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Dental Wear Study in a 14th Century Skull of the Sao Tribe, Cameroon

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A B S T R A C T

The aim of this work was to study the wear affecting the almost complete dentition of a Sao individual fossil from Cameroon prehistory (XIVth century). Occlusal surfaces of the fossil fragile pieces were plaster replicated with an original technique adapted from usual dental impression methods (silicon elastomer polymerising by addition). Axial macrophotographs of both sectional dental casts and original pieces made it possible to produce drawings of the occlusal areas on transparencies in order to superimpose the lateral hemiarch counterparts in their optimal intercuspal position. The study of interarch contacts was completed by confronting and observing the occluding position of hemiarch replicas. The occlusal analysis revealed that the wear extent was equivalent on left and right molars. Hall's occlusal wear index and Van Reenen and Reinach's classification of proximal wear allow assessment of the degree of wear extent on premolar and molar sections in relation to the side or the arch observed[2,4]. The even bilateral proximal and occlusal wears observed on the different kinds of homologous teeth appeared as the main contributor to this well-balanced interarch occlusion. The mandibular incisor losses and the particular type of wear affecting lower canines led to the conclusion of the presence of a labret, a great number of which was found in the area. According to Miles' method of age assessment based on tooth wear, the pieces studied belonged to an individual between 30 and 40 years old[5].

***Keys words**: dental anthropology, dental wear, occlusal wear index, proximal wear index, Miles' method*

Introduction

The aim of this work is the study of the wear affecting an almost complete fossil dentition of a Sao individual living in prehistoric Africa. In 1973, a mission led by Annie and Jean-Paul Leboeuf unearthed the almost complete skeleton of a Sao individual living in the XIVth century in the Chari-Logone region (Cameroon), a vast hilly area where settled ancient inhabitants, collectively named Sao[1]. Sao people seem to have disappeared in the XIVth century.

Twenty-six permanent teeth constitute the extensively abraded dentition of this rare fossil. On the upper arch two right incisors are missing and on the mandibular arch the four incisors are missing. The present study describes, according to Hall's classification adapted from Molnar's scale, the importance and the location of the wear process, according to the presence of dentine patches[2,3]. Proximal wear is assessed by the Van Reenen and Reinach method according to the shape and outline of the proximal aspects of the tooth occlusal tables[4].

In the Sao area, numerous »Labrets« were discovered. Do the absence of the lower incisors and the special wear of the canines on the studied jaws mean that our fossil wore a labret? Quantifying dental wear is also a means to approximate the fossil age at the time of death. The extent of occlusal wear can be indexed on the basis of molar eruption. Miles' method was chosen to estimate the crown height loss of the lower molars[5].

Tooth wear, a general and ancient phenomenon

Whether the result of abrasion or attrition[6], wear is a generally observed process frequently described in dental anthropology[7]. Tooth attrition is constantly observed in the course of evolution[8,9], and gives an information on the first mammals' diet[10]. It has also been helpful in confirming the existence of a main stage in the evolution of the equids[11]. This wear process was observed in current mammals[12], primates[13], chimpanzees[14] and hominoids[15]. It was studied to enlighten dental sexual dimorphism[16]

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and to underline d'Amico's concept of the canine preponderant role in the Californian Maidu Indians[17].

It is necessary to distinguish attrition from enamel cracking which should be related to forceful use of the teeth as additional tools. The presence of abrasive particles in food increases the wear process[17,18]. The tooth position along the arch also seemed to be of importance[19,20]. Dental attrition seems to be related to the diet[21]. Wear has also been observed in *Australopithecus*[22,23] and more particularly studied in *A. africanus* by microanalysis of dental tissues[24]. Microscopic views of dental surfaces belonging to gracile forms of individuals with tender diets composed of fruits and leaves differ from those with hard grain diets as encountered with more robust forms of individuals.

The type of attrition in *Homo* and *Australopithecus* is thought to depend on the dental arch width and the lateral excursions of the mandible[25]. In neolithic populations, the wear observed is very destructive for the dental arches[26–29]. On the contrary, in a group of Sudanese individuals of the same period, the wear is considered lighter and associated with periodontal pathologies[30]. Wear is also recorded in populations living in the Sudan between 700 B.C. and 400 A.D.[31], in Eastern France between IV[th] and VII[th] centuries[32] or in European populations of the Middle Ages, in X[th] and XI[th] centuries[33,34].

The state of attrition was compared in Australian Aborigines, Anglo-Saxons, Mongols and West Africans, who all lived in XIX[th] century[35]. Some present-time populations who have kept ancestral customs, like the South African Bushmen[36] or the Australian Aborigines[37–41] are always quoted as references. The chronology of the crown wear process has been reported in the form of drawings[21].

Contemporary man

In modern populations, attrition is less frequent and less severe[42–45]. The effects of abrasion appear in the form of facets on the occlusal table where 93% of interarch contacts are established in what is called the Maximal Intercuspal Position (MIP) or centric occlusion[46]. Through electron microscopy, the *striae* that run along the wear facets are visible on the surface of replicates made of hardened polyvinyl acid[47] or plaster[47–55]. Buccal and lingual arch surfaces have been observed through a microscope[56] or on digital macrophotos[57]. Examination of the number, orientation and type of *striae* made it possible to infer the nature of food chewed. A confocal reflection microscope giving a 3D image[58] or a profilometer[59] should have offered a more precise and thus more objective assessment of the surface.

Occlusal wear measurements

Different scales have been conceived in the past century[60]. Broca in 1879 described five *numéros descriptifs* (degrees) of dentition abrasion extending from the occlusal surface to the cemento-enamel junction[61]. In 1935, Perier described four degrees, which he did not consider perfectly adapted to his study of 150 Bushmen's skulls[36]. In *Sinanthropus*, Weidenreich (1937) distinguished eight degrees[62]. With the Davies and Pedersen four-stage scale[64], Lysell (1958) gave a numeric value for the occlusal surface wear and calculated a mean[63]. Murphy (1959) described in a series of successive drawings the different patterns of wear encountered in Australian Aborigines' jaws. Seven degrees were displayed for the anterior teeth and nine for the premolar-molar sections[37]. Baron, Lai Son Chan Thu, and Mailland (1972) set up a more precise scale for each cusp with eight indices for enamel and eight for dentine[65]. Their scale was used in other studies on bruxism[66] and on Aborigines[67]. In a prehistoric population of South American Indians, Scott (1979) divided the occlusal surface into four quadrants. Each quadrant wear was appreciated in a ten-degree scale. The measure of the occlusal surface wear was finally estimated in a forty degree resulting scale[68,69]. He compared his observations with the eight degrees Molnar's classification[3] and with the nine degrees Hall's[2] classification adapted from Molnar. Hall used the descriptions proposed by Molnar and added an intermediate 2.5 level where the cusp had not disappeared. Molnar's scale is commonly used in anthropology[70]. Benfer and Edwards (1991) consider the crown height as the average of the distance between the tips and the cemento-enamel junction of the four molar cusps[71]. Data obtained from different observers and the use of a double scale taking into account both the speed and the degree of wear could be beneficial[72]. A volumetric »*attritional index*« was proposed by Abreu Tabarini[73]. In present-day populations, occlusal wear is not sufficient to apply the preceding scales. Therefore, the evaluation of wear facets by Gourdon and Woda[43] is preferred[74]. A new index is used by Hooper, Meredith and Jagger[75].

Proximal wear

In mammals, proximal and occlusal wears develop together[39,63,76,]. Wolpoff (1971) described this kind of tooth wear in groups as different as australopithecines, chimpanzees, Australian Aborigines and American Indians[77]. Poitrat-Targowla (1977) studied this type of wear in Ibero-Maurusian populations who lived 10.000 to 12.000 years ago[18]. After studying twenty medieval dentitions from Northern Sweden, Lysell (1958) argued that attrition in all age groups was more marked for mandibular incisors and molars, and maxillary premolars[63]. Van Reenen and Reinach (1988) studied proximal wear in Bushmen[4].

Mesial migration is probably not related to occlusal wear[78]. On facets deprived of enamel of neanderthalian teeth, *striae* were identified through electron microscopy[79].

Proximal wear reduced the mesiodistal length of each tooth. In Aborigines, Begg (1954) estimated at about 14.7 mm the mean reduction of mandibular arch length[76], but this was refuted[80]. Murphy[39] estimated on the same skulls that this reduction amounted to 3.6 mm and showed remarkable symmetry on each side from P^3 to M^3.

Wear as evidence of function

Tooth wear is a dental trait in close relation with mastication[81,82] and particularly with its neurophysiological component[83,84]. Interarch contacts correspond firstly to the chewing cycle, which is shaped in its upper part when going towards centric occlusion (cycle in) and when leaving it (cycle out)[41]. Secondly, the cycle is also guided by the temporomandibular joint TMJ[85–87] and its possible associated pathologies[88,89]. This was the starting point of studies linking dental anatomy, wear, mastication movements and diet[90–95]. But in platyrrhinians, for instance, a wide range of dental forms is independent from the diet and chewing behaviours[96]. The toughest foods are processed with more lateralized movements of the mandible as was observed in Polynesian Morioris, Maoris[97] and American Indians[81,98]. Differences were noted between hunger-gatherer populations and agriculturalists. Occlusal wear planes have different angulations[99]. Dental wear could represent a mosaic-type evolution[100]. Moreover, Sakka[101–105] underlines a relative dissociation between form and function »in the environment of the stomatognathic system (morpho-functional set) particularly represented by the masticatory muscles, their peripheral and central innervations, their vasculature, the maxillary and mandibular bony structures, the teeth and their functional capacities«[105].

Age at the time of death

In biological anthropology as in forensic dentistry, tooth wear study is one of the criteria taken into account to determine the age at the time of death[5,106–115]. Lucy, Pollard and Roberts (1995) recognised the value of Gustafson or Johanson's methods[116]. But these methods only addressed Scandinavian populations. Song and Jia (1989) studied a Chinese population and established a simple mathematical formula linking wear and age[117]. The co-factors mentioned above did not allow the extension of this method to other populations.

Materials and Methods

The material is constituted of 26 teeth *in situ* belonging to a single individual:

- 14 maxillary teeth. Six on the right: the canine, two premolars and three molars. Eight on the left: two incisors, the canine, two premolars and three molars.
- 12 mandibular teeth. The 4 incisors are missing.

Anthropological nomenclature

In this study, each tooth is designated by its first letter in capitals, followed by a number corresponding to its order in the tooth series (incisors, canine, premolars, molars) increasing from mesial to distal position. The number is an exponent to indicate an upper tooth and a suffix for a lower one. Letters R (right) and L (left) identify the side on which the tooth is located. Premolars are named P3 for the first one, P4 for the second one (assuming that P1 and P2 disappeared with the evolution of mammalian dentition). Cusp denomination is adapted from the Cope and Osborn (1895) theory on mammalian molar cusps[118]. This was extrapolated to human molars and premolars[119,121]. Cusps are named cones for the maxilla and conids for the mandible.

At the maxilla, the lingual (palatal) cusp of a premolar and the mesiolingual cusp of a molar are protocones. The buccal cusp of a premolar and the mesiolingual cusp of a molar are paracones. The distobuccal cusp of a molar is a metacone. On the molars, the protocone, paracone and metacone form the trigon. The fourth distolingual cusp is called the hypocone or heel.

At the mandible, the buccal cusp of a premolar and the mesiobuccal cusp of a molar are protoconids. The distobuccal cusp and the small distal cusp of a molar are respectively a hypoconid and a hypoconulid. The mesiolingual cusp and the distolingual cusp of the molar or the second premolar are respectively a metaconid and an entoconid. The first premolar only has a metaconid. The protoconid and the metaconid form the trigonid. The hypoconid, the hypoconulid and the entoconid form the talonid. The occlusal surface of a mandibular tooth may look upwards and slightly outwards (*ad vestibulum*) or upwards and slightly inwards (*ad linguam*). The occlusal surface of a maxillary tooth may look downwards and slightly outwards (*ad vestibulum*) or downwards and slightly inwards (*ad palatum*). If the occlusal surface looks directly downwards or upwards its direction is called *ad planum*.

The moulds and the casts

Moulding with three different viscosity silicon elastomer and plaster casting techniques to make replicas has been described in an other paper. The reproducible accuracy of the method, i.e. the accuracy of the impression material (irreversible hydrocolloid and elastomer), is limited to 20 μm.

The examination is made on a cast (or replica) of the total mandibular arch and on 3 sectional replicas, i.e. occlusal, buccal and lingual surfaces of each maxillary and mandibular hemiarch. The occlusal replica is sawed to separate the canine from the cuspid teeth.

Observation of the samples and replicas

The occlusal wear is analysed by examining the original samples and their casts with a magnifying glass. Manual staining of the wear facets on replicas of the casts and macrophotographs allows a precise description of the extent and intensity of the abrasion process. Homologous teeth are compared by juxtaposing the real tooth to its image replica viewed in a mirror. Left and right teeth are also compared by tracing the macrophotographs on transparencies, allowing superimposition of each tooth with its homologous tooth. Comparisons between homologous and contralateral teeth (LM_1 and RM^1 for instance) are carried out by superimposition of the first tooth contour on the reversed contour of the other tooth. The tracings are also compared to those published by Miles[5].

Wear assessment

Measurements are made with a calliper rule with curved ends with a 0.1 mm precision, which is very close to the 0.2 mm precision of a dental practitioner.

a) The level of occlusal wear is assessed according to Hall's classification adapted from Molnar's scale (Table 1). This scale allows separate assessments of incisor, canine, premolar and molar wear. Hall established eight degrees of abrasion taking into account the location, number and extent of dentine patches. The wear observed on the Sao fossil is ranked between degrees two and four.

b) Proximal wear is assessed according to the six stages of the Van Reenen and Reinach scale. The area of proximal wear extends up to the marginal crest of the tooth occlusal surface. The outline of the occlusal surface could be convex when not abraded (degree one) or concave when abraded (degrees three to five). Four degrees are enough to evaluate the Sao tooth wear.

c) The mandibular intercanine shortest distance is 16 mm. This is the chord of an arc where the four missing incisors should be positioned. A fine wax thread is applied along the tooth buccal surfaces from LP_4 to RP_4 to give a harmonious contour at the level of the missing incisors. It is then cut at the level of the mesial surface of each canine. The resulting measure on the arch is 19 mm. This dimension is close to the space commonly occupied by four incisor crowns measured at tip level (22 mm).

Age at the time of death

Age at the time of death was assessed by Miles' method[5]. The measurements of the fossil teeth were taken. A set of human teeth of equivalent sizes and forms showing no sign of wear[120]was selected. On the fossil and on the set of teeth without wear the crown heights on the buccal side of the mandibular molar were measured. The loss of crown height was calculated by the difference between the two preceding values. A precision calliper with curved ends was used. This crown height differences take into account the chronology of crown eruption[109,110,121,122]. Therefore, according to Miles, it would take a 6 years time lapse for the first molar to attain the wear observed on the second molar in 6.5 years, and a in 7 years on the third molar, if we assume that its eruption occurred at 18 years of age.

Results

The dentition observed was that of a Sao individual unearthed in January 1978 by the Annie and Jean-Paul Leboeuf mission in the United Republic of Cameroon. The Region was described as *a vast area with hillocks of different sizes corresponding to the settlements of the former inhabitants collectively named Sao*[1]. The dentition is almost complete consisting of 26 fossil teeth concerned by proximal and occlusal wear. Around the site of the Sao fossil a lot of labrets were discovered. They were 22 to 37 mm wide and 18 to 32 mm thick and were either from massive or hollowed wood. The external part was convex while both lateral parts were concave to fit the canine collar shapes. Thus, we assume that the loss of the four mandibular incisors result from ritual tribal mutilation. Because of their socket persistence, both right maxillary incisors were lost post-mortem. Wear is noticeable on

TABLE 1
SAO TEETH OCCLUSAL WEAR EVALUATED ACCORDING TO HALL (1976) SHOWING COMPARATIVE DATA BETWEEN LEFT AND RIGHT TEETH

	Hall's Scale index	Comparison between left side and right side	Tipping of occlusal plane
LI^1	4		
LI^2	3		
C^1	4	L	
C_1	4	L	
P^3	2,5	R	*Ad palatum*
P^4	3	R	*Ad palatum*
P_3	3	R	*Ad linguam*
P_4	3	R	*Ad vestibulum*
M^1	3	L	*Ad palatum*
M^2	3	L	*Ad planum*
M^3	2	L	*Ad vestibulum*
M_1	4	R	*Ad vestibulum*
M_2	4	L	*Ad planum*
M_3	2	L	*Ad linguam*

Letter L (left) or R (right) point out the side of the arch with greater wear. For each cusped tooth, the wear index is correlated with the tipping of the occlusal plane. Hall's scale is adapted from Molnar's, with the addition of the 2.5 index. From Hall (1976, appendix 1 page 75). Index reading is as follows: 2 – for molars, wear facets present, no observable dentine; 2, 5 – small dentine patches, cusp pattern not obliterated; 3 – for incisor and canine, cusp pattern obliterated. dentine patches present. For premolar and molar: cusp pattern partially or completely obliterated; small dentine patches. 4 – For incisor and ca- nine, dentine patch (minimal). For premolar: two or more dentine patches; secondary dentine may be slight. For molars: three or more large dentine patches; secondary dentine, none to slight. Degree 2.5 corresponds to the second upper bicuspid wear (RP^3). This allows the difference from the wear of the con- tralateral tooth to be shown. Incisors and canines have an index, which is as high, or even higher than that of bicuspids and molars, whereas abrasion had less impact on their height. Wear is more important on M_1 and M_2 than on their maxillary counterparts. This is due to a different cusp pattern (thick transverse enamel ridge at the maxilla) and to the occlusal relation between buccal and lingual cusps (overjet). The right bicuspids are more abraded than the left ones. The left molars are more worn than the right ones. The wear index corresponding to each tooth can be specified by the disposition of the occlusal plane. The Latin expressions describing the tipping of the occlusal plane i.e. *ad palatum*, *ad linguam*, *ad vestibulum*[124] and *ad planum*[88], indicates the transversal slant of the occlusal surface. For example the worn surface of M^1 looks downwards and slightly inwards (*ad palatum*).

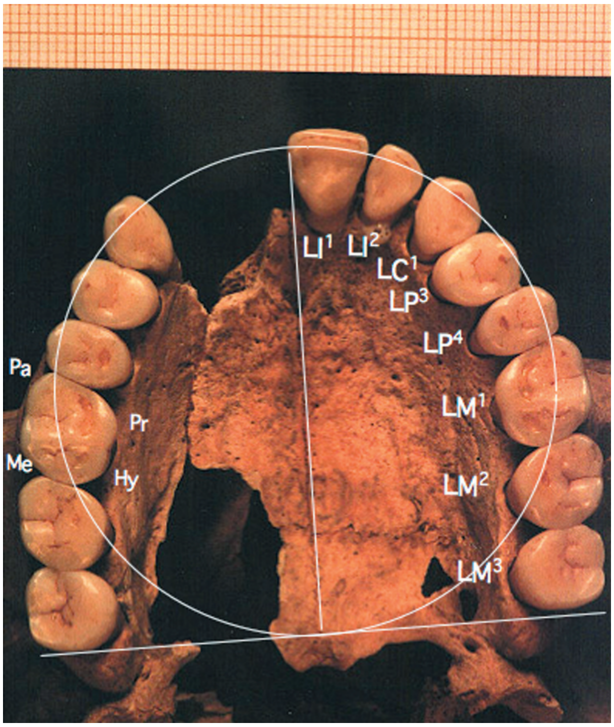

Fig. 1. Occlusal view of the Sao fossile upper dental arch. The arch disposition is of parabolic type. Dental wear resulting from attrition seems equally shared between the anterior and lateral parts of the arch. A sagittal line corresponding to the diameter of a drawn circle covers the intermaxillary suture. A second line perpendicular to the first one is drawn tangentially to the two distal surfaces of the third molars. The circle diameter is the distance between the occlusomesial angle of LI^1 (maxillary left medial incisor) and the posterior line. The circle underlines the presence of an anterior overjet at arch labial level. The presence of interdental spaces can also be noted. Both homologous landmarks LM^1 and RM^1 are on the circle line. Anthropological nomenclature symbols identifying the right first upper molar (RM^1) cusps: Pr – protocone, Pa – paracone, Me – metacone, Hy – hypocone.

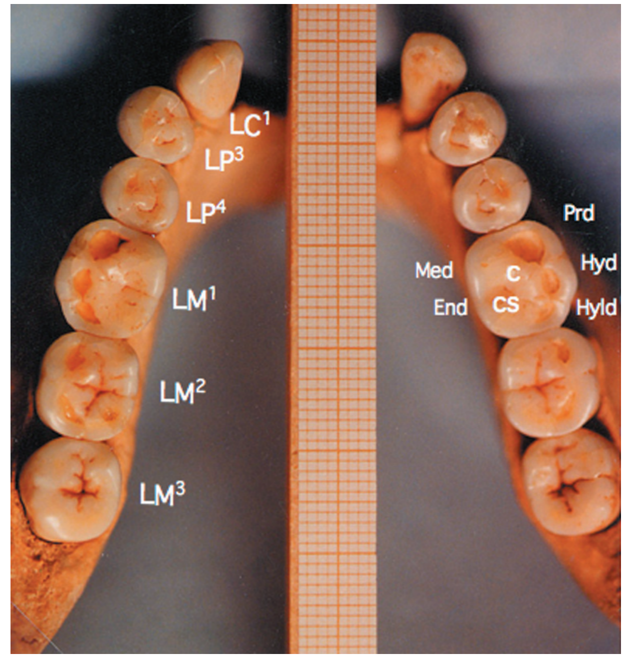

Fig. 2. Occlusal view of the Sao fossile lower arch. The incisors were probably eliminated prior to insertion of a labret. The arch is almost V-shaped or ellipsoid type. Anthropological nomenclature symbols identifying the first right mandibular molar (RM_1) cusps: Prd – protoconid, Med – metaconid, Hyd – hypoconid, Hyld – hypoconulid, End – entoconid. Odontological nomenclature: cf – central fossa, cs – central slope (internal), sc – supporting cusp (buccal), gc – guiding cusp (lingual).

occlusal and proximal (mesial and distal) surfaces of all the teeth, on labial and mesiolabial crown and root parts of the mandibular canines, and on the buccal aspects of the lower molar cusps at the time of death.

Occlusal wear

The crown height of all fossil teeth was reduced by attrition and this process concerns all the cusps. Wear values assessed according to Hall's scale (1976) are presented in Table 1. Wear differences between right and left homologous teeth are recorded and the most worn side is noted. The tipping of the occlusal plane for each crown is indicated according to its orientation (*ad vestibulum, ad linguam or ad palatum*). It is noted that:

– Most of the occlusal contour is maintained (Figure 1 and Figure 2)

– The same degree of wear affects the four remaining maxillary anterior teeth i.e. both canines and the left incisors

– The left upper medial incisor (LI^1) shows wear loss (1 mm) on its occlusal aspect

– The left upper lateral incisor (LI^2) has a wear facet erasing half of its distal marginal ridge

– The left canines are more occlusally abraded than the right ones. The cusp tips of the lower canines are erased forming a flattened area. The lingual aspects of the maxillary canines are levelled even where no occlusal contact exists in centric occlusion

– The premolars has the same degree of wear at cusp tip level except for the right first upper bicuspid (RP^3) which is more abraded. The right premolars look more abraded than the left ones

– The occlusal surfaces of the lower molars are disposed in a 3-segment helicoid shape due to their different individual slants. This helicoid shape beginning at the levelled occlusal surface of premolars wear decreases from the first molar to the third one (M_1 to M_3), maintaining a posterior-anterior Von Spee curve (Figure 3)

– The mandibular molars are more abraded than the maxillary ones

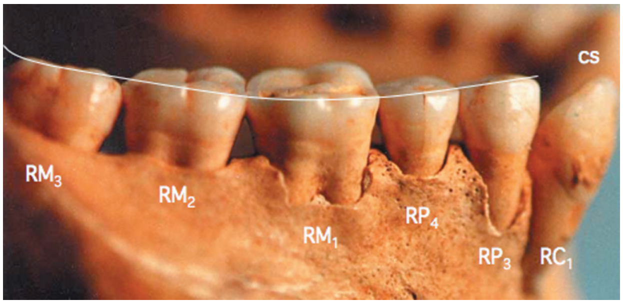

Fig. 3. Buccal view of the lower right mandibular hemiarch of the Sao fossile. The wear process has levelled and smoothed the occlusal surface. At molar level, the intensity of wear decreases from the first molar (RM_1) to the third one (RM_3). This corresponds to the tooth chronological eruption and orientation. The orientation of molar occlusal surfaces is helicoidal. M_1 occlusal surface is looking ad vestibulum, M_2 ad planum, and M3 ad linguam. The Von Spee curve (CS) is the result of both tooth eruption and tooth abrasion and combines with a variable Wilson curve (transversal curve) to form an arch of helicoid disposition (see Figure 5).

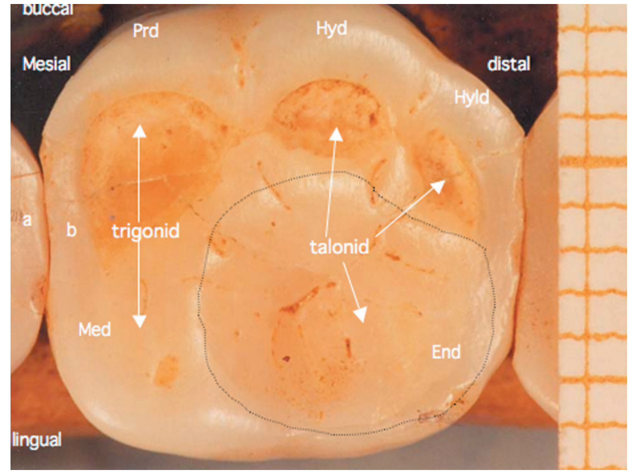

Fig. 4. First right mandibular molar (RM_1) of the Sao fossile. (occlusal view). All the cusps have been worn off. This process is more pronounced on buccal cusps (supporting cusps) than on lingual ones (guiding cusps). Dentine patches are showing through the enamel. The occlusal wear here visible is evaluated as stage 4 on Hall's scale. The enamel surface has been reshaped by wear giving the talonid a mortar like shape (contoured area) in which the M^1 protocone acts as a pestle at the uppermost part of the chewing cycle. Intra-arch contacting zones adopt a congruent shape i.e. the RM_1 mesial zone of contact (a) being slightly concave (stage 3 of Van Reenen and Reichnach) whereas the RP_4 distal one (b) is convex (stage 1). This interlocking maintains arch cohesion and compensates for less interarch intercuspation.

- In comparison to M_2 and M_3, the first mandibular molar (M_1) wear reaches dentine level creating more numerous and wider dentine patches, especially on the buccal side
- The first right lower molar (RM_1) is more abraded than the left one (LM_1),
- On M_1 the loss of enamel of the cusp decreases in the following order: hypoconulid, hypoconid, protoconid, entoconid and metaconid (Figure 4),
- The uneven wear of the M_1 occlusal surface is less noticeable at metaconid level, suggesting a mortar-like inside wall. This is less visible on M_2.
- The concave disposition of the entoconid and part of the M_1 metaconid suggest a kind of mortar in which the protocone of the opposite tooth actes as a pestle. The same disposition is noted for M_2 and M_3,
- On M_1 the central slope of the metaconid, occlusally concave, is continued buccally in the form of an enamel strip. It is a remnant of the protoconid and hypoconid central slope separating trigonid and talonid. It then extended distally with the shape of a lingually concave arc separating the buccal and lingual aspects of the talonid. On M_2 and M_3, with a similar occlusal aspect, that shape is less marked
- Occlusal grooves are partially erased on M_1 and their Y shape disposition (Dryopithecus pattern) is not easy to make out. The cross disposition of occlusal grooves on M_2 and particularly on M_3 is still visible
- The left second and third lower molars (LM_2 and LM_3) were more abraded than their right counterparts (RM_2 and RM_3). Consequently the maxillary molars are more abraded on the left side than on the right side
- Maxillary molars keep their occlusal oblique ridge but this structure become less acute or somewhat flat (Figure 5)
- The occlusal surface of M_1 is made of two concave areas (trigon and hypocone) separated by a rounded enamel ridge oriented transversally and obliquely linking metacone with protocone. The mesial part, larger and more abraded, represents the trigon in which M_1 hypoconid comes into contact. The distal part is the hypocone (heel) worn by the contacts with M_2 metaconid and protoconid. The ridge becomes flat on M_2 and really bowl-shaped on M_3.

On the whole, the tooth occlusal abrasion was more marked on the left molars and on the right premolars compared to the opposite side.

Proximal wear

Proximal wear is observed on all proximal surfaces except on the distal surface of the third molars and the lower canines. Wear is assessed with the method of Van Reenen and Reinach[4]. These values are shown in table 2. Mesial and distal surfaces are compared:

- In premolars, few differences are observed between mesial and distal surfaces. On the lower premolars wear has the aspect of a yellowish oval area and a dentine patch is clearly visible on RP_4 (right second lower bicuspid)
- A section of the cast arch between lower canine and first bicuspid enables the appreciation of the contig-

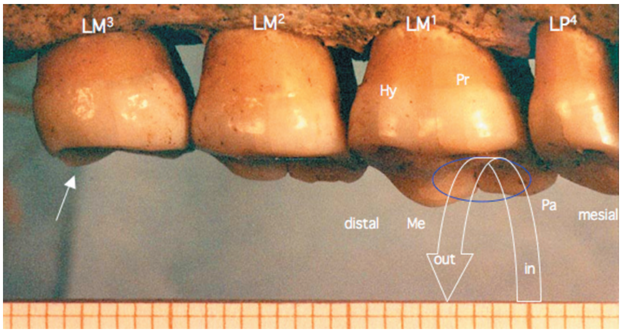

Fig. 5 Lingual and partly occlusal view of the upper left maxillary hemiarch of the Sao fossile. Lingual cusps (supporting cusps) are more abraded than buccal ones (guiding cusps), as can be seen particularly on first (LM^1) and second (LM^2) molars. The occlusal surface is orientated ad palatum for LM^1, ad planum for LM^2 and ad vestibulum for LM^3. This helicoid disposition of the upper molar segment is complementary to the opposed mandibular one. The big arrow shows the displacement of the opposite mandibular structure during the uppermost part of the classic chewing pattern before (»cycle in«), during and after (»cycle out«) the mandible reaches centric occlusion. For instance, the LM_1 hypoconid meets the LM^1paracone (Pa) during the cycle in and glides along the mesial aspect of the oblique enamel ridge during the cycle out. The trigon fossa widens and levels out into a mortar-like shape in which the M_1 hypoconid acts as a pestle (circle). The small arrow shows the posterior abutment of the LM^3 (salient ridge of the LM^3 metacone) as distal stopper.

uous proximal surfaces exposed. There is no visible wear in these places

– On the premolar-molar section, wear is more important mesially than distally (Figure 4),
– Proximal wear of the molars was more marked on the left side.

Canine wear

Wear attack was localised on the labiomesial part of the crown and root cervical portions (Figure 6). This shaping action results from the presence of the labret which modified the previous convex, anterior surfaces of the lower canines into a flat and perfectly polished surface. Wear is symmetrical on each lower canine. It doesn't reach the lingual aspect of the canines. A recession of the medial adjacent alveolar ridge shows part of the rather short canine root.

The missing incisors

The lower arch portion without incisors corresponds to a 19 mm space on the alveolar ridge. A 1 mm gap on each side results from the presence of a diastema between bicuspid and cuspid. That explains the 21 mm in the evaluation of the lower arch dimension. This is close to the 22 mm evaluation of the mesial-distal width of the four missing incisors, taking into account mean measurements at tip level. The latter value corresponds to the width of some of the labrets found near the fossil. After a first mesial migration of the teeth, the labret contributed to the preservation of their mesiolabial wear

TABLE 2
SAO TEETH PROXIMAL WEAR EVALUATED ACCORDING TO VAN REENEN AND REINACH (1988). COMPARISON BETWEEN MESIAL AND DISTAL SURFACES

	Mesial surface	Distal surface
LI^1		
LI^2		
C^1		
C_1		
P^3	1	1
P^4	2	2
P_3	1	2
P_4	2	2
M^1	4	1
M^2	3	1
M^3	1	
M_1	3(R) 4(L)	1(R) 2(L)
M_2	4	1
M_3	1	

The two first mandibular molars are differentiated by the letters L (left) or R (right). The Van Reenen and Reinach classification was only applied to Bushmen's molars, but for the Sao teeth it was also used for bicuspids. The oscillating movements occurring between the teeth produce this proximal wear. The mesial surface of a tooth comes into contact with the distal surface of the more forward tooth. Mesial surfaces are flatter whereas distal ones are more convex. These different values represent the outline of the worn marginal ridges. The index diffe- rence between mesial and distal surfaces is greater in the molar section than in the premolar section. On both mesial and distal sides the first left mandibular molar (LM_1) is more abraded than its contralateral counterpart. (1 – convex contact area. 2 – straight contact area. 3 – slight concave contact area. 4 – definite concave contact area).

and to the possible abrasion and wear against the lower canines. They could also help to preserve the highly regular shape of the arch.

Age of the fossil at the time of death

The time of death is deduced from the abrasion of the lower molars. The first lower molar crown wear is assessed buccally at 3.1 mm on the left side and 3.0 mm on the right side. The wear of the second lower molar was 2.5 mm on the left and 2.3 mm on the right. Thus the difference between first and second lower molars is 0.6 mm on the left and 0.7 mm on the right. This difference corresponds to 6.5 years of wear, in relation with the time interval between first and second molar eruptions. Supposing a regular wear time-rate identical on both sides, the 3.1 mm wear on the left side should correspond to 33.5 years of life. This duration, added to the mean time of first molar (M_1) eruption, gave a total of 39.5 years at the time of death. The same calculation for the right side gave 33.8 years. It was therefore reasonable to assume that the age of the Sao fossil was between 30 and 40.

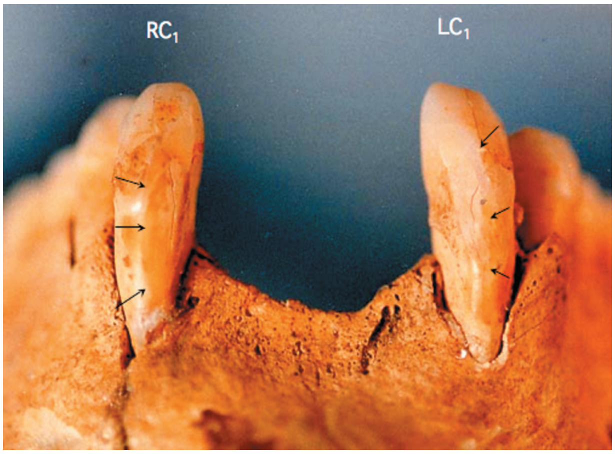

Fig. 6. Mandible of the Sao fossile. Labial and mesial view of the canine. The four lower incisors were lost ante-mortem. This could probably be the result of a ritual practice before insertion of a labret, akin to those found in the Chari and Logone area. Involution of the alveolar process followed, leaving a bone ridge with concave outline. Extension of the alveolar regression is also noticeable at the canine labial and mesial aspects, thus showing the worn part of the crown and the root in probable relation with the use of a labret (arrows). Both canine attritioned tips are beyond the level of the occlusal plane as a result of insufficient blocking contacts from opposite teeth. The labret has undoubtedly played the role of a retainer as the intercanine distance has been maintained.

Evaluation of wear on the second and third molars could also help corroborate the first estimation of the fossil's age. For instance the 1 mm wear of the second molar crown would have corresponded to 15 years of wear. Given that the second molar eruption occurs between 18 and 20, we estimate the death between 30 and 40 years of age. The wear reduced the crown height by 1 mm at third lower molar level and perhaps even more at entoconid level. If the third molar has erupted around 18–20 years of age its wear would correspond to a function span of 15 years. This corroborate the preceding deduction.

However the wear process was slowed down by the presence of other teeth and there is no data available to indicate the third molar time of eruption. Miles' Table indicates that according to the wear aspects of the three mandibular molars the age of the fossil was at least 30. The slight wear of the upper incisors (1 mm) corresponded to the time they were in anterior rubbing contact with their counterparts. The avulsion of the lower incisors, possibly around 13 to 14 years of age, could have stopped the wear of the upper incisors and accelerated the wear of the posterior teeth. If the labret were more than 15 mm thick the upper incisor wear would have continued.

Discussion

Dental wear

Hall's Scale adapted from Molnar seemed suitable to describe and assess the mean wear in one individual. It is more accurate than the scales quantifying the massive dental attrition occurring in ancient populations and somewhat less accurate than the scales designed for contemporary populations. Scott's scale[68,69] could have been used being more accurate than Molnar's. Actually, the main use of Scott's scale is statistical analyses, which is not the objective of our study. Hall's scale is simple. Degree 2.5 does not exist in Molnar's scale and in our study it corresponded to the first upper bicuspid wear (RP^3). It was then possible to make the difference in the wear of contralateral teeth. With Molnar's scale, the value would have been the same that is 3. The use of a scale reduces the occurrence of a possible bias. For each tooth series, except for lower incisors, the continuous shape progression and the precise description made it possible to underline the role of each tooth or group of teeth. This was a clue to determine the preferred chewing side.

The wear was analysed on original samples and replicas. On macrophotographs a precise colour scale helped in the evaluation of the intensity of wear. It would have been useful to compare these records to digital ones. The non-reflecting surfaces of the replicas (in comparison with the surfaces of the original samples) helped in assessing the extent of wear areas. Painting the surfaces made it easier to reveal the contours and extent of dentine patches. Computer science should open up research paths and well-adapted software would be useful.

The samples studied are a perfect example of what Begg called attritional occlusion[76], also described by Campbell[123], Beyron[41] and Tobias[25] in Australian Aborigines. Ackermann[124,125] used to mention unequal and dyschronic wear of the teeth. Abrasive processes create planes visible on the arch and the occlusal surface of each tooth. Two planes are visible on M^1 (trigon and hypocone) and M_2 (trigonid and talonid). The angulations between each tooth occlusal plane and the mean overall arch occlusal plane are always difficult to determine[2,99], as for the assessment of the Von Spee Curve[126]. However the quantification of the wear (depth, area) and its chronology could be studied with better accuracy through modelisation[73]. The structure of enamel and the modelisation of the wear process should stimulate further research.

In the arch, the interdental attrition process was correlated with the mesial drift of the teeth[77,88,127]. According to Kubein and Kruger[128], and Lasserre[28] the oscillating movements between the teeth produce this proximal wear associated with occlusal wear in the posterior sections. The contact zone migrates occlusally, as was noted by Hillson[21]. In a posterior-anterior relation, convex proximal surfaces are confronted in a horizontal plane. Through abrasion they become flat and progressively acquire an S-shape outline (stage 6 of Van Reenen and Reinach). It is as if, as the occlusal interlocking flattens and disappears, a new intra-arch tooth by tooth articulation appeared increasing the dentition stability. Conspicuously on the Sao teeth, the distal proximal surfaces have remained convex as observed by Kubein and Kruger. The flatter or hollow mesial proximal surface would have come into contact with the more convex distal proximal surface of the mesial tooth[129]. Some factors should be quantified according to the chronology of tooth eruption, the convex shape of proximal surfaces, the thickness and quality of enamel and dietary habits. These factors also play a role in the characteristics of occlusal wear.

The reduction of the mesial-distal crown length is linked to the mesial drift, which reduces the arch length. Campbell, Murphy and Begg's data on Australian Aborigines or Drennan's data[130] on Bushmen are different according to Wolpoff[77]. The measurements given by Murphy were of relative value to quantify the mesial drift[39]. Slightly more than a mean 0.4 mm could have been lost on each proximal surface. These figures are far from those of a modern population. In adults, Harris[131] found a very slight reduction of arch length amounted to a mean 0.25 mm between the distal surface of M2 and the mesial surface of C1. Nevertheless these figures depend on of the kind and the number of samples, as was underlined by Corruccini[80] when quoting Dawes[132]. A mesial drift occurred on the Sao teeth. Proximal wear concerns all the teeth except the anterior ones at the mandible by absence of contact between canines and premolars, at the maxilla except the three left anterior teeth separated by diastemas. When swallowing, the tongue protrudes through the space left by the lack of mandibular incisors and produces a forward hyperpressure on the upper incisors. Therefore, these diastemas directly derive from the pressure of the tongue.

Estimation of dental age in relation to dental wear

According to Vallois[107] or Dalhberg[133] fossil men generally had short lives. Determining the age at the time of death through the study of tooth wear[26] was difficult due to the subjectivity of observation (assessment errors), interrelation between physical phenomena (dental tissue anisotropy, saliva lubrification), complex kinematics and dynamics[134,135], role differences between supporting cusps and guiding ones, dental axes orientation, TMJ morphology[87], diet and chewing habits related to age, social and cultural habits, etc… all factors leading to different results according to the authors.

The models of mandibular molar wear of the Sao fossil were compared to those presented in Miles' table. Even though Miles' method is still considered reliable[112] some criticism are put forward[136]. The age of the fossil deduced from these models could have been around 30. These models present an instant picture at a given time of the occlusal surface, as in the models of Murphy's or Molnar's Tables. No author associates an age value to the models. Moreover Miles' Tables only represents mandibular molar occlusal surfaces viewed occlusally. They do not take into account cusp height loss. Some authors[5,108] estimate a 1 mm wear reduction for a 6–12 year period, but this had never been demonstrated.

The metric study would have led to the conclusion that the Sao teeth had sizes fitting those of mean values of contemporary human teeth. However the curve representing of the cusp height loss in function of age is not linear. Wear process cannot be considered as a continuous and constant phenomenon throughout life. Dental eruption is followed by a progressive occlusal confrontation concerning, sometimes distally, sometimes mesially, M1, P3 and P4, then M2 and finally M3, thus increasing the interarch confronted surfaces. Therefore, wear process of the first erupted teeth is slowed down. Wear would have followed 3 stages. The first stage was represented by M1 wear up to 11 or 12 years of age in the case of mixed dentition. The second one was dominated by the premolars and M2 wear up to 18 years of age and could have been accelerated by early avulsion of the mandibular incisors. The third one was slowed down by the presence of permanent teeth, but accelerated by the presence of a larger exposed dentine surface compared to enamel on the early erupted teeth.

Thus it seems difficult, from the dental remains dating back to African prehistory, to give this human fossil the age at the time of death. Occlusal and proximal wears were not the sole criteria to be taken into account. To assess the age of the subject, the presence of secondary dentine, the cement layer, the relative thickness of dental tissues or their composition[137], and the root translucence must be considered[138]. This implies penetrating and partly destroying the dental structures? This explains why the above-mentioned criteria are not assessed on the Sao teeth. It was decided to preserve the pieces. The persistence of a neat pulp chamber and an almost intact alveolar crest observed on radiographs confirm that the pieces belonged to a young adult. The study of the skeletal characteristics[102,139] could bring forth further information. The chronology of dental abrasion and the search for its aetiology are thus not easy to establish. To trace back to a past activity is impossible to reproduce in the present day[20]. It would have been interesting to compare this type of wear to the one found in today's older individuals, and in those suffering from bruxism. But such severe wear is very rarely encountered nowadays.

Conclusion

Modifications of the crown shape are partly related to wear. This ancient and general phenomenon in the course of evolution is less frequently observed today. In that respect, the study of an almost complete dentition of a prehistoric African individual is of particular interest. Moulding fragile pieces such as fossilized teeth to obtain replicas was suitably achieved with a method adapted from the impression procedures used in dentistry. The moulding of the occlusal surface alone was performed without exerting any pressure on the original pieces with three different viscosities of silicon elastomer. This allowed solid replicas of high precision. The observation of the original pieces and their replicas through a magnifying glass was completed with the examination of the corresponding macrophotographs and transparencies. Occlusal wear was assessed using Hall's scale while proximal contact wear was assessed according to the Van Reenen and Reinach scale, thus detailing this perfect model of typical helicoid wear.

It appeared that occlusal wear is more marked on the left molar side and on the right premolar side compared to the opposite side. The wear facets noticed on the upper incisors are probably due to the contacts established with the opposed lower incisors prior to their avulsion. The unusual root and crown wear of the lower canine is related to the labret that plays the role of a retainer in spite of the mesial drift of posterior teeth.

The wear observed on the Sao teeth reflects his diet and masticatory habits. This is why the permanent teeth were probably submitted to the abrasion process as soon as the first molars erupted. The type of wear is specific to each tooth, even to each cusp, and reflects the way antagonistic teeth made contact and interacted. In spite of the mandibular incisor loss, the arches stayed balanced and stable in the arch distal parts, particularly at molar level. Proximal wear contributed to maintain interdental abutment as if the dental interlocking inter-arch disposition had evolved to be replaced by a complementary adaptation (helicoid shape) at intra- -arch level. Miles' method makes it possible to assume that the Sao fossil died between 30 and 40. This does not invalidate the results obtained with Murphy's diagrams. In the case of bone and tooth pieces scattered on the ground and belonging to one or more individuals, the study of tooth attrition completes the occlusal analysis. Such elements combined with those coming from the metric and morphological studies are true markers and, as such, a great help in identifying the samples and reassembling them.

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ISTRAŽIVANJE ABRAZIJE ZUBA NA LUBANJAMA PLEMENA SAO (KAMERUN) IZ 14. STOLJEĆA

SAŽETAK

Svrha ovog rada bila je istraživanje abrazije koja je izražena u području cijelog zubala kod fosilnih nalaza iz Kameruna koji potječu iz 14. stoljeća. Okluzalne plohe zuba proučavane su na sadrenim modelima fosilnih nalaza koji su otisnuti korištenjem adicijskih silikona uobičajenom stomatološkom metodom. Korištenjem makrofotografija modela i originalnih dijelova zuba bilo je moguće rekonstruirati izgled antagonističkog zubnog luka na foliji u svrhu pozicioniranja u habitualnoj okluziji. Zubni lukovi su fiksirani u zagrizu. Analizom okluzijskih ploha utvrđena je podjednaka abrazija na lijevim i desnim kutnjacima. Hallov indeks okluzalne abrazije te Van Reenenoav i Reinachova klasifikacija interproksimalne abrazije korištene su u utvrđivanju abrazije na pretkutnjacima i kutnjacima obaju zubnih lukova.

Bilateralna aproksimalna i okluzalna abrazija na homolognim zubima upućuju na dobro balansiranu okluziju. Nedostatak donjih sjekutića i djelomična abrazija donjih očnjaka upućuju na prisustvo labreta koji su već pronađeni u ovom području. Milesova metoda utvrđivanja životne dobi temeljem abrazije zuba ukazala je da istraživani uzorci pripadaju pojedincima u dobi između 30. i 40. godine života.