Pig husbandry and environmental conditions in Northern Gaul during Antiquity and the Early Middle Ages: the contribution of hypoplasia analysis

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ABSTRACT: Ongoing archaeozoological analyses into the Roman –early medieval transition in the fertile area of the Middle Belgian and Dutch loess region have shown a diachronic shift in the importance of pigs. The present paper examines the linear enamel hypoplasia (LEH) of pig teeth from five sites covering the early Roman, late Roman and early medieval periods. The results are confronted with palynological, archaeological and textual data regarding land use and forest cover in an attempt to explain the observed trends in species composition and to document possible changes in pig husbandry and the environment.

KEYWORDS: PIG, HYPOPLASIA, ENVIRONMENT, HUSBANDRY

RESUMEN: Investigaciones arqueozoológicas en curso sobre la transición entre la época romana y la Edad Media en la fértil región de los loess belga-holandeses han evidenciado un giro en la importancia del porcino. En este trabajo se analiza la hipoplasia esmaltógena (LEH) en dientes de cerdo de cinco asentamientos que incluyen horizontes romanos tempranos, horizontes tardorromanos y horizontes del inicio de la Edad Media. Los resultados son cotejados con información palinológica, arqueológica y contextual referida al uso de la tierra y la extensión de las masas forestales en un intento por comprender las tendencias constatadas en las taxocenosis así como para documentar eventuales cambios en las prácticas ganaderas referidas al porcino y el ambiente.

PALABRAS CLAVE: CERDO, HIPOPLASIA, AMBIENTE, GANADERIA

INTRODUCTION

The transition of Antiquity to Merovingian times in northern Gaul has been much debated in the literature, in particular the aspects of change versus continuity. It is generally accepted that the highly specialised Roman economic system did not survive the fall of the Roman Empire (Bitter, 1991a). By the end of the 3rd century AD, signs were already visible of a decline and decentralisation of economic and social structures. In the countryside a decrease of production capacity is seen (Van Ossel & Ouzoulias, 2001), and there would have been a tendency to return to a more autarkical economy. This type of closed economy is presumed to have been dominant in the rural world until the 7th century (Bitter, 1991b). In addition there was a change in the composition of the human inhabitants, with Germanic populations settling inside the frontiers of the Roman Empire from the end of the 3rd century onwards (Ouzoulias, 1997). Under the influence of these populations, the gallo-roman cultural landscape gradually transformed into a gallo-frankish or gallo-germanic society. It is worth underlining that this also had implications for the human perception of the environment. The Roman culture had little esteem for uncultivated spaces that were seen as a true antithesis of civilization. The *saltus* represented the virgin, non-human, non-civil nature, a place of marginality and exclusion. Opposed to it was the *ager*, the set of cultivated grounds, nature tamed and ordered by mankind. In the German culture, in contrast, the wild world and uncultivated zones were prized as an environment with a wealth of exploitable resources (Montanari, 1995). These different attitudes towards the environment and land use may also have had an effect on the husbandry practices through the time periods considered here.

In order to address these issues, about 90,000 faunal remains have been studied from five archaeological sites, located in the fertile Middle Belgian and Dutch loess region (Figure 1). These range in date from the Roman period until the end of the early medieval period, or roughly the first millennium AD (Pigière, in preparation). Some of these sites yielded material from all considered periods; others cover fewer periods (see description of sites below). When the proportions of cattle, ovicaprines and pigs are considered through time, it appears that all sites, despite their differing status, show a similar trend, i.e. a marked increase in pigs during the late Roman period that is maintained into Merovingian times.

In the present paper, the observed trends in the species composition are described and an analysis is carried out of the linear enamel hypoplasia on the pig teeth, in an attempt to understand the ecological conditions and pig husbandry practices through time. This linear enamel hypoplasia (LEH) is a deficiency in enamel thickness occurring during tooth crown formation and is visible as macroscopic lines or depressions on the tooth crown surface. The enamel producing cells, ameloblasts, are very sensitive to physiological disruptions that temporarily lower, or stop, the enamel production, resulting in the appearance of LEH (Goodman & Rose, 1990; Hillson, 1996, 2005). Once the disruption is over, the ameloblasts have the ability to recover and begin secreting again. Any disruptions occurring during tooth crown formation are permanently recorded, as the enamel becomes inert once it is mature and, therefore, cannot be further remodelled. The main disruptions that cause LEH are physiological stress (such as birth, weaning…) and stress of infectious and nutritional nature (food availability and quality) (Skinner & Goodman, 1992). Although hypoplasia studies initially concentrated on primates, other taxa, including pigs, have recently also been investigated (e.g., Dobney & Ervynck, 1998, 2000; Ervynck & Dobney, 1999; Witzel *et al*., 2006). As the prevalence and intensity of LEH is mostly related to food availability, its study can shed light on the environmental conditions and different husbandry practices under which pig populations were kept. Although the analyses in this paper are made on teeth from domesticated pigs it is worth mentioning that in wild boars LEH appears less frequently as a result of natural selection which favours the stronger and more resistant animals with a better overall fitness and therefore lower LEH frequencies (Dobney *et al*., 2004). When the woodland in which pig herding was traditionally practiced degrades, an increase in LEH-frequency can be expected, whereas a decrease in the prevalence can occur when pigs are kept in semi-confinement where the feeding regime is under better control (Ervynck & Dobney, 1999).Because palynological analyses have been carried out on most of the sites discussed here, a confrontation of the environmental, faunal and LEH-data is possible.

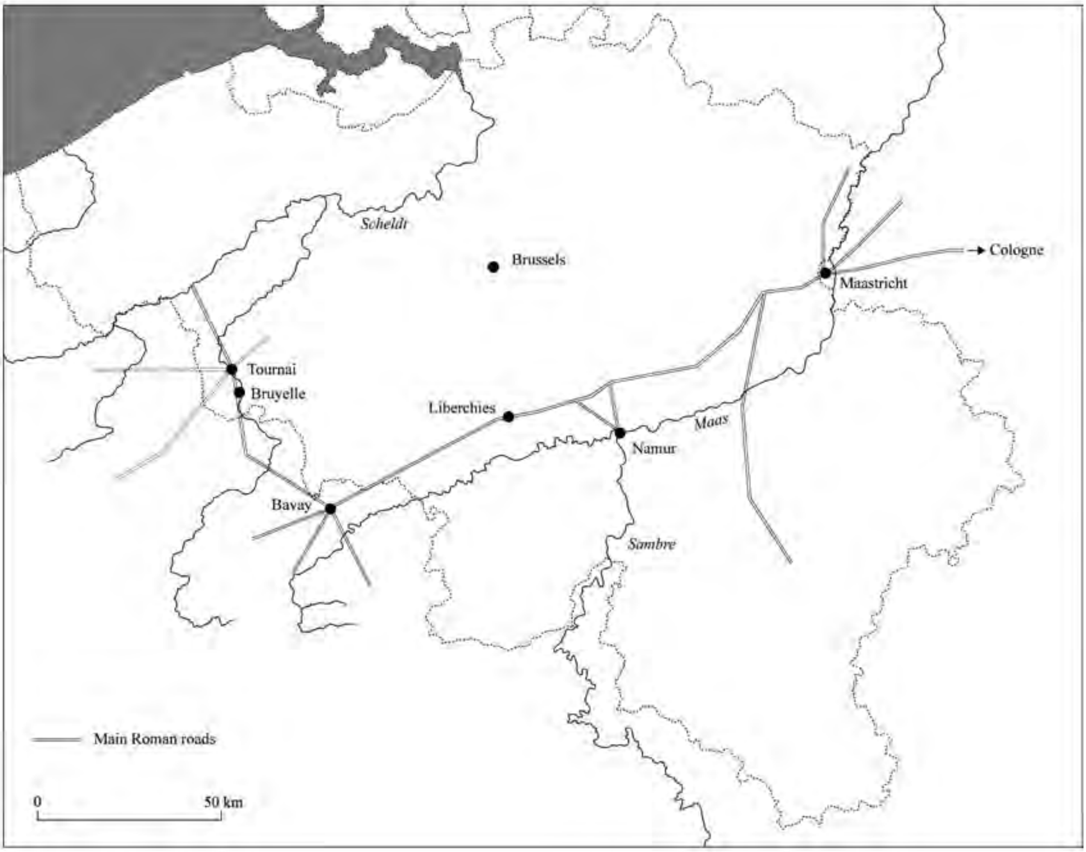

FIGURE 1
Location of the different sites.

THE ARCHAEOLOGICAL SITES, THEIR FAUNA AND THE ENVIRONMENTAL CONDITIONS

Below the five sites are briefly placed in their archaeological and historical context and the general composition of their domestic fauna is described for the various occupation periods. In addition, the environmental data obtained on the sites through palynological analyses are summarised.

The villa of *Bruyelle* is the only rural settlement with a sufficiently large sample of pig teeth suitable for LEH analysis, for both the early and the late Roman periods (Table 1). The site is located near the River Scheldt at about 5 km from Tournai. The villa of Bruyelle was a large, wealthy, farming estate during the early Roman period until its decline in the 3rd century. During the late Roman period (2nd half of 3rd until 1st half of 4th c. AD) domestic stock keeping continued (Bausier *et al*., in press), but in addition artisanal activities such as pottery production occurred. Because the number of faunal remains from the late Roman period is low, the evolution of the domestic stock cannot be precisely documented at the transition of early to late Roman periods. However, it is worth mentioning that a high proportion of pig remains is found in the early Roman period (47% of the classical trio cattle, pig and sheep/goat) (Figure 2). The analysed pig teeth are mainly from consumption remains found both in the farmyard and in the residential area of the villa (Pigière *et al*., in press). Pollen analysis has shown a recovery of the natural vegetation, mainly of the shrubs and bushes, at the end of the early Roman period. A repopulation with trees, bushes and hedges is observed with not only an increase in alder and hazel, but also in oak, pine and hornbeam (Defgnée and Munaut, in press).

	M1	M2	M3	total
Namur Early Roman	27	27	17	71
Namur Late Roman	0	1	3	4
Namur Merovingian	30	42	24	96
Namur Carolingian	24	22	15	61
Maastricht Late Roman	87	96	51	234
Maastricht Merovingian	26	34	32	92
Liberchies Early Roman	55	66	73	194
Tournai Early Roman	8	6	3	17
Tournai Late Roman	11	15	15	41
Tournai Merovingian	19	9	4	32
Bruyelle Early Roman	6	8	6	20
Bruyelle Late roman	7	8	3	18
				sum = 880

TABLE 1

Time periods and number of examined teeth at the different sites.

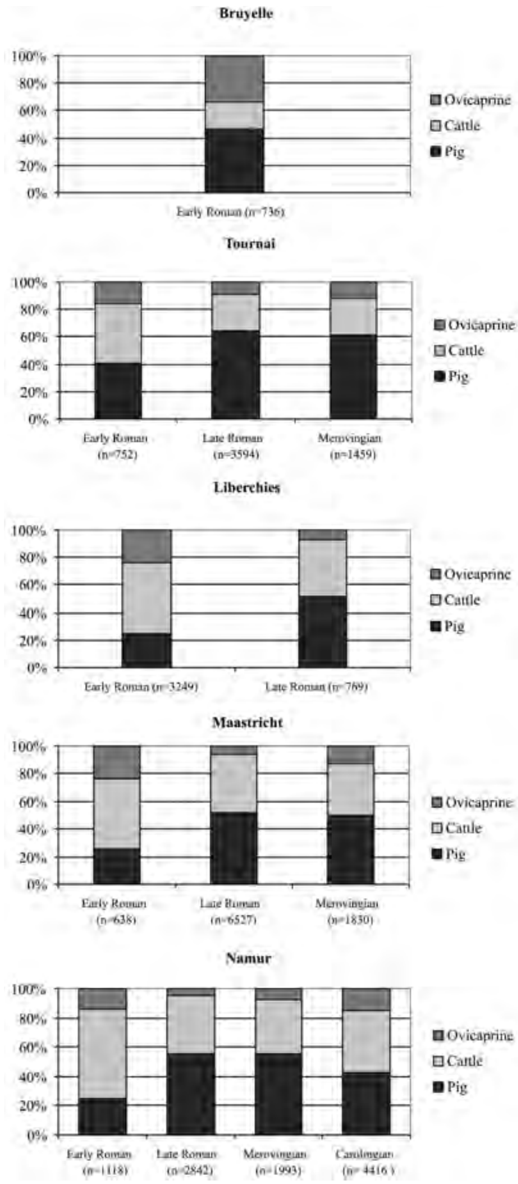

FIGURE 2

Proportions of pig, cattle and ovicaprines for the various sites and periods.

The *vicus* of *Tournai* was founded in early Roman times along the river Scheldt at an important junction of Roman roads. When it became a *civitas* capital in the late Roman period, it was intensively rebuilt. The town maintained a high status in Merovingian times as a royal residence of the Franks and as an Episcopal seat (Brulet, 1984; Verslype, 1999). The site of Cloîtres, in the heart of the fortified city, yielded numerous pig molars from the consumption refuse of the early Roman (1st – 3rd c. AD), late Roman (4th – 5th c. AD) and Merovingian periods (6th – 7th c. AD) (Brulet *et al*., 2004; Pigière, submitted). As in the other considered sites, the consumption refuse consists mainly of the typical trio of domestic mammals. Through time an increase in the contribution of pig is seen (Figure 2) with 41% in early Roman times and 64% in the late Roman period. In Merovingian times pig continues to be important (61%). Pollen analysis has shown that the region of Tournai was an open landscape with few trees in early Roman times. A recolonisation of the forest occurred in the Merovingian period with a rise of the pioneer forest species (hazel, birch and alder) and an increase in oak (Defgnée & Munaut, in press; Brulet *et al*., 2004) (Figure 3).

The *vicus* of *Liberchies* was located along the main road between Bavay and Cologne. Towards the end of the early Roman period, during the third quarter of the 3rd century, it was abandoned, but was subsequently re-occupied by the military who erected two fortresses in the course of the late Roman period (Brulet *et al*., 2002). Important changes in the food provisioning are visible through time: the proportion of pigs increases dramatically from 25% in the early Roman (1st – 3rd c. AD) contexts (Lentacker & Vilvorder, 1997) to 51% in the consumption refuse of the 4th century fortress (Gautier, 1982, 1988). The analysed pig remains are derived from several sectors of the *vicus* (Lentacker & Vilvorder, 1997; Lentacker *et al*., 2001). Unfortunately the late Roman period yielded no molar teeth which could be examined for LEH. Concerning the natural vegetation at Liberchies, a shift is observed from the early to the late Roman period (fig. 3). In the early Roman period few trees were recorded, the ligneous vegetation being mainly composed of bushes and shrubs (alder and hazel). Grassland and cereal fields must also have occurred in the vicinity (Heim, 2002). The arboreal pollen percentage increases in the late Roman period, showing a recovery of the forests, with especially the pioneer species hazel and birch becoming more abundant. In addition, a rise of oak, alder and beech is observed, together with the reappearance of species such as hornbeam, wild cherry, willow, lime and elm.

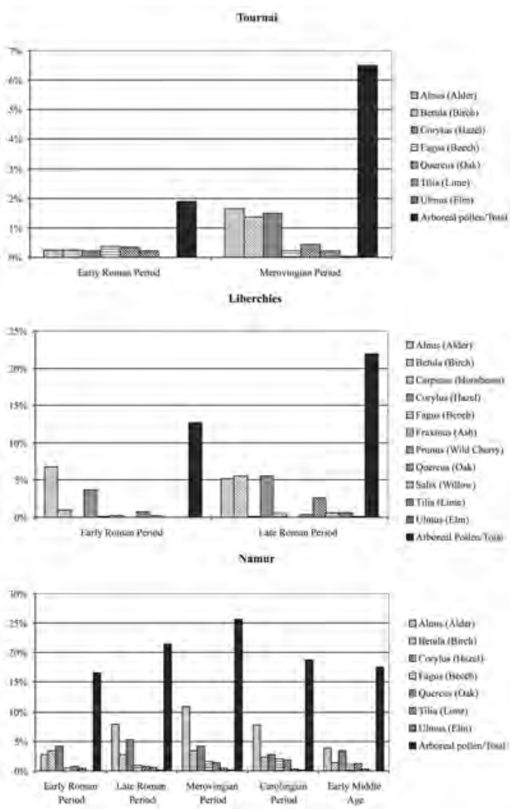

FIGURE 3

Evolution of the medium percentages of the tree and bush species at the various sites and periods.

Maastricht was occupied during all the periods considered. In the early Roman period a *vicus* was settled on the important Bavay-Cologne road, near the bridge crossing the river Maas. The *vicus* was destroyed around AD 270 by Frankish tribes. To defend the bridge a fortification was built in AD 333 that also served as a *horreum*. In the Merovingian period Maastricht became an important political, economical and religious centre (Panhuysen, 1996; Dijkman, 1999; Verhulst, 1999). The consumed pig remains available for analysis come from different early Roman (1^{st} – 3^{rd} c. AD), late Roman (4^{th} – 5^{th} c. AD) and Merovingian (6^{th} – 8^{th} c. AD) sites located inside and outside the fortification, namely Mabro, Derlon, Pandhof, Boschstraat, Rijksarchief and Jodenstraat (Pigière, in preparation). Through time the following trend is observed in the composition of the livestock: the proportion of pig is 25% in early Roman times, then increases to 52% in the late Roman period and remains more or less constant in Merovingian times (50%). For the LEH analysis the material from the different sites is grouped by period. However, the early Roman period yielded no suitable molars, so only teeth from the late Roman and Merovingian period could be analysed for LEH. In the early Roman period the vegetation in the Heerlen basin, in the vicinity of Maastricht, was characterised by an open landscape dominated by cereals, grasslands and cultivated fruit trees, but with few wild trees. From the late Roman period onwards the agricultural activity became less intense. Globally, the decrease of the human population probably gave the original vegetation the opportunity to restore. Pioneer species (walnut, wild cherry, hazel) and also forest trees (such as beech and oak) became more abundant. This tendency of a mixed beech forest colonising the loess plateaus and of carr or riverine forests colonising the river and brook valleys continued until the end of the Merovingian period and was followed by a period of deforestation. This ultimately led to a decrease of the arboreal pollen, an increase in cereals and more erosion (Kooistra, 1996; Bakels & Dijkman, 2000).

The *vicus* of *Namur*, situated at the confluence of the rivers Sambre and Maas, was occupied during all the periods considered. In late Roman times, the occupation density markedly decreased compared to the early Roman *vicus*, but during Merovingian times the occupation expanded again (Plumier, 1999). The excavations attest for a population practising craft activities from the very beginning of the Merovingian occupation; afterwards the development of the *portus* seems to reveal the extension of the commercial activities

(Vanmechelen *et al*., 2004). Namur may have had quite a political importance during this period (Verhulst, 1999). The studied material consists of consumption refuse from several sites: Grognon (Pigière *et al*., 2003, 2004), Place Marché-aux-Légumes (Van Neer & Lentacker, 1994), Rue d'Harscamp (Pigière *et al*., 2004) and Place d'Armes (Pigière, unpublished). The proportion of pig again changes significantly throughout the various occupation phases (Figure 2). In the early Roman period (1st – 3rd c. AD) pigs represent 25% of the consumed domestic mammals. Their contribution increases to 56% in the late Roman period (4th – 5th c. AD) and this high proportion is maintained in Merovingian times (mid-5th – 8th c. AD). In the Carolingian occupation phase (9th – 10th c. AD) the amount of pig decreases to 43%. As for Maastricht the suid material is grouped by period for the LEH examination. The natural landscape of the region of Namur was originally composed of a mixed forest of oak, lime, alder, birch and hazel (Defgnée & Munaut, 1994; Defgnée & Munaut, 1996a). During the early Roman period a deforestation of the region occurred, explaining the low arboreal pollen percentages in Figure 3. Hazel, alder and birch were more abundant than beech, oak and lime. Together they represent less than one fifth of the total vegetation spectrum. From the late Roman period until the end of the Merovingian period, a continuing increase of pioneer species (hazel and birch) and of mixed forest species (oak, lime, elm and beech) is observed. At the end of the Merovingian period the human population increased, resulting again in deforestation. This decline in arboreal pollen is seen for the Carolingian period and continues into the high middle Ages (Defgnée & Munaut, 1996a, 1996b, 1998; Defgnée, 2004).

Summarising, a general picture emerges of an increase in pork consumption at the expense of beef –and to a lesser extent of sheep and goat– in the late Roman period at several sites of differing status; namely the town of Tournai, the *vicus* of Namur and the fortresses of Liberchies and Maastricht. The proportion of pig rises, depending on the site considered, from 25-41% in the early Roman period to 51-64% in late Roman times and this great importance of pigs in the food provisioning is maintained throughout the Merovingian period (50-61%). The palynological data suggest a deforestation due to more intensive land use and agriculture in early Roman times, followed by a recovery of the forest that continues into Merovingian times. In Carolingian times a new degradation of the forest is observed.

THE HYPOPLASIA ANALYSIS

Material and Methods

In order to document the evolution of ecological and husbandry conditions of pig rearing throughout the considered periods, a linear enamel hypoplasia analysis was carried out on pig teeth from the five aforementioned archaeological sites. Teeth that were not fully erupted (wear stages C, V, E and $^1/_2$ of Grant, 1982) could only be partially examined, and were excluded from analysis. For the first and second molars only specimens were used that were still in the mandible. A total of 880 lower molars were retained for LEH analysis (Table 1), carried out according to the methodology developed by Dobney & Ervynck (1998) and Dobney *et al*. (2002). To observe the absence or presence of LEH, the lingual surface of each cusp of each molar was carefully examined using oblique light and slight movements of a fingernail over the enamel. When LEH was present, a distinction was made between depressions (Figure 4) and lines (Figure 5), as these may represent different causes and different time periods of disruption. Finally, the height from the lines or depressions to the cemento-enamel junction was measured along a perpendicular axis.

It is possible to make a reconstruction of the chronological patterns of developmental stress during the tooth crown formation by counting and recording the position of the lines and depressions and relating them to a known chronology of formation and eruption of the tooth. According to Dobney & Ervynck (2000) the lines and depressions on the first molar probably represent the birth and weaning stress. The depressions on the second and third molar are most likely a result of nutritional stress during the animal's first and second winters, respectively. The lines on the second and third molar are believed to be a result of random stress events.

In order to compare the occurrence of LEH between different sites, an index was calculated to enable a simultaneous evaluation of all observations on the different cusps of the three molars (Ervynck & Dobney, 1999).

$$\text{Index}_{(\text{site A})} = \text{average} \left[F_{(\text{tooth x, cusp y})(\text{site A})} / F_{(\text{tooth x, cusp y})(\text{all sites})} \right]$$

with F= number of LEH lines or depressions observed, divided by the number of specimens.

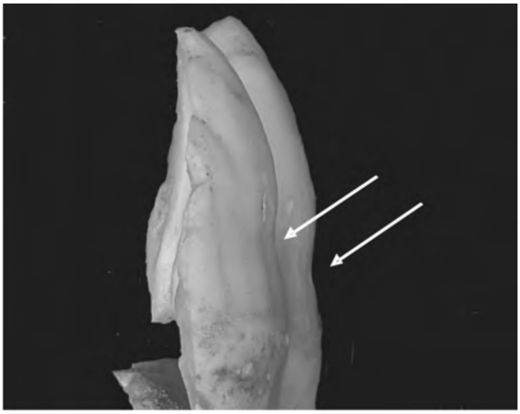

FIGURE 4

LEH visible as a depression on the lingual surface of a second molar.

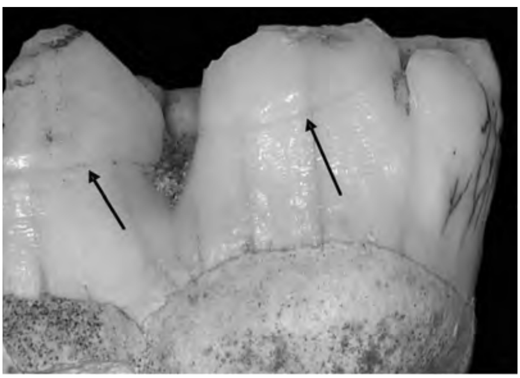

FIGURE 5

LEH visible as a line on the lingual surface of a second molar.

site	no. specimens	no. teeth with LEH	% teeth with LEH
Namur Early Roman	71	29	33
Namur Late Roman	4	2	36
Namur Merovingian	96	37	30
Namur Carolingian	61	21	29
Maastricht Late Roman	234	92	30
Maastricht Merovingian	92	35	29
Liberchies Early Roman	194	99	37
Tournai Early Roman	17	8	48
Tournai Late Roman	41	22	40
Tournai Merovingian	32	11	23
Bruyelle Early Roman	20	12	43
Bruyelle Late roman	18	9	32
All sites	880	377	34

TABLE 2

LEH prevalence within the various sites and time periods. The middle column indicates the number of teeth that are affected and the right column shows the percentages when the prevalence by cusp is taken into account.

The first and second molars consist of an anterior (cusp a) and a posterior (cusp b) cusp. The third molar consists of three cusps, an anterior (a), a posterior (c) and a middle (b) cusp. As the cemento-enamel junction of the posterior cusp of the third molar is generally partly covered by the ascending ramus of the mandible, the observation and measurement of any line or depression is hampered. Therefore, this cusp was eliminated in the calculation of the index.

Results

LEH was frequently observed on the molars of all sites (Table 2). The average number of lines and depressions on the various cusps of the three molars are given in Figure 6. The most frequent occurrence of LEH was observed on the posterior cusp of the second molar. Below we only use the depressions which reflect food shortage during the winter period, rather than the lines which normally represent rather random stress events (such as illness) that are of no major relevance to the discussion of the pig herding strategy. A separate figure (Figure 7) indicates the average number of depressions for the different sites and time periods. Figure 8 shows the hypoplasia indices calculated to compare hypoplasia frequencies between different sites and chronological periods. At Tournai, the hypoplasia frequency decreases from the early to the late Roman period, and this is followed by a lower incidence at the end of the late Roman period and an even further decrease of hypoplasia prevalence in Merovingian times. The various sites at Namur cover the early Roman to Carolingian periods, but unfortunately the late Roman sample is small. With only one second molar and three third molars, only 8 observations were available that could be used for the calculation of the index. Nevertheless, if the late Roman material is not taken into account, the decreasing trend in LEH prevalence between early Roman and Merovingian times remains. At Namur, the hypoplasia prevalence increases in Carolingian times. The three other sites that were considered cover a smaller time span, but the observed patterns confirm the ones described above. The Maastricht samples show a decrease in LEH between the late Roman and Merovingian periods, and at the site of Bruyelle, which yielded only Roman material, the LEH index clearly shows the decrease between early and late Roman times.

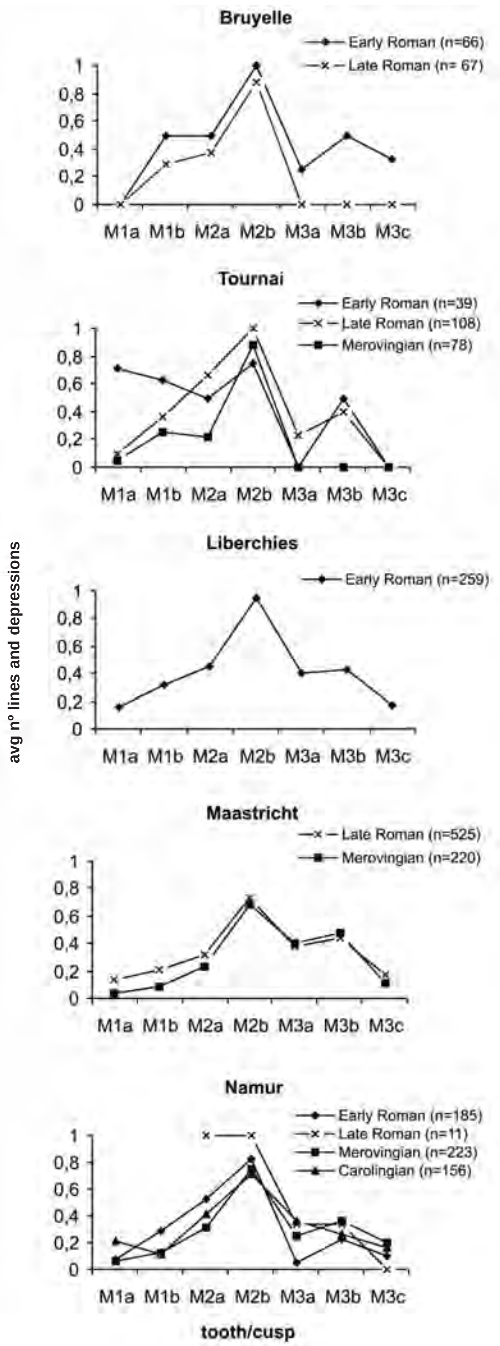

FIGURE 6

Average number of lines and depressions per tooth cusp for the various sites and time periods.

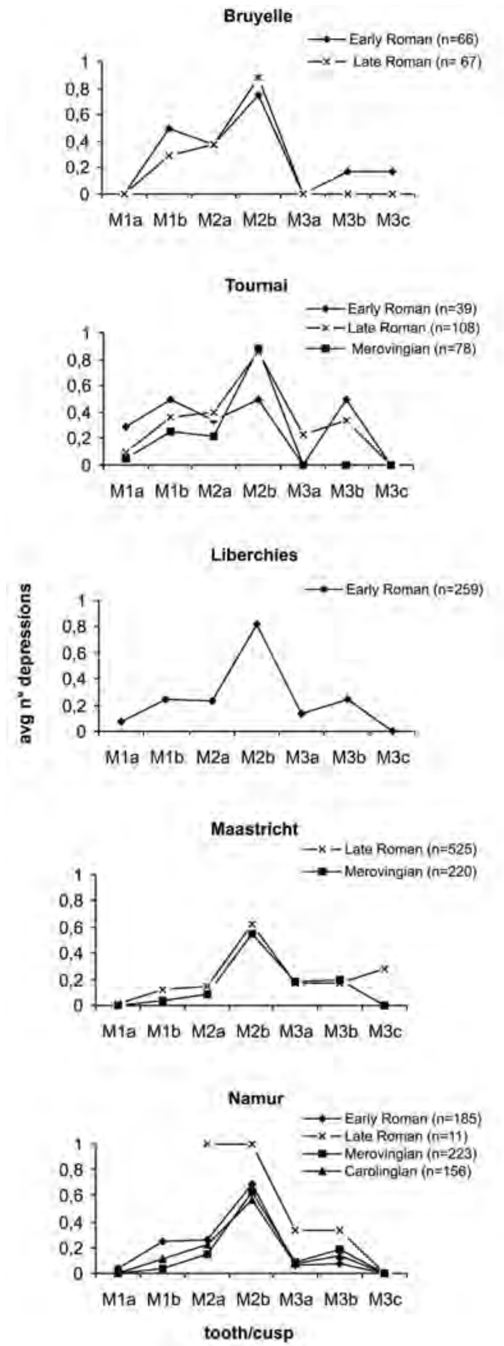

FIGURE 7

Average number of depressions per tooth cusp for the various sites and time periods.

Finally, at Liberchies only early Roman material was available but the index is relatively high and falls within the variation of what was observed in the contemporaneous phase at Bruyelle. Summarising, there is a general trend of decreasing LEH prevalence from the early Roman to the late Roman period and this continues into the Merovingian period. In the subsequent Carolingian period an increase occurs, but this observation is based on one site only.

DISCUSSION AND CONCLUSIONS

In general, the hypoplasia index gives an overall estimation of the life and stress conditions of the pigs. The higher the index value, the poorer the living conditions for that population. To explain variations in the prevalence of hypoplasia it is necessary to consider the habitat requirements of pigs. In Europe a mixed deciduous forest composed of oak (*Quercus*) and beech (*Fagus*) is the optimal habitat. Although these animals are omnivorous, they have a preference for acorns and beechmast, and they also like to root and dig up roots, fungi and all kinds of insects (Grzimek, 1975; Heptner *et al*., 1989). As pigs were originally forest dwellers, it can be assumed that the living conditions and stress level will be closely connected with the amount of forest in the proximity. Previous work carried out on pig remains from high and late medieval sites in Belgium was able to link a high LEH frequency index with degraded woodland, offering poor herding conditions (Ervynck & Dobney, 1999). However, the same study also explained the low incidence of LEH at one of the sites, located in a deforested area, as an indication of the keeping of pigs in semi-confinement. An intensive pig management regime appears to have existed on that particular site, allowing better control and thus reducing under-nutrition and developmental stress. For this reason, it remains to be verified if the trends observed at the sites presented in this paper can be explained in terms of diachronic changes in the environment and/or in the conditions of keeping.

The palynological data of all sites considered here are in accordance with previous palaeoenvironmental data describing northern Gaul as being originally covered (about 7500 years ago) by a mixed deciduous forest consisting mainly of oak, birch, hazel and alder (Munaut, 1967, 1986; Tack *et al*., 1993: 11; Verhulst, 1995: 107). As people settled down, agricultural areas replaced forests. The more the population grew, the greater the food demands became, implying more need of agricultural areas, and therefore more deforestation of woodland (Tack *et al*., 1993: 12). Another reason for deforestation was the use of timber in constructions and daily life (Tack *et al*., 1993: 124). In the early Roman period agriculture intensified under the influence of the Romans. Northern Gaul, which seems to have already been heavily deforested, was further depleted of its shrubs and under wood in this period (Groenmann-Van Waateringe, 1983; Defgnée & Munaut, 1996b). The forests in this period were, therefore, probably not a favourable environment for pig keeping.

For the late Roman period, a recolonisation is observed of the natural vegetation in the sites considered, with bushes, shrubs, and forest tree species becoming more abundant. In some regions the recolonisation can be linked with a decrease in the human population and diminishing agricultural activity, for which several reasons have been proposed. One of them is the exhausting of the soil by the intensive agriculture of the previous centuries (Groenmann-van Waateringe, 1983), although the political and economical crisis also has to be taken into account (Kooistra, 1996). As the ligneous vegetation recovered, food quantity and living conditions for pigs herded in woodland improved.

The tendency of colonisation and reforestation continued in the Merovingian period. In addition, there was a shift to a more humid climate, which also favoured the growth of the forest (Verhulst & Blok, 1981; Bourgeois, 1997). This continued reforestation may have created an even better environment for pig keeping. In the second half of the 8th century AD, the human population increased and forests were again replaced by arable land (Verhulst, 1995: 118-119; Bernard, 1998; Defgnée & Munaut, 1998).

A decline of the LEH frequency index from the early Roman period over the late Roman period to the Merovingian period is observed as a common trend. One site, inhabited into Carolingian times, shows a subsequent increase of the index. These variations are in perfect agreement with the amount of forest cover: phases with a relatively high prevalence of LEH are characterised by a deforestation period, whereas relatively low incidences correspond to periods during which woodland is recovering. At the same time the proportions of pigs, versus cattle and ovicaprines, vary accordingly with high numbers of pig in periods of forest recovery and relatively low numbers when

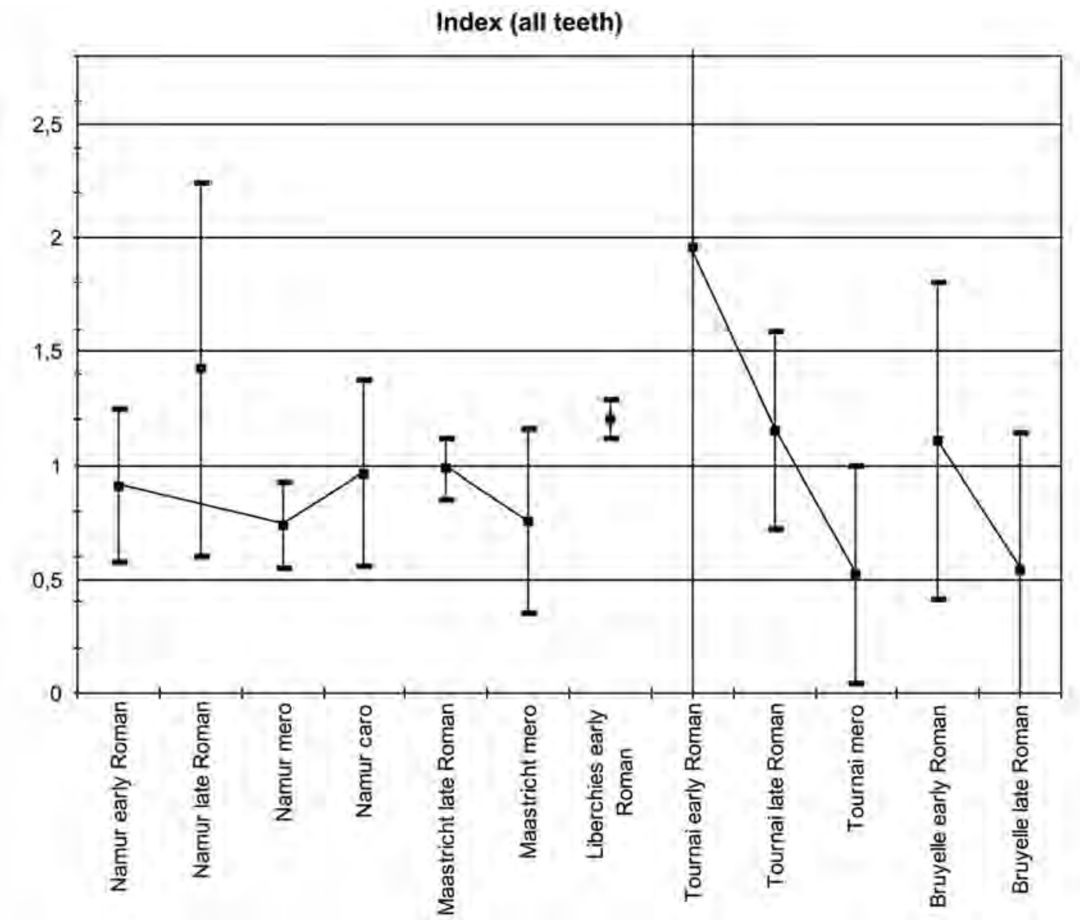

FIGURE 8

Index comparing the average frequency of hypoplasia on pig teeth from different North Gallic sites, calculated for all molars combined. The error bars represent the mean, plus and minus the standard deviation.

woodlands were degraded. All this suggests that the observed variations in pig proportions and in LEH prevalence are due to the diachronic changes in forest cover and quality. The importance of forests for pig husbandry is also partly confirmed by historical sources dating to the early medieval period (Ten Cate, 1972). Some texts even mention that the most frequent way of counting the forest value is by means of the number of pigs that can be raised in it (Deveze, 1966).

The alternative explanation, that relates low incidences of LEH to the keeping of pigs in semi-confinement, seems less likely. The abundant depressions seen on the second and third molars, especially on the posterior cusp of the second molar (Figure 7), seem to exclude the keeping of pigs in sties. These depressions on the second and third molar result from food stress during the animal's first and second winter, respectively, whereas the lines are probably a result of random stress events. If pigs had been kept in confinement during the winter period, or during their entire life, they would have suffered less food shortage because their owners would have fed them. In that case depressions would have been less frequent.

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