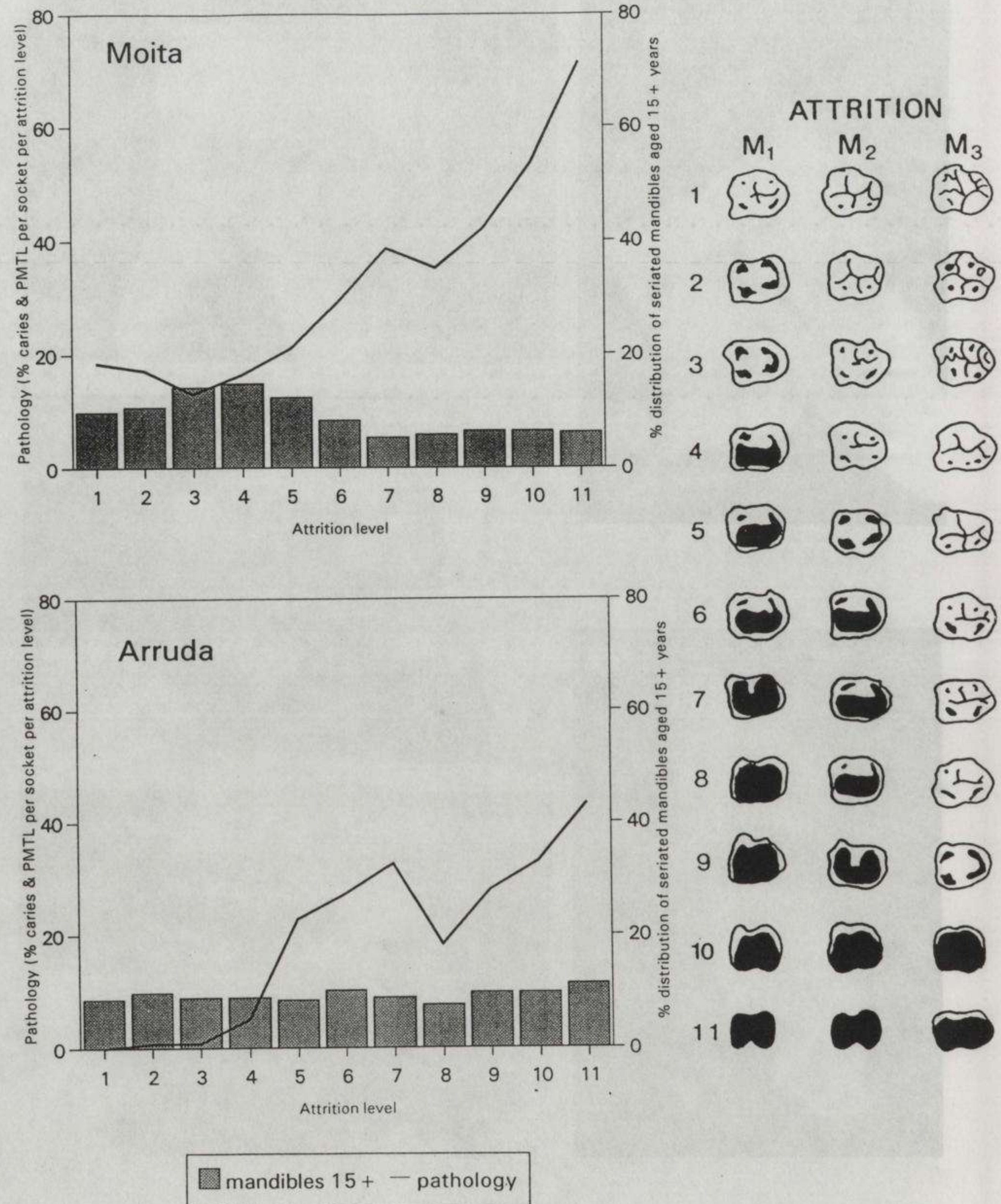

Fig. 5. : Comparison of the pathology rates (premortem tooth loss caries) within each attrition grade for Moita do Sebastião and Cabeço da Arruda. Shaded bars represent the percent distribution of mandibles over 15 years of age across the 11 attrition grades as shown on the right.

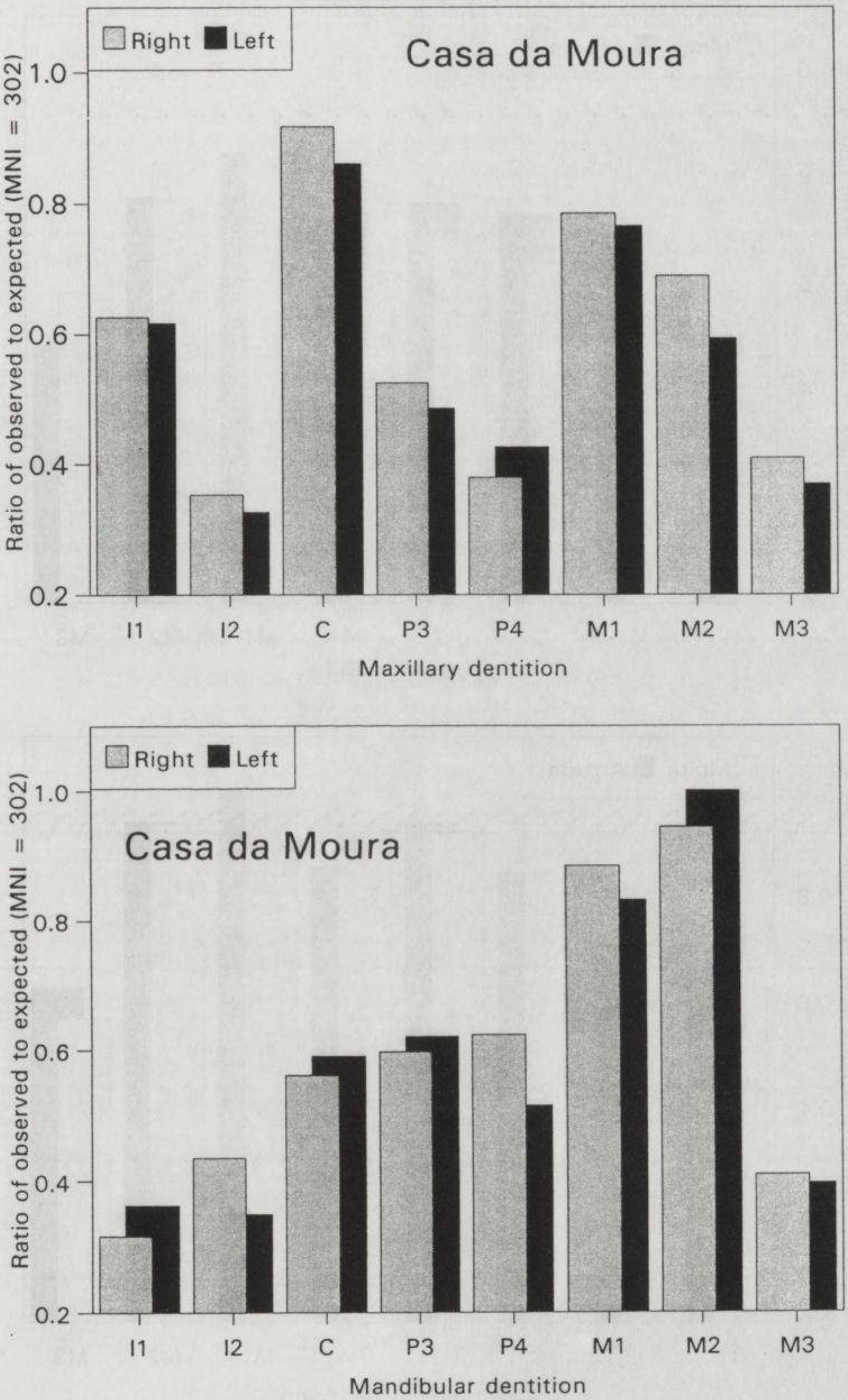

Fig. 6. : Ratio of observed to expected teeth for (a) maxillary and (b) mandibular dentition from Casa da Moura based on an MNI of 302 adolescents and adults.

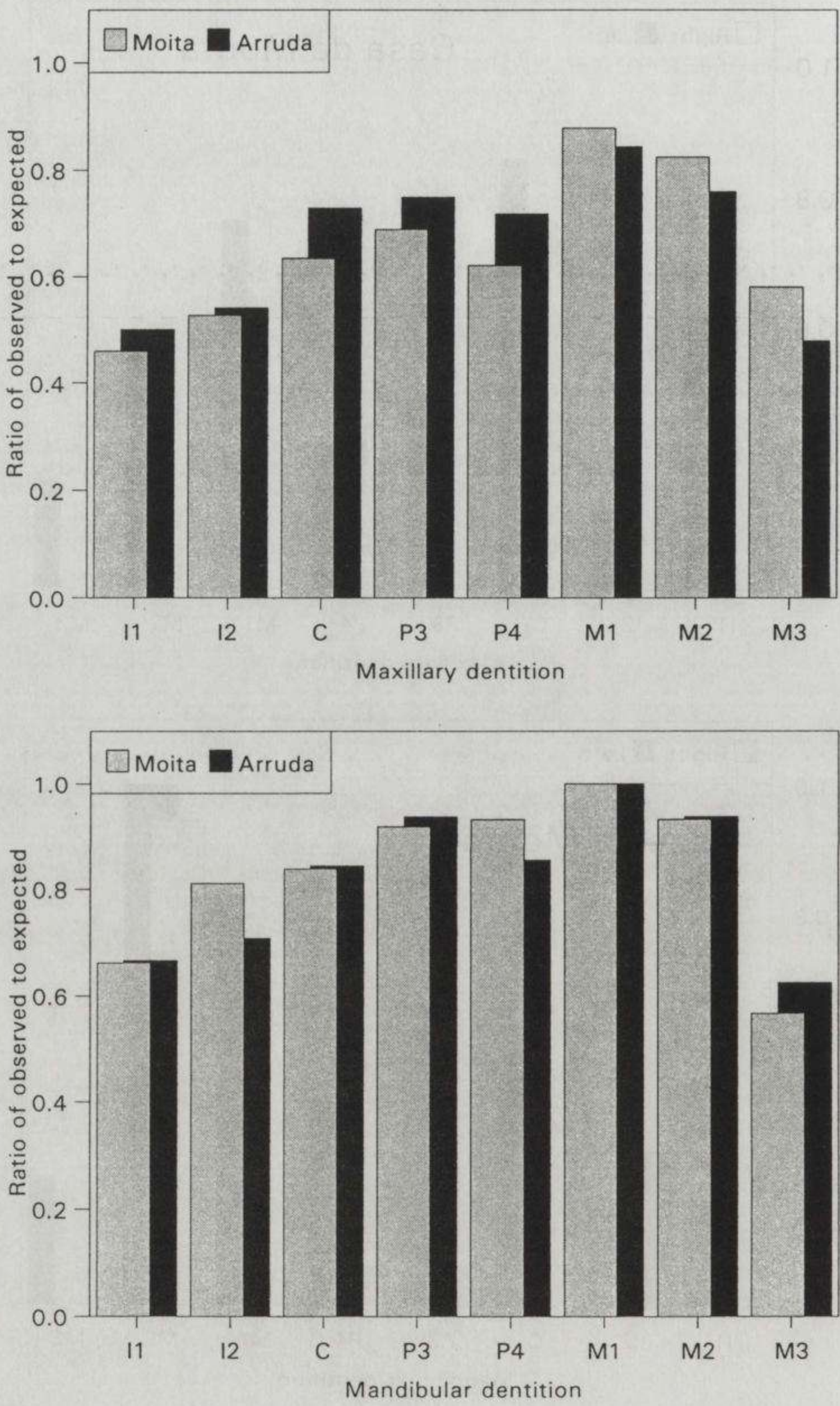

Fig. 7. : Ratio of observed to expected teeth for (a) maxillary and (b) mandibular dentition from Moita do Sebastião and Cabeço da Arruda based the number lower first molars which are the most frequently preserved teeth.

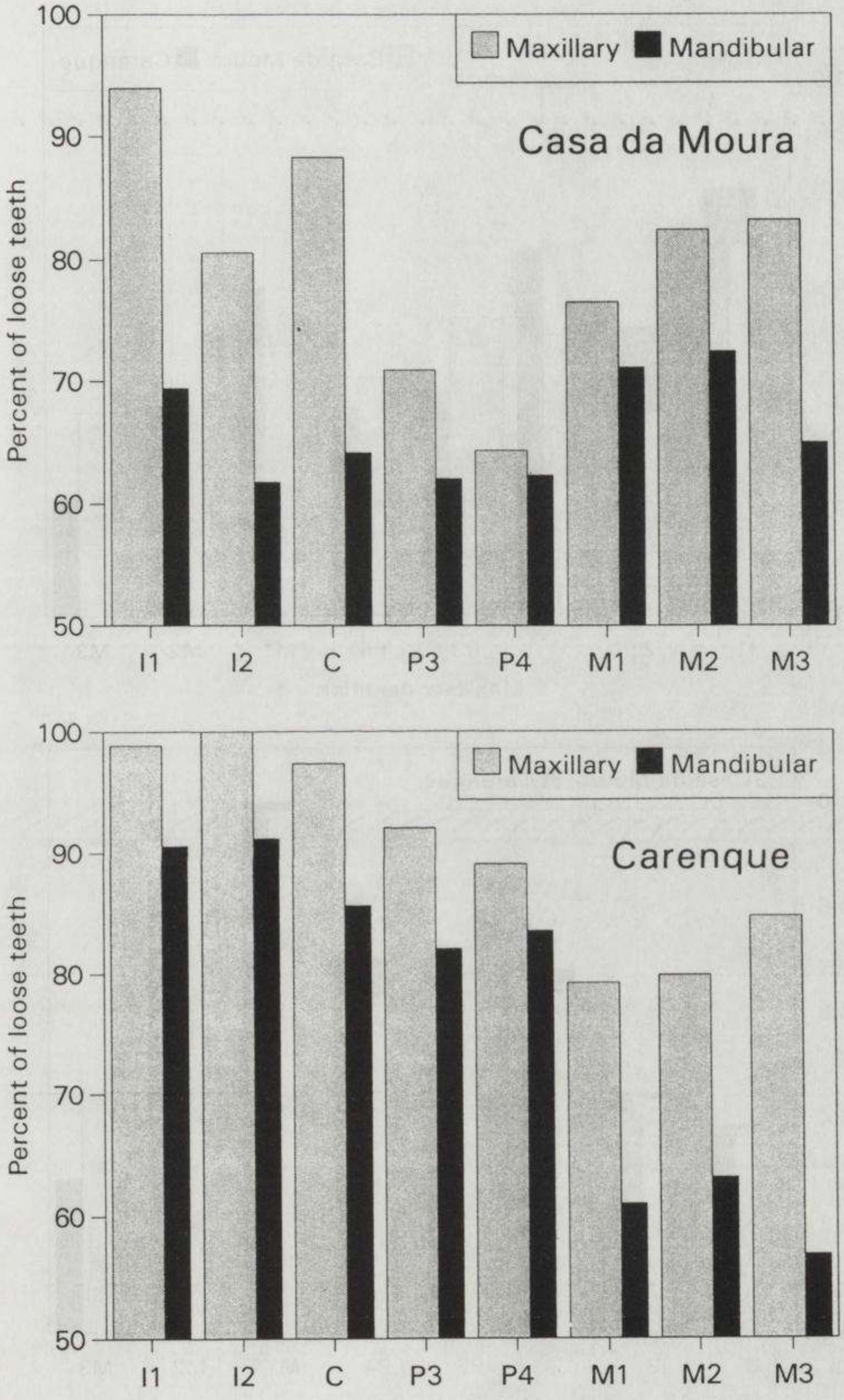

Fig. 8. : Percent of loose teeth in the Neolithic samples from (a) Casa da Moura and (b) Carenque.

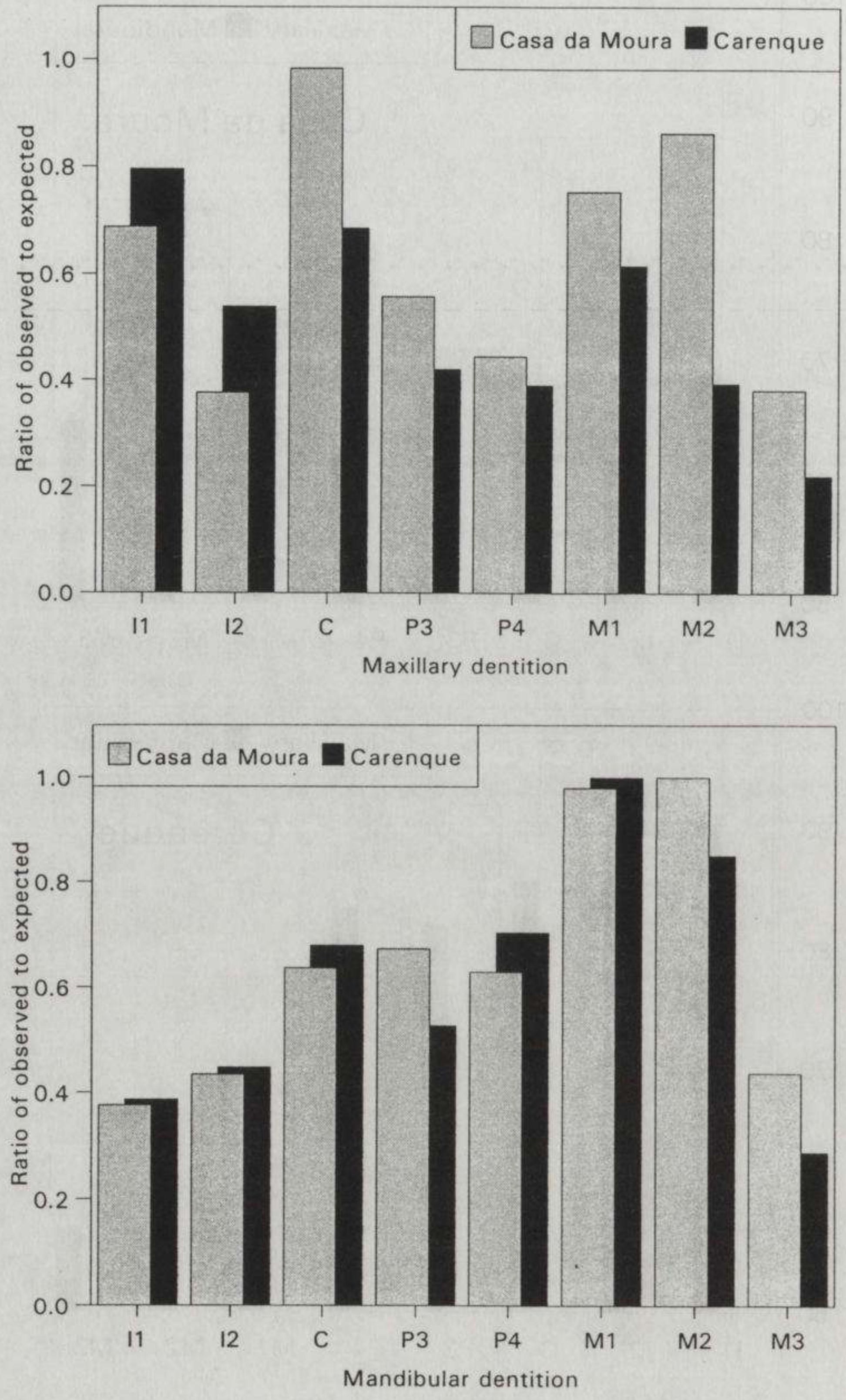

Fig. 9. : Ratio of observed to expected teeth for (a) maxillary and (b) mandibular dentition from Casa da Moura and Carenque.

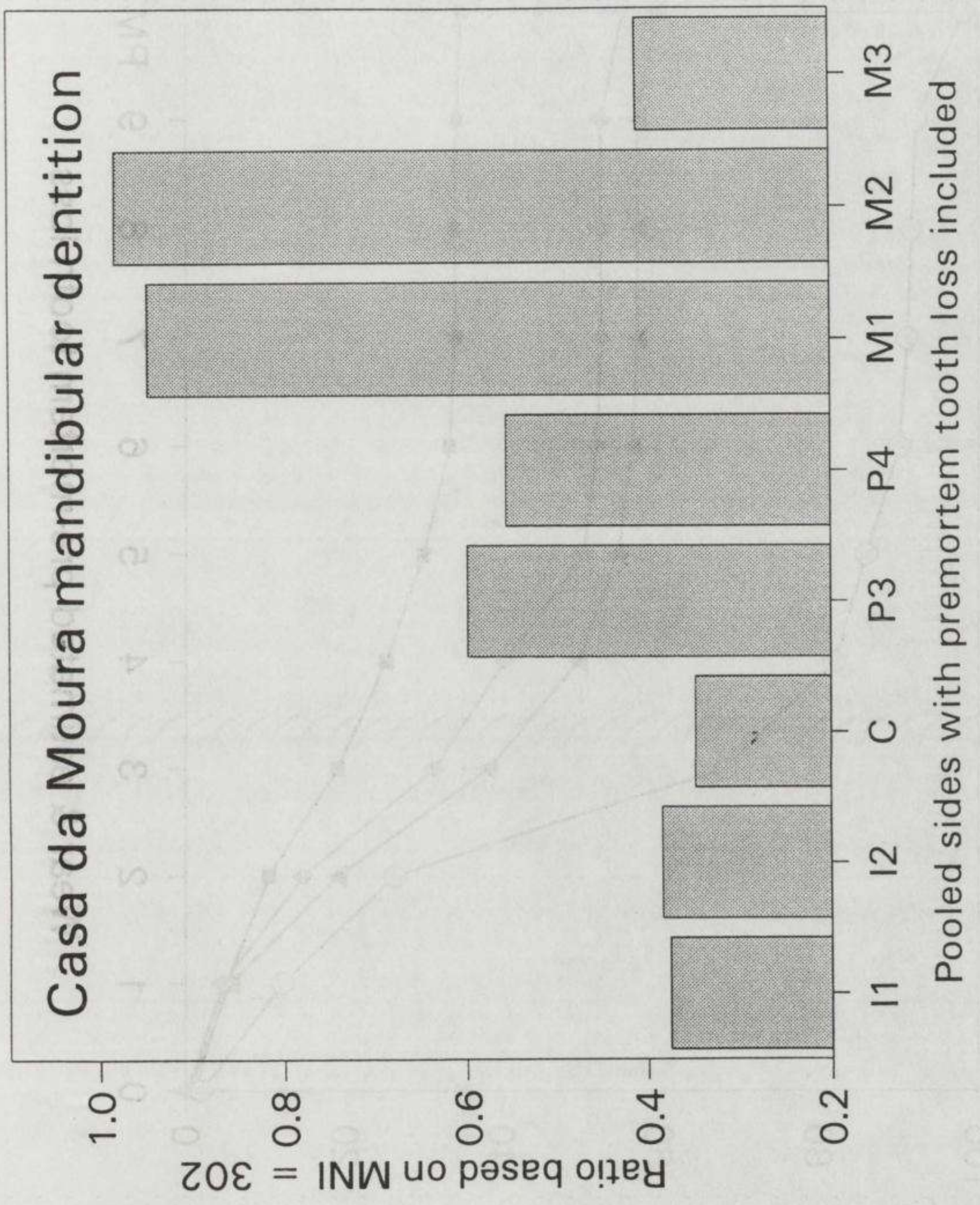

Fig. 10. : Ratio of observed to expected teeth for Casa da Moura loose mandibular teeth and mandibles with premortem tooth loss included.

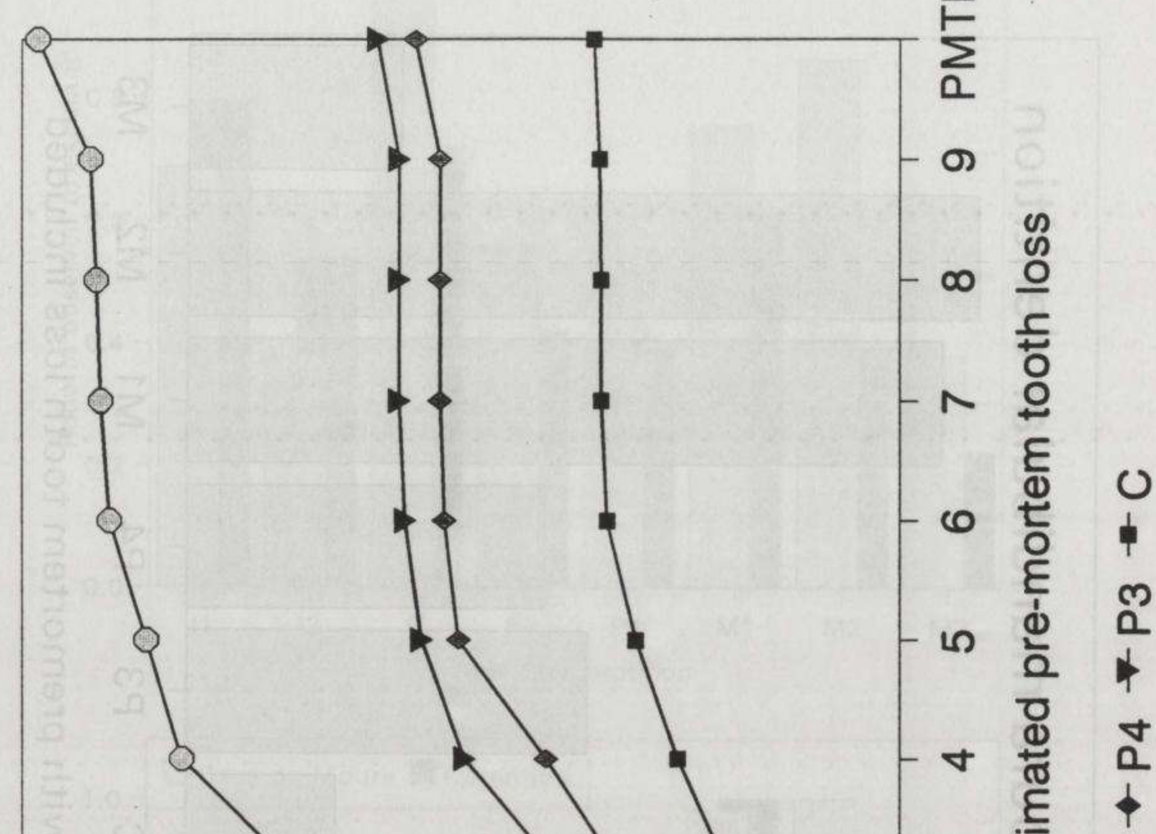

Fig. 11 : Casa da Moura: frequencies of mandibular canines, premolars and second molars plotted as cumulative percentages across attrition stages, premortem tooth loss included.

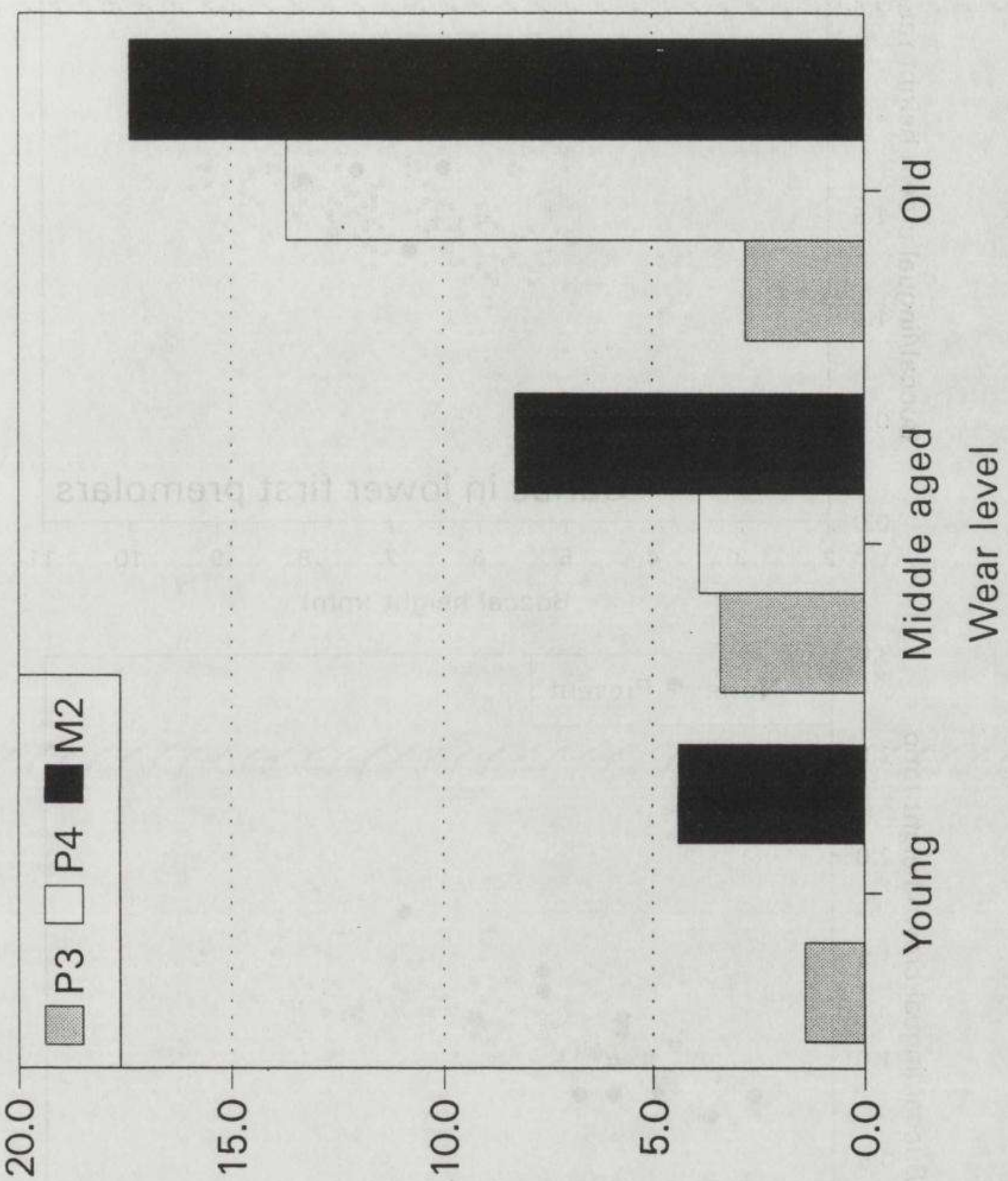

Fig. 12 : Casa da Moura: frequencies of caries in mandibular premolars and second molars by grouped wear levels.

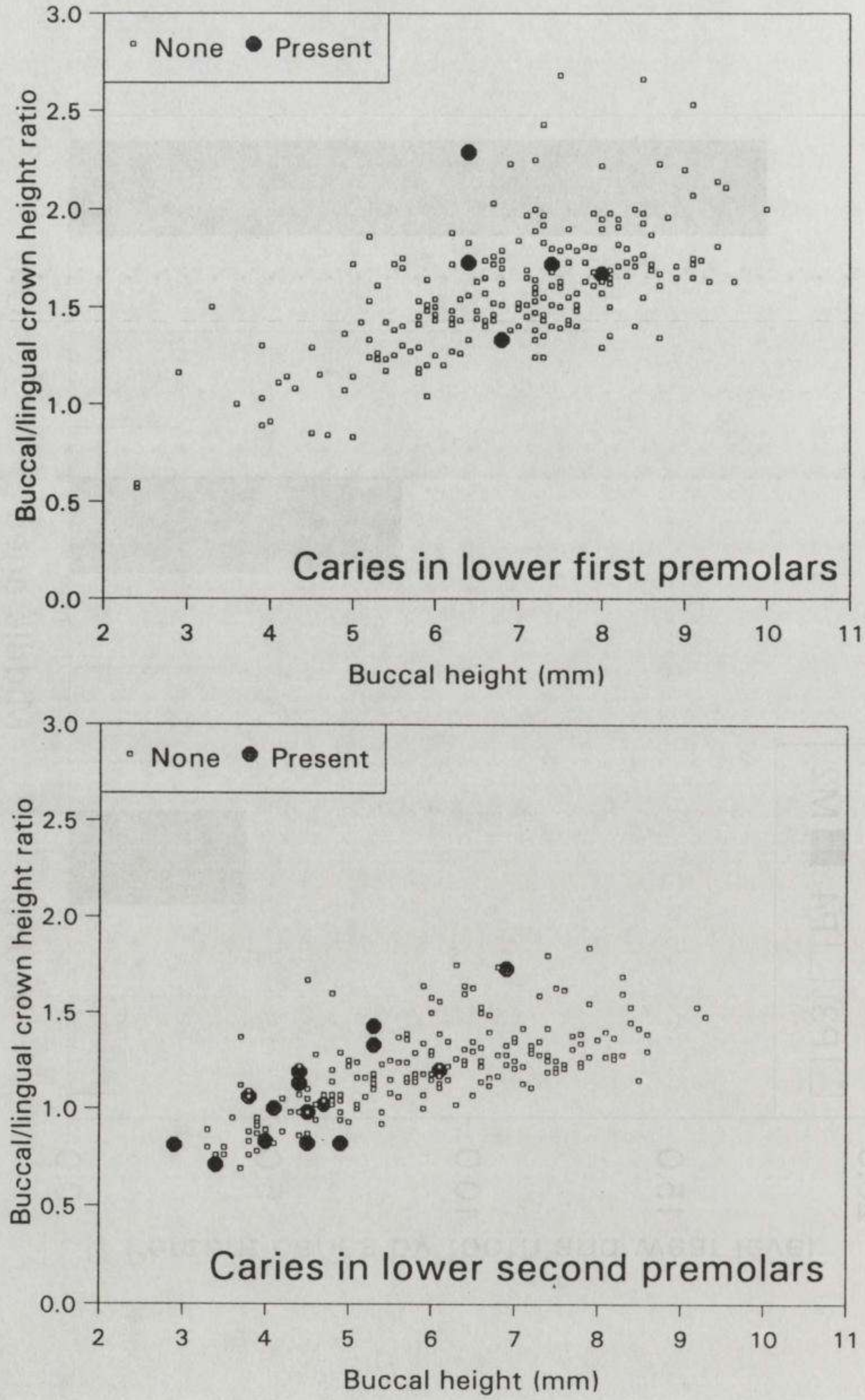

Fig. 13 : Casa da Moura: distribution of caries in (a) lower first premolars (P3) and (b) lower second premolars (P4) based on buccal crown height and angle of wear as expressed by the ratio of buccal to lingual crown height. Sample includes only those teeth in which root formation is complete (apart from closure of the tip).