Dental crowding
The role of genetics and tooth wear

David Normando, Marco A.O. Almeida, Cátia C.A. Quintão

ABSTRACT
Objective: To evaluate the role of genetics and tooth wear in the etiology of dental crowding through the analysis of a split indigenous Amazon population.

Materials and Methods: Dental crowding prevalence (n = 117), tooth wear (n = 117), and inbreeding coefficient (n = 288) were compared for both villages. A biometric investigation was performed by dental cast analysis of 55 individuals with no tooth loss. Mann-Whitney statistics, independent t-tests, and Fisher exact tests were used at P < .05.

Results: A high coefficient of inbreeding was confirmed in the resultant village (F = 0.25, P < .001). Tooth wear was not significantly different (P = .99), while a significantly higher prevalence of dental crowding was confirmed in the original village (PR = 6.67, P = 0.02). Forty dental arches (n = 20) were examined in the new group, and only one (2.5%) had a dental crowding ≥5 mm. In the original villages, we found 20 arches (28.6%) with dental crowding. No difference was observed for tooth size, while larger dental arch dimensions explained a lower level of dental crowding in the resultant village.

Conclusions: Our findings downplay the widespread influence of tooth wear, a direct evidence of what an individual ate in the past, on dental crowding and emphasize the role of heredity, exacerbated through inbreeding, in the etiology of this malocclusion. (Angle Orthod. 2013;83:10–15.)

KEY WORDS: Orthodontics; Tooth attrition; Epidemiology; Malocclusion; Inbreeding; Indigenous population

INTRODUCTION

Despite millions of people seeking orthodontic treatment for dental malocclusion, an understanding of the etiology is not clear.1 The classic Begg study2 reported that tooth wear was an important mechanism to reduce tooth size in Australian aborigines. Although the role of environment and genetics in the etiology of dental crowding is still questioned, new evidence has emerged that indicates that dental crowding is a malocclusion common to modern postindustrial human populations, occurring as a result of increased processing of modern foods.3

Scientifically, this issue has been discussed under three models of study design: experiments with animal models,4–8 the analysis of skull remains of ancient populations,3,9–14 and research in human twins.15–19 Most of these investigations have advocated that the recent increase in the occurrence of malocclusion must be attributed to the availability of a more processed diet and the reduced need for powerful masticatory action or other environmental factors.

The Arara-Iriri indigenous people live by the Xingu River in the Amazon region in the state of Pará, Brazil. This population was isolated and first contacted in 1987. A previous anthropological study20 reported that the indigenous people who constitute this village are descendants of a single couple who were expelled from a larger village, Arara-Laranjal. Though the Arara-Laranjal village was expanded by non- or rarely consanguineous relations, the initial expansion of the Arara-Iriri group occurred through the mating of closely related people (parents-sibs) and later by marriages between relatives somewhat less close, such as uncle-niece, aunt-nephew, and first cousins.
A previous genetic investigation reporting the presence of a single Y DNA and mtDNA haplotype, and a variation of 1–4 alleles from the autosomal loci, confirmed an extreme case of lineal fission (involving related individuals) from the original village. However, the molecular variance and genetic distance between these two Brazilian tribes was greater than those observed between them and other Amazonian tribes. Thus, the fission process has produced remarkable genetic differences between the villages caused by a marked genetic cohesion and a striking founder effect.

The eating habits of the indigenous tribes inhabiting the Xingu region are predominantly traditional and more often based on cassava, nuts, fish, meat of wild animals, sweet potatoes, yams, and wild fruits. All children are breast-fed until the birth of the next child, which usually occurs 1.5–2 years after the birth of the older child. Processed foods are rarely eaten due to geographical isolation and the absence of regular transportation between villages and urban centers. The city of Altamira is the nearest town and is located 120 km and 320 km upstream of the Laranjal and Iriri villages, respectively. This implies a 1- to 3-day journey by boat.

A recent epidemiologic investigation confirmed a marked divergence between the villages for dental malocclusion prevalence. In the original village (Laranjal), only one third of the population showed dental malocclusion. By contrast, in the resultant village (Iriri), the rate of malocclusion was nearly doubled, and the common pattern was a Class III malocclusion (32.6%). Class II malocclusion, anterior open bite, and anterior/posterior cross-bites were also more common in the resultant village.

Since the role of genetics and environment in the etiology of dental crowding is still a subject of great controversy, an examination of two indigenous populations from the same ethnicity expanded by different levels of inbreeding and preserving original feeding habits seems to be a unique opportunity to investigate etiological factors of dental crowding that are camouflaged in modern humans populations.

MATERIALS AND METHODS

This study was approved by the Brazilian National Research Ethics Committee under process number 25000.066559/2010-11. All participating individuals in both villages agreed to sign an informed consent.

The total population was composed of 239 individuals living in the Arara-Laranjal village and 80 living in the Arara-Iriri. All the individuals, except those who were not present in the villages (n = 17), were clinically examined. Subjects were excluded upon examination if they had a primary or mixed dentition, were more than 50 years old, or had lost more than eight permanent teeth. The prevalence of dental crowding in the permanent dentition and tooth wear were examined in 117 subjects (Table 1). After the clinical evaluation, 55 individuals with no tooth loss were selected for biometric measurements. Measurements were obtained from dental casts (Table 1).

### Inbreeding Coefficient

The inbreeding coefficient (F) was determined by the Wright method calculated using the freeware FSpeed (Cambridge, UK, available at http://www.tenset.co.uk/fspeed/). Data were entered in accordance with the heredograms obtained by geneticists from the Laboratory of Human and Medical Genetics, Federal University of Para. It was possible to calculate the inbreeding coefficient for 215 individuals from the original village and for 73 indigenous participants from the resultant village. Because of the unequal variances in the groups, the difference between the two villages was examined statistically by Mann-Whitney statistical test.

### Clinical Evaluation—Dental Crowding and Tooth Wear

Dental crowding was determined when the discrepancy was greater than 3 mm. Agreement for dental crowding prevalence and tooth wear score was performed by the same examiner on dental casts and clinical photographs of the sample selected for the biometric study (n = 55, 47%). This method was used because of the large distances between villages and the nearest town (Altamira). Diagnostic agreement of dental crowding was performed by kappa statistics. The prevalence ratio for dental crowding was calculated, and the differences between the two villages were examined statistically by Fisher exact test.
 Tooth wear was examined through a slight modification of the classification system described by Mockers et al. For each individual, an arithmetic mean for these scores was obtained. Intraclass correlation was used to test the reliability of tooth wear evaluation. The mean scores obtained during the clinical evaluation were compared to those obtained from the occlusal photographs of 20 subjects. The differences between the villages were examined using the independent t-test after normal distribution examination.

Biometric Evaluation—Tooth Size, Dental Arch Dimensions, Dental Crowding, and Little’s Irregularity Index

Biometric measurements were obtained for all indigenous participants in the permanent dentition stage and without tooth loss. Dental casts and intraoral photographs were obtained from 55 subjects (Table 1). Tooth size, arch widths, diagonal length of the arches, dental crowding, and Little’s irregularity index for the indigenous village were measured by one blinded investigator. The measurements from dental casts were obtained using a digital caliper (model Ultra-Cal Mark III; Fowler, Newton, Mass) with 0.01-mm sensitivity. Repeated measures of all subjects were performed after 30 days.

Mean values were used for statistical analysis. Errors for each measurement were obtained through comparative analysis of doubled measurements performed in the 20 individuals. Random error was examined using the Dahlberg formula, and the paired t-test was used to check the presence of systematic error. Normality was analyzed by the Shapiro-Wilk test. Those variables that assumed an abnormal distribution or unequal variances were examined using a non-parametric Mann-Whitney statistical test in lieu of the parametric Student’s t-test for independent samples.

All statistical analyses were performed using the program BioEstat (version 5.0; Mamirauá Institute, Belém, Brazil). Statistical differences were significant at P < .05.

RESULTS

Inbreeding Coefficient

Inbreeding coefficients were statistically different between the villages (P < .0001). The population of the resultant village, who are descendants of a single couple, presented a median inbreeding coefficient of 25% (interquartile range [IQR] = 25), confirming consanguineous relations in this village. Moreover, the original village presented a low coefficient of inbreeding, with a median value equal to zero (IQR = 0).

<table>
<thead>
<tr>
<th>Crowding prevalence (%)</th>
<th>Arara-Laranjal</th>
<th>Arara-Iriri</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth wear (SD)</td>
<td>0.9 (0.7)</td>
<td>0.9 (0.6)</td>
</tr>
</tbody>
</table>

Table 2. Clinical Examination: Dental Crowding Prevalence in the Permanent Dentition and Mean and Standard Deviation for Tooth Wear in the Villages Laranjal and Iriri

Clinical Evaluation—Dental Crowding and Tooth Wear

Clinical examination showed an excellent reproducibility for dental crowding (kappa = 0.9, P < .0001) and tooth wear (r = .80, P < .0001). The occurrence of dental crowding was significantly different between the two villages (Table 2). It was common among individuals of the original village in the permanent dentition (18.5%), while in the resultant village only one man presented dental crowding (Table 2). Regarding tooth wear, our findings revealed no significant difference between the villages (P = .99, Table 2).

Biometric Evaluation—Tooth Size, Dental Arch Dimensions

Random error was smaller than 0.5 mm for arch dimensions and irregularity index (range 0.18–0.48, P > .05) and smaller than 1 mm for the total tooth size (0.88–0.97, P > .05). Comparative analysis of dental arch dimensions revealed marked differences between the villages (Table 3). The main difference was the diagonal length, which was 2.2–3.4 mm larger for the resultant village. For the upper arch, the mean difference between the villages was larger than in the lower arch for both sexes. Lower intermolar and intercanine widths were not significantly different. However, for females, the upper intercanine width was 2.17 mm wider in the resultant village (P = .0009). For males, although slightly higher (0.92 mm), the difference was not statistically significant (P = .21). The larger dimensions of the dental arches in the resultant village associated with the similar tooth size (upper arch, P = .6537; lower arch, P = .1894) corroborate the lower prevalence and amount of dental crowding (Tables 2 and 3).

The mean irregularity index in the original village ranged from 3.1 to 3.8 mm (Table 3). In comparison to the resultant village this rate was higher, justifying the data obtained in the clinical evaluation of dental crowding prevalence. In the upper arch, the irregularity index was significantly larger in the original village for both sexes. This tendency was also observed for the lower jaw but at a smaller magnitude. For the lower
dental arch, the differences among females was 2.64 mm ($P = .0003$); however, for males the difference of 0.59 mm was not statistically significant ($P = .196$).

Forty dental arches were examined in the resultant village group, with only one (2.5%) having an irregularity index $\leq 5$ mm. This 32.4-year-old Class III indigenous participant had an irregularity index of 10.2 mm in the lower arch (Figure 1). For this individual the irregularity index in the upper arch was 0.5 mm. In the original village group, where the epidemiological survey reported a prevalence of 18.5% dental crowding in the permanent dentition, we found 20 dental arches in 35 individuals (28.6%), with an irregularity index $\leq 5$ mm.

**DISCUSSION**

Our findings show a marked difference in the occurrence of dental crowding when the two villages are compared. While only one case (2.8%) was found in the resultant village, in the original village crowding occurred in 18.5% of the population, and dental arches occurred in 28.6%. This difference between clinical examination and dental cast biometry seems to be related to the fact that the sample used in the epidemiological analysis includes indigenous with tooth loss, which can lead to changes in incisor alignment.

The composition of teeth of similar size and larger dental arch dimensions seems to justify the lower prevalence of dental crowding and a better tooth alignment in the new village (Table 3). These results should not be attributed to environmental changes since a previous report demonstrated similar feeding habits for both villages, which was corroborated by the

**Table 3. Random and Systematic Errors, Mean, Standard Deviation, Mean Difference, and $P$ Values for the Biometric Evaluation**

<table>
<thead>
<tr>
<th>Variables (degrees/mm)</th>
<th>Method Error $P$</th>
<th>Dahlberg Value* Mean SD</th>
<th>Mean SD</th>
<th>Mean SD</th>
<th>Diff. SD</th>
<th>Diff. $P$ Value Mean SD</th>
<th>Diff. $P$ Value Mean SD</th>
<th>Diff. $P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper arch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-6 width</td>
<td>0.27</td>
<td>.94</td>
<td>92.6</td>
<td>2.7</td>
<td>.56</td>
<td>.5200</td>
<td>45.98</td>
<td>.03</td>
</tr>
<tr>
<td>3-3 width</td>
<td>0.23</td>
<td>1</td>
<td>95.6</td>
<td>1.6</td>
<td>.78</td>
<td>.698</td>
<td>46.1</td>
<td>.03</td>
</tr>
<tr>
<td>5-5</td>
<td>0.26</td>
<td>1.39</td>
<td>96.6</td>
<td>1.6</td>
<td>.63</td>
<td>.539</td>
<td>46.1</td>
<td>.03</td>
</tr>
<tr>
<td>Little's index</td>
<td>0.97</td>
<td>.38</td>
<td>97.3</td>
<td>2.6</td>
<td>.75</td>
<td>.658</td>
<td>46.1</td>
<td>.03</td>
</tr>
<tr>
<td>Lower arch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-6 width</td>
<td>0.28</td>
<td>.85</td>
<td>44.5</td>
<td>0.7</td>
<td>.59</td>
<td>.798</td>
<td>45.98</td>
<td>.03</td>
</tr>
<tr>
<td>3-3 width</td>
<td>0.23</td>
<td>.96</td>
<td>28.6</td>
<td>1.5</td>
<td>.58</td>
<td>.886</td>
<td>28.5</td>
<td>.09</td>
</tr>
<tr>
<td>5-5</td>
<td>0.26</td>
<td>1.31</td>
<td>95.6</td>
<td>3.1</td>
<td>.95</td>
<td>.996</td>
<td>28.5</td>
<td>.09</td>
</tr>
<tr>
<td>Little's index</td>
<td>0.98</td>
<td>.56</td>
<td>98.6</td>
<td>2.8</td>
<td>.66</td>
<td>.886</td>
<td>28.5</td>
<td>.09</td>
</tr>
</tbody>
</table>

* SD indicates standard deviation; bold type, Mann-Whitney; italic type, $P = .05$.

* $P$ values based on $t$-test or Mann-Whitney.

**Figure 1.** Intraoral photographs of a 32.4-year-old indigenous male from the resultant (Iriri) village. He was a Class III malocclusion, associated with an anterior open bite (b). The irregularity index was 0.5 mm in the upper dental arch (c), while in the lower arch the irregularity index was 10.2 mm (d). Tooth size-arch length discrepancy was 4.5 mm.
similar pattern of tooth wear found in the present investigation (Table 2).

Although scientific investigations have advocated that the recent increase in the occurrence of dental malocclusion must be attributed to environmental changes during human evolution, a critical analysis of these studies should take into consideration some important methodological issues that require further discussion. Reports examining skulls of ancient populations have advocated that a primary factor in the occurrence of dental crowding is the environment. However, the lower frequency of dental crowding in these isolated populations may be a primary consequence of a homogenous genetic background expressed in a small population. This hypothesis is supported by studies examining ancient populations with crowding, even in the presence of a severe tooth wear.\textsuperscript{10–12} It seems difficult to determine the exact age in such skulls or individuals and its influence on dental wear. Thus, the observation of tooth wear in human skulls is limited and may not be associated with diet but also with aging.\textsuperscript{28,29}

The most widely used research model to define the primary role of dietary consistency on malocclusion has been the animal studies. Several species of mammals, including apes, have been used. Animals raised on a hard diet showed more rapid tooth wear than did animals raised on a soft diet.\textsuperscript{29} The extrapolation of this result to craniofacial and occlusal development in humans is critical since electromyography data demonstrated that jaw-closing muscle recruitment patterns for macaques and baboons differ from those of humans.\textsuperscript{30} Some changes arising from manipulation of food consistency in animals, although statistically significant, are small in magnitude and mainly related to the transverse maxillary growth.

Some studies examining twins have suggested dental malocclusion as a primary consequence of environmental changes. Recently, several criticisms have been made about this research model.\textsuperscript{19} A major issue of concern in previous studies of twins has been the accuracy of zygosity determination by comparison of physical appearance. The use of highly polymorphic regions of DNA has proved to be more accurate and reliable.\textsuperscript{31} It is also questionable whether it is reasonable to extrapolate the findings from twin studies to a general population.

The epidemiologic study of primitive human populations is an interesting opportunity to determine the influence of genetics and environment in the occurrence of dental malocclusion. These studies are mostly inconclusive, since it is not possible to define the genetic background and ethno-historic factors for populations under analysis. The examination of the Arara villages provides a unique opportunity, given the historical\textsuperscript{20} and genetic records\textsuperscript{21} obtained for these populations. A previous investigation revealed that these two indigenous populations belonging to the same ethnicity showed marked differences regarding dental malocclusion prevalence.\textsuperscript{23}

Our findings strongly suggest that the marked difference in dental crowding and arch dimensions are related to the genetic distance and the molecular variance between the two Arara villages. Therefore, despite the common origin, these populations have different genotypes.\textsuperscript{24} This difference is explained by the genetic drift, a stochastic process, acting more frequently on small populations, changing the frequency of alleles and the prevalence of certain characteristics in a given population. Also, this study supports the hypothesis of a distinct case of founder effect, where the founders of the resultant village (Arara-Iriri) presented dental characteristics different from those observed for most of the indigenous population living in the original village (Arara-Laranjal). Probably, they were people without crowding and with larger dental arches. These founder characteristics have been spread among their offspring through the genetic drift, amplified by inbreeding.

CONCLUSIONS

- A marked difference in the occurrence of dental crowding and dental arch dimensions is observed when the two villages are compared.
- With the support of previous anthropologic and genetic investigations, we suggest an outstanding influence of hereditary factors, exacerbated by inbreeding.
- Our findings downplay the widespread influence of tooth wear, a direct evidence of what an individual ate in the past, on the etiology of dental crowding.

ACKNOWLEDGMENTS

We are grateful to the FUNASA-Altamira and CAPES (Brazilian Federal Agency for Postgraduate Education). We thank Dr. Sandra Meihubers and Jane Moreno for revision of the English text.

REFERENCES


