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Dental Contribution to Paleo-Odontological Study of Interarch Relations in a Human Fossil

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A B S T R A C T

In paleo-anthropology the fragility of fossil pieces (teeth and supporting bones) reduces their possible manipulation when studying the interarch relations. Two original impression methods of the jaw pieces are proposed, both adapted from those currently practiced in odontology. The plaster replicas of the dental occlusal parts are prepared according to the manufacturing procedures used in prosthetic dental laboratories. This study led to the following observations: 1) the impression techniques used by odontologists are adapted to the moulding of fragile samples. 2) The replicas elaborated from these mouldings made easier the cast manipulation in confrontation. 3) Macrophotography is a complement to direct observation of the pieces and their replicas. 4) For paleoanthropologic purposes, such studies can be easily carried out on almost any animal or human fossils.

Key words: *fossil teeth, moulding, replica, dental arch relations*

Introduction

Odontological research concerning dental occlusion of Hominids is rare[1]. The aim of this work was the paleo-anthropological study of a fossil skull based on intra- and interarch relations in a biodynamic approach[2–4]. This occlusal study takes place in a more general framework of research in comparative anatomy from morphological, functional and evolutionary standpoints[5–15,16]. Manipulating the tooth arches and their replicas enables the analysis of mastication kinematics. Such kinematics revealed by the confrontation of molar occlusal replicas facilitate the understanding of the shape modification of teeth. The occlusion analysis here carried out on fossil pieces is adapted from that practiced on living human individuals. This simple method can help anthropologists to record information on the site of excavation. This is the first step towards the study of dental wear and morphometrics. This work committed to me by Michel Sakka was carried out on an almost complete skeleton of a Sao native from prehistoric Cameroon to study its intra-and interarch dental relations.

Material and Methods

Moulding of the teeth – pre-experimental study

The three surfaces (buccal, occlusal and lingual) of a dental hemi-arch from a contemporary maxilla skeleton was moulded separately by direct deposition of impression paste without an impression-tray. The moulding material was a polyvinylsiloxane silicon elastomer, polymerizing by addition. Because of its longer time stability, it was preferred to a silicon elastomer polymerizing by condensation. Its final rigidity after setting prohibited the use of a tray. In fact the moulding of each hemi-arch surface extended intentionally onto a small part of the adjoining surfaces of the samples to check the limits of these mouldings visually.

The moulding was made in a three-stage process (Figure 1):

1) A regular impression paste (medium viscosity) is laid evenly with a syringe on the hemi-arch surface (Figure 1a). After polymerization the layer remains on the sample.
2) To consolidate and sustain the first layer, a highly viscous second material is laid onto the first mould, which gets hard after polymerization. (Figure 1b).

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3) This double layer moulding is then removed and a thin layer of low-viscosity impression material is deposited into the inner side of the mould. This third material is kneaded through a syringe fitted with a spiral-mixing tip, providing automatic and adequate mixing of the base material with its catalyst. The mould is then reinserted with gentle pressure on the dental surface (Figure 1c). After setting, the final moulding is removed, uncovering earth particles which were washed off before examination, as earth could not be removed from the original fragile pieces (Figure 1d).

Moulding of the teeth – experimental study

The 26-tooth dentition of an almost complete skeleton of African Prehistory was brought to light in an occupation floor excavated by the Annie and Jean-Paul Lebeuf 1978 Mission on the site of Sou (Logone and Chari Prefecture, Cameroon).

1) 14 teeth are on the maxilla. Six on the right: the canine, two premolars and three molars. Eight on the left: two incisors, the canine, two premolars and three molars. On the left the two remaining incisors were stuck back into their sockets.
2) 12 teeth are on the mandible. The four lower incisors are missing.

After checking the stability of the teeth in their sockets, two types of mouldings are made with two different materials: one moulding of the complete dental arch (full mouth impression in dentistry) is made on the mandible in one procedure. A custom tray is filled with a hydrocolloid (an alkaline alginate and water mix), changing from a sol to an irreversible gel state when set (Class A II Alginate). This material has a 20 μm size precision comparable to that of the elastomer silicones. The mix is pasted onto the surfaces to be moulded to avoid air cavities and subsequent formation of plaster micro-bubbles on the cast surfaces[17]. Then a tray filled with the same impression material is immediately applied and gently pressed onto the arch. After the gel has set, the mould is removed and put into a watertight box to be cast a few hours later. In the same way as in the pre-experimental study, another type of mould (sectional impression in dentistry) is made to obtain, with one moulding, a replica combining the lingual, occlusal and buccal surfaces.

Replicas

The replica material is made of plaster (dental stone) used in dentistry (100 g for 20 ml water). To avoid micro-bubbles, spatulation is performed under low air pressure. The plaster is first laid down with a small spatula into the mould, which is vibrated in the same time to expel the air trapped during the filling process. After the

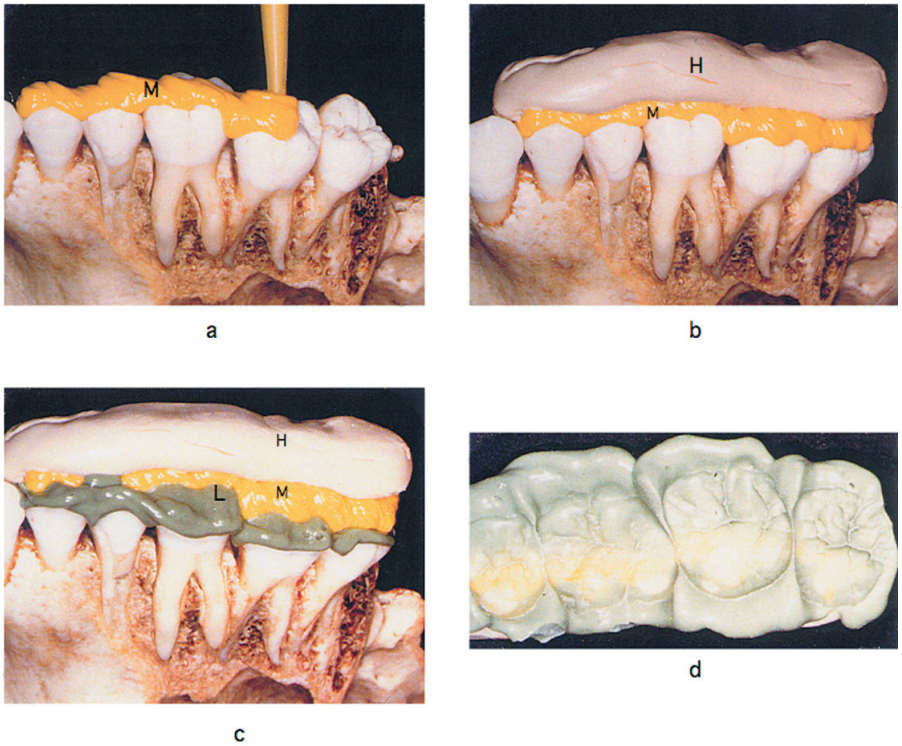

Fig. 1. Moulding fragile samples with polyvinylsiloxane silicone. a) Moulding of a hemi-arch occlusal surface. A medium (M) viscosity non-running material is deposited with a syringe on the occlusal surface. It extends slightly beyond the edges of the adjacent surfaces (lingual and buccal). b) A high viscosity material (H) is deposited upon the previous layer to ensure its rigidity, thus forming an impression tray. At this step, the moulding could be removed. c) A low viscosity material (L) is deposited inside this impression tray that is reinserted on the original samples to obtain a final, more detailed impression. d) The moulding is removed and cast in plaster.

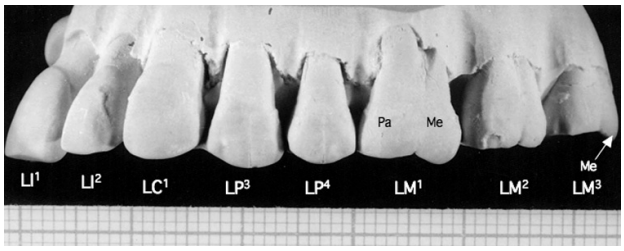

Fig. 2. Plaster replica of the left maxillary dental hemi-arch of the Sao skull (labial and buccal surfaces). Parts of proximal zones are detailed and can be observed. Parts of the edge of the cast were trimmed to better reveal the dental embrasure. (Scale: 10 mm = 5.6 mm).

setting, the plaster replica is removed from the mould (Figure 2). Then, the global replica of the mandibular arch and the sectional replicas of the hemiarch surfaces are prepared. Its base is trimmed as in dental prosthetic laboratories. Each sectional cast is »boxed« with wax to obtain, after casting, a small regular base making manipulation easier. For manipulation purposes two or several »dowel pins« (false roots) orientated in the line of the root axis are pegged into the plaster base. The longer length of the dowel pin, sheathed in plastic, remains loose. The dowel pin is then embedded in plaster, completing the first base. Once the plaster has set, the plastic sheath remains attached to the base and the pin slides inside. The replicas are then sawed into sections in a vertical plane between two adjacent teeth. The global replica of the mandibular arch makes it possible to observe at the same time the buccal, lingual and occlusal hemi-arch surfaces (Figure 3). The false roots are placed in both the right and the left as follows: one at second molar level and another at second premolar level. The cast is cut sagittally through the middle of the toothless anterior crest. The two hemi-arches are thus separated. For each of the four occlusal sectional replicas only two dowel pins are placed in the maxilla and the mandible, one at molar level and the other at the level of the diastema between the canine and the first premolar. Thus, we can remove the crown of the canine and isolate the premolar-molar section from the anterior section (Figure 4).

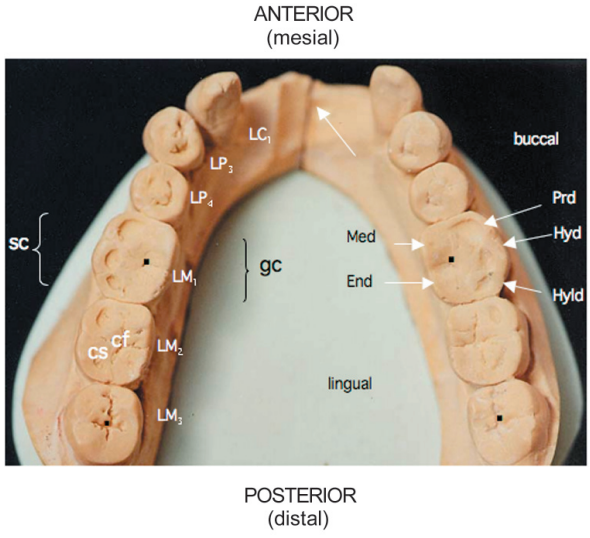

Fig. 3. Occlusal view of the lower dental arch replica of the Sao skull (Scale: 10 mm = 5.6 mm). This plaster cast was made from a one-step impression with an irreversible hydrocolloid material (Alginate) which mechanic properties allow removal without damaging the samples. The cast was sawed sagittally (top arrow) in order to facilitate the manipulation and confrontation of antagonist hemi-arches. Note the V-shaped dental arch. The distance between both central fossae of LM1 and LM3 (black spots) (20.11 mm on the left and 20.12 mm on the right) was assessed with Mac Draw Pro® (1.5 F v1). Anthropological nomenclature: on the left, symbols identifying left teeth (LC_1 – left lower canine, LP_3 – left lower first premolar, LM_1 – left lower first molar…) On the right, symbols identifying lower first molar (RM_1) cusps: Prd – protoconid, Med – metaconid, Hyd – hypoconid, Hyld – hypoconulid, End – entoconid. On the left, odontological nomenclature: cf – central fossa, cs – central slope, sc – supporting cusp (buccal), gc – guiding cusp (lingual).

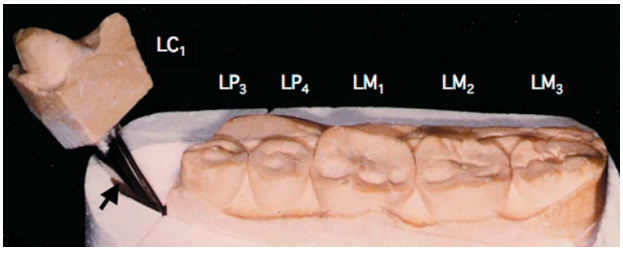

Fig. 4. Occlusal and part of the buccal surfaces of the Sao skull lower left hemiarch segment from canine to molars. The cast is obtained by the moulding technique shown in Figure 1. The canine is removable from the cast by a dowel-pin device (arrow). This was possible in so far as there was an interdental space between the canine (LC_1) and premolar (LP_3). Removing this tooth facilitated the manipulation of hemi-arch parts, thus suppressing the canine interference during confrontation. The canine has erupted after anterior tooth loss (incisors). Note the buccal cusp wear and dentine patches.

Results

Interarch relations

It appeared impossible to obtain a proper intercuspal confrontation when manually handling the original pieces. The study of interarch relations was made easier by the examination of each hemi-arch replica in occlusion, instead of the complete arch replicas. Observation of the lingual and buccal surfaces is performed at high or low angle. Removing the dowel pin and the crown of the canine makes it possible to establish a stable contact between upper and lower premolar-molar sectors.

A drawing is traced on a transparency superimposed onto a real size photograph (1/1 reproduction scale) of the mandibular arch in occlusal view picture and photographs of the maxilla hemi-arches. The superimposition of both kinds of traces (upper hemi-arches) onto the mandibular arch associated with the observation of the replica occlusion allowed a schematic representation of this inter-arch relation.

Intra-arch disposition of teeth

The Wilson curve, observed in a frontal view of the mandibular arch at first molar mandibular level, is concave upwards at the age of six and tangential to buccal and lingual cusps tips of the relevant tooth. In a well--worn dentition, it becomes concave downwards due to the ad vestibulum wear of the first molars (Anti-Monson curve). Observed on the hemi-arch replica, part of the Von Spee curve runs along a line separating buccal and occlusal wear-flattened surfaces of premolars and molars.

Measurements

The real size photographs of the occlusal surfaces of right and left, maxillary and mandibular molar sections, are used to measure the distance between the central fossae of the first and second molars, and between the second and the third molars (Mac Draw Pro ® Software, 1.5 F v1). For mandibular molars the chosen landmark is the intersection between the buccolingual and mesiodistal grooves on the occlusal surface. It corresponds to the lower portion of the molar central fossa (Figure 3). For maxillary molars the landmark is the deepest point of the occlusal groove separating the three cusps of the trigon.

Discussion

The moulding process and the replicas

The impression material commonly used in dentistry (silicon and alginate) was particularly suitable for the moulding techniques of especially fragile fossil samples.

Moulding hemiarch surfaces

The occlusal and lateral surfaces of the hemi-arches were moulded with a silicon elastomer on the maxilla and on the mandible. For each surface in turn, this was done in a three-stage procedure with three impression pastes of different viscosities, according to a »wash-technique« manner: the two first constituted a primary mould and the last one recorded the finest details by a rebasing effect. However the separate moulding of buccal, lingual or occlusal hemi-arch surfaces does not allow a complete reconnection of the adjacent surfaces since the impression limits were not sufficiently accurate to put together the adjacent cast surfaces. Nevertheless it was useful to appreciate the Von Spee and Wilson curves.

Moulding a complete lower arch

An irreversible hydrocolloid was used here to mould the complete mandibular arch. The fact that alginate gets easily torn when removing the impression tray was not detrimental to the original samples. The mould could not be removed sharply as is done in the mouth. There are warping risks. Moreover, material fragments remain in interdental spaces, and consequently the replica is not very precise in those places compared with the sectional lateral replica. Generally, only silicones with time-constant physical properties are used by anthropologists and paleontologists[18]. Irreversible hydrocolloids, which are cheaper, are used for the moulding of more voluminous and fragile pieces. However the hydrophilic property of the material requires fast treatment of the mould. Plaster, which is not sensitive to thermic variations, is preferable to epoxy resin for the replicas. As plaster is not particularly fragile, very hard and bubble-free replicas are obtained with »vacuum spatulation«. In anthropology, computed tomography of fragile pieces is used but 3D reconstructions are restricted by the thickness of the slices[19].

Occlusal analysis

The study of occlusal relations from direct mouth photographs as shown in publications is of limited value. Inappropriate shot angles can lead to the conclusion of interdental contacts that do not actually exist[20]. The occlusal analysis of the samples themselves should be done very carefully as the manipulation of the models could lead to errors. For instance, the maxillary teeth of KNM-ER 1813 could occlude correctly with OH 13 mandible[21] and the Dmanissi mandible[22]. The maximal intercuspal position (MIP) obtained with the epoxy cast arches of the Taung child (available at the Museum National d'Histoire Naturelle, France) was not stable. The present study shows that it becomes stable if maxillary and mandibular hemi-arches are severed.

When the broken maxilla of the Sao skull was reconstructed, the left lateral incisor and the left canine were reset in their sockets. This could have induced a slight shift in the occlusion of some sections. This is why the upper arch was not completely moulded and hemi-arch replicas of the maxilla and the mandible were preferred. During the examination, the suppression of lower canines on the cast permitted a stable contact between 2 or 3 isolated teeth and allowed observation to be done at right, high or low angles. However some biological conditions could never be reproduced: teeth mobility in their sockets due to the periodontal support, guiding effect of TMJ, ligaments, teguments, warping of the mandibular arch during chewing, etc. Nevertheless occlusal surfaces measurements and their crosschecking allowed a closer assessment of interarch relations and made it possible to represent through drawings the occlusal confrontation in an occlusal view or a 3D representation.

Semi-adjustable articulators used in dental practice are not beneficial. They are a complement to direct clinical study of occlusion in living humans. In the context of fossil pieces this would imply a sufficient number of teeth in both arches. Nevertheless it would have been impossible to record the cranio-mandibular position without valid cranial marks and TMJ relations. Moreover articulators do not represent the mandible movements in the way they are actually performed (chewing cycle) but in a reverse displacement. This lateral excursive movement of the mandible is not natural, but guided by the dentist with a view to prosthetic restorations[23].

The occlusal plane

Cusp slope inclination, Von SPEE or Wilson curves help to complete the study of occlusal relations of dental arch or hemi-arch replicas. More elaborate methods could be used but require adapted material. This is the case, for instance, if one wants to measure the occlusal plane angle in relation to a plane of reference[24], which remains to be defined, or assessed by planimetry[25]. Laser beam devices are now used in paleo-odontological research, but imply the manipulation of original pieces to record their 3D anatomy before replicating it in hard (epoxy) material.

Conclusion

The occlusal relations between dental arches of an almost complete dentition were studied minutely by comparing the original samples and their plaster replicas. The latter were obtained from reversible hydrocolloid, when possible, and from silicon mouldings widely used by odontologists. Research in dental practice has validated the quality of the materials used here for a long time. Here the moulding technique is original in preserving the particularly fragile samples unearthed. Dividing the replicas into sections made the study of occlusion easier. Real size photographs provided additional elements to the information collected through the mere observation and manual confrontations of the replicas. It was then possible to propose a schema of interarch occlusal relations[26]. Occlusal relations in the parasagittal plane (Angle classification, FDI Classification, Von Spee Curve) and in the frontal plane (Wilson Curve) were carefully examined. They are essential in the study of intra and interarch relations.

Through safer preservation of its structures the fossil tooth provide biological anthropology and human paleontology with valuable information. In the case of scattered remains belonging to several individuals, the study of occlusion completes the morphological and morphometric studies and should be of great help to put the pieces back together. In the absence of more elaborate techniques, simple methods could foster exchanges between odontologists, paleontologists and anthropobiologists.

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DENTALNI PRILOG PALEO-ODONTOLOŠKIM ISTRAŽIVANJIMA OKLUZIJSKIH ODNOSA KOD LJUDSKIH FOSILNIH NALAZA

S A Ž E T A K

Osjetljivost na oštećenje nalaza koštanog i zubnog tkiva smanjuje njihovu mogućnost korištenja kod paloantropoloških istraživanja. Predloženo je korištenje dviju metoda uzimanja otisaka koje se koriste u stomatološkoj praksi. Sadreni odljevi okluzalnih ploha zuba izliveni su standardnim metodama korištenim u zubotehničkom laboratoriju. Ovaj rad ukazao je da 1) tehnike otiskivanja koje se koriste u stomatološkoj praksi pogodne su za otiskivanje osjetljivih fragmenata. 2) odljevi načinjeni ovim načinom omogućuju lakše rukovanje s istraživanim uzorkom. 3) makrofotografske snimke mogu se koristiti za kao nadopuna direktnom pregledavanju uzorka. 4) korištenje ove metode može se jednostavno primijeniti na bilo koje ljudske ili životinjske fosilne nalaze.