JOINT MEETING NO. 4

Section of Odontology with Section of the History of Medicine

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(President of the Section of Odontology)

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C. E. WALLIS MEMORIAL LECTURE

Methods and Materials Used for Artificial Teeth [*Abridged*]

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MY first duty is to speak of Charles Edward Wallis, whose name is commemorated in this lecture. He was born in London in 1869, and received his professional education at King's College Hospital and the Royal Dental Hospital. He joined the staff at King's as Assistant Dental Surgeon in 1899 and became interested in the dental treatment of school children. He was elected Dental Surgeon in 1911 when A. Swayne Underwood retired. It was largely due to his writings that the first London County Council School Dental Clinic was established and he was appointed to supervise these clinics. He was active in the affairs of the British Dental Association, and widely read in history and archæology. He held several honorary appointments and published a number of papers on school dental clinics and historical subjects. He died suddenly in 1927.

I am the first Wallis Lecturer to be sufficiently junior not to have had the privilege of knowing Wallis personally, and I am indebted and grateful to Mr. S. E. Wallis for these facts, which are taken from his unpublished book on the history of King's College Hospital Dental School.

The literature on artificial teeth is unexpectedly large, but unfortunately the period before Fauchard, while abounding in passing references to artificial teeth, provides very few details of their material or construction. The eighteenth and nineteenth centuries, however, which saw great development in the art, are more fruitful, since a number of textbooks for the instruction of dentists were published, besides a flood of advertising material. I have thought it best to confine my attention to original works I have myself examined, with a few exceptions, and to examples of dentures I have actually handled. Although it has been impossible to cover the whole field or to visit every museum where old dentures are to be found, it is hoped the additional accuracy so obtained will compensate for the necessarily restricted survey.

I propose to deal with removable artificial teeth, except in the case of Etruscan dentures, and not to touch on crowns or the history of porcelain teeth, and to end with the introduction of vulcanite in the middle of the nineteenth century.

A very few examples of prostheses have been discovered, the earliest dating from 2500 B.C., having their origin in Egypt, Phœnicia and Greece, but according to the physical evidence now available it must be agreed that the Etruscans were the first people to make artificial teeth in any numbers.

The Etruscans were a people who inhabited at one time the greater part of Italy before the founding of Rome, perhaps between the ninth and third centuries B.C. They were skilled metal workers and architects and many examples of their buildings are still in existence. From the large number of graves excavated have been obtained numerous interesting everyday objects and beautiful specimens of jewellery and metal work including artificial dentures. As may be expected the majority of such dentures are in Italian museums but there are two examples in this country, both in the Liverpool Museum (Fig. 1). They are in a collection formed by Joseph Mayer and presented to the city by him in 1867. Nothing is known of the history of the objects before they came into the possession of Mr. Mayer. The collection is particularly rich in gold jewellery, nearly all in extremely good condition, and is dated from the seventh century B.C.

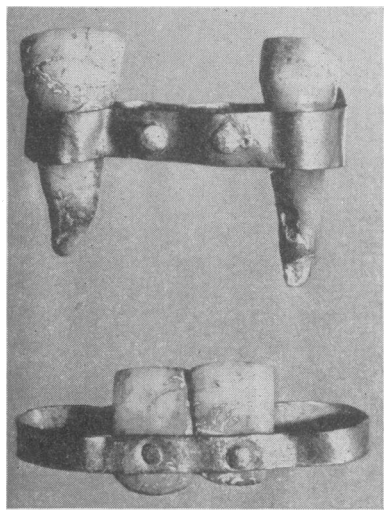

FIG. 1.—Etruscan dentures. Upper specimen: central incisors (? not original) as abutments, artificial teeth missing. Lower specimen: abutments missing, artificial teeth (human) present. (By permission of the Liverpool Libraries, Museums and Arts Committee.)

to the third or second century B.C. when gold working as an art died out. The collection has been described in 1932 by Mary A. Johnstone [1], and in at least one Italian publication. The two dentures are illustrated by Johnstone and a very accurate description given, but as far as I can discover, have not been illustrated in any dental history. The earliest reference I can find to the Liverpool specimens is a note in the *Independent Practitioner* (1885) by W. H. Waite describing the dentures [2].

From a study of illustrations of Etruscan artificial teeth it would appear that models of the mouth would be necessary for their construction although Johnstone makes the interesting suggestion that "it is possible that some, but certainly not all, of the gold dressings were added when the body was entombed in order to make it more comely."

It is likely that the practice of dentistry spread from Etruria to Latium, and from the numerous and well-known references in Martial and other Roman authors to artificial teeth, it appears to be certain that they were commonplace in ancient Rome, but not enough examples have survived to enable accurate evaluations to be made.

I have not been able to find any references to artificial teeth during the so-called Dark Ages, and it is not until the time of Albucasis (936–1013) that a reference can be found. This writer, after describing how loose teeth may be bound together and supported by gold or silver wire, states "Sometimes, when one or two teeth have fallen out, they are replaced in the sockets, bound in the aforesaid manner and they will remain there. . . . The vacancy left by fallen teeth can be filled with artificial ones, made of ox bone, they also being fixed in the manner above described; they will be found not only an advantage from the æsthetic, but also the functional point of view" [3].

The first illustration of artificial teeth is to be found in the works of Ambroïse Paré [4]. The following description is taken from the second English edition of the collected works translated by Thomas Johnson, 1649 [5]. ". . . other teeth artificially made of bone or Ivorie may bee put in the place of tho/e that are wanting, and they mu/t bee joined one fa/t unto another, and al/o fa/tened unto the natural teeth adjoining, that are whole; and this mu/t chiefly bee don with a thred of gold or /ilver, or for want of either, with a common thred of /ilk or flax, as it is declared at large by Hippocrates, and al/o de/cribed in this figure following." The original French also states that artificial teeth may be made of the *dents de Rohart* which Lindsay [6] states is from the Icelandic *rosmhvair* meaning a walrus.

Guillemeau, whose work on surgery was translated into English in 1597 [7] describes a paste consisting of white wax, gum elemi, white coral and "prepared pearls" which may be used for forming artificial teeth or filling cavities in teeth, the actual passage being "Farthermore anye bodye by arte may make teeth of white waxe which beinge meltede, & liquefactede with as much gumme Elemni, or a little ma/tick, white Coralle, and preparede pearles & thereof a pa/te beinge made, of the which we may forme as manye teethe as we plea/e. This pa/te is al/o verye commodiou/e to repleni/h therewith a hollowe toothe, becau/e ther might noe viandes remayne therin, through which the teethe doe more corrupte, and more intollerable payne is heer bye /u/citatede [*sic*]". This has already been noted by Lindsay [6, 8]. Weinberger does not regard the paste of Guillemeau as of any value in the filling of the teeth saying "a tooth made from it could hardly have withstood the pressure of mastication and at its best could not have been more than a temporary filling" [3]. I have constructed some dentures using the paste and on the contrary, the material is exceedingly hard. For "prepared pearls" I have used mother-of-pearl, since it is hardly likely that pearls would have been ground up. It appears, therefore, that Lindsay was quite correct in regarding the paste "as a great advance in dental surgery." James Cooke (1676) says, "some make them [artificial teeth] thus, Cer. alb. Gum Elim. an

part. equal. Or, with Mastich, a little white coral prepared and made into a paste, of which Teeth may be framed: it may also be useful to stop Teeth that are hollow, to keep the Air out" [9]. Although no doubt Cooke was copying from Guillemeau, this passage does indicate that the paste was known to surgeons in the seventeenth century.

Peter Lowe (1654) states, regarding the treatment of loss of teeth, "for remedie whereof we make artificiall teeth of Ivory, Whales bone or hounds teeth, which ſhall be faſtened by a wyre or thread of gold, paſſing the wyre or thread betwixt the whol tooth on either ſide next adjacent, then put the artificiall tooth in the part, then knit the thread faſt through about the ends of the thread . . . I am not mindfull to inſiſt in this practick as I might, becauſe it is ſeldome practiſed" [10].

Nuck (1696) gives an interesting short account of artificial teeth, in which he says that nothing is more common than to make artificial teeth out of elephant ivory and having made them to tie them to the neighbouring teeth with a thread of gold or silk. But since they become stained by food or saliva in a short time they are better made from hippopotamus teeth, especially if the outer surface is of good colour. If all the teeth in the lower jaw fall out a complete set of teeth should be made from elephant ivory or hippopotamus teeth and so placed within the lip that with the movement of the jaw it also is moved and food taken into the mouth can thus be chewed [11].

The first detailed instructions for the making of artificial teeth are to be found in the wonderful textbook by Pierre Fauchard (1728). This book has now become rare and valuable, but fortunately there is available for English-speaking students the translation made by Lindsay and published by the British Dental Association in 1946. There is no doubt that this is one of the most considerable pieces of scholarship ever completed by a single dental historian, and all workers in this field must remain permanently in the translator's debt.

Fauchard says that human teeth are usually used and that the pulp cavity should be filled with lead, but that hippopotamus (or sea-horse) teeth, the teeth of oxen, and even the bones of their legs, the tusks of walrus and the core of ivory which is finest and most beautiful are also used. He must mean that teeth may be carved from hippopotamus tusk, ox bone, walrus tusk and elephant tusk. Ox teeth would appear to be too large, but calves' teeth might be suitable.

He goes into considerable detail about the drilling of the holes for linen thread, waxed silk or gold wire which served to retain the piece by being tied round the neighbouring teeth. Where a number of teeth are to be replaced, the row of artificial teeth is to be supported by a narrow band of gold, each tooth being fixed to it by a rivet which passes from the lingual to the labial surface. Sometimes an artificial piece can be supported by a post crown, which is cemented in place by the following: Flake gum lac two ounces, finest Venice turpentine half an ounce, white coral in powder very fine, two ounces. The gum is melted, the turpentine and coral added. The mixture is formed into little sticks and pulverised when required.

A little of the powder is put up the enlarged root canal and the post is warmed.

He also gives instructions how to prepare ox bones for artificial teeth. I have not been able to obtain ox bones, oxen being large draught animals, but I have prepared some leg bones of a cow more or less according to his instructions and it is apparent that no large denture could be made from such a material. Fauchard says he prefers ox bone to elephant ivory because the latter soon becomes yellow.

When a complete upper denture is to be made it is supported by a sort of frame fitted over and around the lower teeth, to which the upper plate is attached by flat steel springs which are inserted into the distal aspect of the last tooth and retained by threads through both the denture and the spring. He says "This machine combines not only the qualities of those which have preceded it, without their discomfort, but it has several other advantages which distinguish it and render it a hundred times more convenient. . . . The experts in this art in the attempts they have made at an upper denture have only used, up till now, springs of whalebone which are fastened to the natural teeth of the lower jaw with thread." Later he suggests that whalebone may be added to the steel springs he used to make them last longer. From this passage it is obvious that attempts had been made by dental practitioners in the seventeenth century to construct full upper dentures, although descriptions have not survived, and Fauchard states in a later passage that springs coiled like corkscrews or spirals were used before this time, but were not satisfactory. When complete upper and lower dentures are constructed the steel or whalebone flat springs are fitted into slots and tied into the denture; the springs are then covered with several layers of thread. Finally Fauchard describes a method of making a strip of gold or silver enamelled with colour to represent the gum and the tooth. The work is to be done by those who are used to working with enamel, and the strip is fastened to the bone base with rivets [12]. It is an extra-

ordinary thing that Fauchard does not mention the taking of impressions and, as Lindsay says, "it is certain that Fauchard knew nothing about impression taking, since there is no mention of such a thing in his work, and it is not likely that such an accurate and careful describer would have omitted to speak of this important point. He evidently measured the gums and spaces between the standing teeth with compasses, since he frequently speaks of taking the measure of the mouth" [8].

From the statements made by Fauchard it appears that he did not fix artificial teeth, whether human or animal, by means of posts in the pulp chamber, but that the rivets were at right angles to the long axis of the tooth. When dentures are seen with teeth fastened in this manner, they may well be assumed, therefore, to date from the first half of the eighteenth century, but I have yet to examine any, and it is thought that no teeth attributable to Fauchard now exist.

The first mention of a model is in a work by Purmann (1684). Lindsay gives a translation of the relevant passage, and while the meaning is not quite clear, it would appear to indicate that a model in wax is made in the mouth and a denture in bone or ivory constructed from it [8].

Pfaff (1756), however, specifically mentions taking an impression in sealing wax of edentulous jaws in two halves and from this a model is made. The sealing wax used would be largely beeswax and softened at a much lower temperature than the sealing wax now used [8].

Bourdet's book of 1757 is an important work, and the chapter and plate dealing with artificial teeth are in some respects superior to Fauchard's work, with which Bourdet was obviously well acquainted.

He says that artificial teeth are rarely made of ivory, i.e. elephant ivory, and that sea-horse is the best material because of its colour and solidity. He has often mounted a human tooth on a small piece of sea-horse, the tooth being retained by a rivet. When the gums have shrunk a long way, an artificial tooth may be made with enamelled gums and it is necessary to take exactly all the necessary measurements and to form a model in wax. Such dentures are retained in the mouth by threads, and need great care. Bourdet describes dentures for the four upper incisors which were retained by threads, the teeth being attached by two pins, one vertical and one transverse, and must have been very secure. Fauchard apparently did not use vertical pins. A number of natural teeth can be mounted on a piece of gold fitted to the gum, the pins and teeth are fitted, then removed and the piece sent to the enameller for colouring the gums. When it is enamelled, the teeth are mounted and cemented with Fauchard's mastic cement. Bourdet says that Fauchard only used the cement for crowns, but that he, Bourdet, used it to cement artificial teeth on to plates. The springs used by Bourdet appear to be flat, and he says that gold is better than whalebone or steel, and while he does not use whalebone, he sometimes places whalebone springs on the dentures temporarily to enable the patient to get used to them [13].

Berdmore (1768) discusses artificial teeth in general terms, and says that while gold ligatures often cut the teeth, this does not happen if silk twist is used. He says that complete dentures may be made for both jaws by the help of springs of a new and peculiar description, but unfortunately he does not describe them, merely saying "they are totally different in shape and action from those which have been used by my predecessors" [14].

I have a letter written by Dr. Erasmus Darwin dated March 18, 1785, to a Mr. Richard Dixon of Felsted, Essex, in which he states "If you could get false teeth, you would find that another consolation, as you would speak easier, and if you could get it (for it is but one piece cut to look like 2 or 3 teeth) made of ivory instead of the bone [bone deleted and horn substituted] of the sea-horse, it would become dusky and look like your other teeth. I should recommend Beardmore [*sic*] to you in Bolt-Court, Fleet Street. I advised my brother at Elston to get an artificial tooth, but I believe he thought it a sin and would not at all listen to me about it."

An interesting sidelight on the practice of dentistry in the late eighteenth century is seen in an unpublished letter in my possession, written on March 6, 1782, by Manette Talma who at that time was living with her father, the well-known dentist in London, to her brother, the future actor, in Paris. Manette says [trans.] "Father asks you to do everything you can to get him some teeth, and if you can go into the mortuary, to take advantage of the opportunity. If that is not possible, you must try and get to know the brother who is in charge of the place and ask him to let you have some; you will pay for them, the big incisors and the little laterals. Father used to pay his predecessor 12 livres a hundred for the canines. Don't forget all my messages. And the little molars [buy them] if they are fine and white, but much cheaper than the others." A livre was an alternative name for a franc and had the approximate purchasing power of the contemporary English shilling. Talma junior was apparently somewhat dilatory about executing his commission since M.

Georges Dagen of Paris has given me a copy of a letter written by Talma senior with a note also written by Manette and dated May 31, 1782 [trans.]. "You will not forget the teeth that Father asked you for, for he has not any more and needs them very badly."

There is a large number of patents dealing with the construction of artificial teeth from 1791, the earliest being that of Dubois de Chémant. Unfortunately the works of de Chémant from 1797 give no details of the manufacture of his mineral paste, but there is one statement which might be of value in deciding whether a particular denture is in fact of the period of de Chémant. He quotes from the "Report of the Academy of Sciences concerning the Teeth and Sets of Teeth of the new composition of M. Dubois de Chémant, Extracted from the Registers of the Royal Academy of Sciences 10 June 1789", where it is stated that "M. Brisson . . . found that a cubical inch of it weighed one ounce, two gros ($\frac{1}{4}$ oz.) and sixty nine pennyweights, whereas the lightest china of Seve [*sic*], of the seventeen kinds which he tried, weighs one ounce, three gros ($\frac{3}{8}$ oz.) and nine grains." The report is signed by D'Arcet and Sabatier [15]. It is not known to me how this weight would compare with the porcelain blocks and continuous gumwork of a later period, but it is a matter which would appear to be worthy of further investigation, when a full history of porcelain teeth is undertaken.

De Chémant's English patent dated May 11, 1791, gives some details of the process and the formulæ of the pastes. It is apparent that frequently three bakings were necessary. The procedure for constructing the denture was as follows: A quantity of soft wax was placed in the mouth, which was then shut giving an exact impression of the space required to be filled. In this was poured a composition formed of plaster of Paris, which when dry gave a true and solid model of the mouth. The well-kneaded paste was pressed into the plaster mould, removed, allowed to dry and then fired. As the paste in drying (and baking) lost some of its thickness it was necessary to spread or widen the wax mould when taken out of the mouth to an increase of about one-seventh, by pressing on the middle of it with the finger and thumb. Holes for the fastenings, that is threads or gold wires, had to be bored before the paste was quite dry. When the paste was dry enough to be handled, the teeth were carved in it with a sharp instrument before the piece was fired. After firing, the enamel colouring was painted on the teeth with a brush and the piece baked. Finally the gums were painted and the denture again fired (Fig. 2).

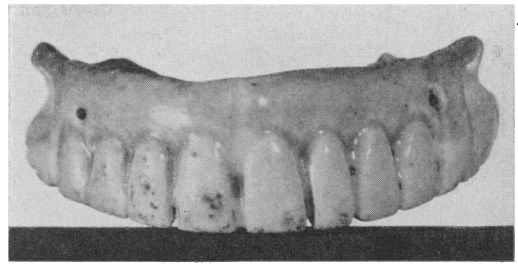

FIG. 2.—Upper denture, porcelain, believed to be by de Chémant, *c.* 1800. (The Odontological Museum of the Royal College of Surgeons.)

The last part of the patent specification concerns the making of spiral springs formed by twisting gold wire round a mandril.

Tomes' patent of March 3, 1845, is of considerable interest. It is in two parts, the first consisting of a method of obtaining a model of the proposed denture and the second the copying of this in hippopotamus or walrus ivory. A wax impression of the mouth was first taken and a plaster model made of the denture. The composition consisted of shellac, ivory dust or plaster of Paris and a solution of india rubber. This composition model was tried in the mouth and adjusted as necessary. It was then fixed in the machine and copied, the essential principle being the movement of a blunt point over the model transferred to a sharp point cutting the ivory. Reverse surfaces and undercut areas could be obtained. Tomes did not claim priority regarding the copying principle, there being in fact a number of such devices previously described, but he did claim that he was the first to use it for dental purposes. Unfortunately there is no example now in existence and there is no model of it in the Science Museum at Kensington, although they have a number of copying machines.

Of the remaining patents, comparatively few are of importance, and it is to be assumed that the majority of such patents were enrolled because of their advertising value.

Harrington patented a press for forming tortoiseshell into dentures in 1849 and an example of such a denture (Fig. 3) is shown by the courtesy of the Director of the Fauchard Museum, Paris, but it is not known if it was made by Harrington. I have tried to press tortoiseshell into dentures, but have not been able to give the matter sufficient time to have much success.

Laurie patented the process of John Allen for continuous gum work in 1853, using a platinum base, and Massey (1854) and Loomis (1854) also

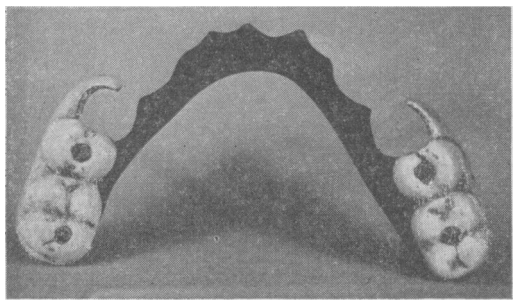

FIG. 3.—Lower denture, tortoiseshell and hippopotamus ivory, posts of silver or platinum and amalgam (?), *c.* 1850. (The Fauchard Museum, Paris.)

worked in porcelain. Charles Goodyear's famous vulcanite patent (the English patent) is dated March 14, 1855, but it is known he was experimenting for many years previously.

Rubinstein's patent of 1859 is of interest since it mentions the use of mother-of-pearl as a base.

Dental patents are a large and difficult subject, involving questions of priority between English, American and Continental patents and also priority between different workers, but it is a field which is worthy of the attention of dental historians.

Gariot, whose book was published in 1805, makes some interesting statements. He says that human teeth are very seldom used (i.e. in 1805), those of the sea-horse and those manufactured from mineral paste having been substituted for them. This is certainly not true of English dental practice of the period. He says that he has purchased from de Chémant the recipe for making his composition teeth, but he is not allowed to give it. He describes ligatures for retaining dentures in position and states that while springs for dentures may be steel or gold bands or whalebone, spiral gold springs are best [16].

The best account of dental practice regarding artificial teeth in the first quarter of the nineteenth century is to be found in the work of Maury (1828). There exists a picture of his workroom, reproduced by Dagen in 1926, but I have not been able to find an original example suitable for copying [17]. However, through the courtesy of Dr. Ernest Weil I am able to show a copy of a lithograph of Fattet's dental laboratory, dating from about 1840 (Fig. 4).

Maury states that materials used for artificial teeth have been the bones and teeth of oxen, horse, sheep, stag and several other animals, ivory, mother-of-pearl, teeth of the hippopotamus or sea-horse, and teeth made from mineral

FIG. 4.—From "La Vie de l'Illustrissime Inventeur des Dents Osanores" (Georges Fattet), *c.* 1840, Paris.

paste.[1] Persons who have lost their front teeth, he says, have for a long time replaced them with teeth made of white wax. He describes all these materials, giving their advantages and disadvantages, and states that at the present time (1828) hippopotamus teeth are much used, both with and without their enamel. Human teeth are far the best imitation and should be obtained from those who die in hospital, aged 18-40, and are brought to the amphitheatre for dissection. They should be carefully removed, cleaned and kept in bran, sand, fine grain or sawdust. Those from cemeteries are generally not suitable, as they become yellow and brittle.

Two models are necessary, one to fit the plate roughly, the other to finish on. The teeth adjoining the space to be filled should be scraped a little so that the piece may be a little larger than actually necessary. The cast is covered with black or red paint and the piece gradually cut with the rasp and the flat graver. Various types of teeth and dentures are described, and he states that the inner skin of the birch tree dipped in varnish is the best method of cementing human

[1]There is a good deal of confusion in the use of the names sea-horse, sea-cow and morse, the Oxford Dictionary giving all three names as synonyms for both walrus and hippopotamus. I believe that morse should be used for the walrus, sea-cow for walrus and sea-horse for hippopotamus. Ash's catalogues of 1851–1875 quote "Hippopotamus or Sea-horse teeth" and "Walrus or Sea-cow Tusks".

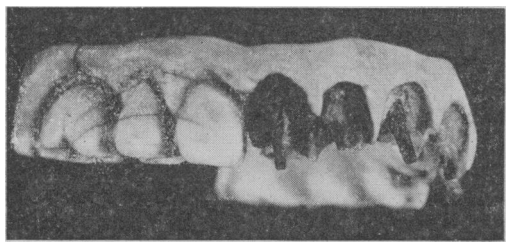

FIG. 5.—Upper denture, hippopotamus ivory, incisors (probably human) missing. Five posts copper, one iron (1|). Silk packing can be seen round posts. (The John Humphreys Odontological Museum, University of Birmingham.)

teeth on to their pins. Many English dentists use no other means to secure artificial teeth to the plates (Fig. 5). He retains complete dentures by spiral springs and there is no mention of flat springs. His book contains a very valuable vocabulary describing the French technical terms [18].

Lefoulon makes some interesting suggestions, although his work of 1841 owes a great deal to Maury. When he uses human teeth, he prefers those of men slain in battle, in the full vigour of life from the eighteenth to the fortieth year (thus following Maury). Those chosen are pierced at the end of the root, arranged on a thread and kept in flax-seed. He describes ligatures in the same terms as Maury, and says that while they had been in use for a long time he considered them undesirable and he rarely used them. He states categorically that human teeth are daily employed with the greatest advantage. He suggests that to overcome the shrinkage which is inevitable when a porcelain denture is baked, a process used in statuary to enlarge or reduce a model might be employed to enlarge the model by say a tenth part [19].

A most detailed account of the making of artificial teeth in England is to be found in Robinson (1846). He describes gold dentures with English, French and American porcelain teeth, with the differences between them, and the carving of hippopotamus tusk to fit a model. A section of the tusk is cut into two halves and applied to the model so that the fibres are horizontal, unless the enamel is to be retained, when the fibres are placed vertically. This is in fact seen in dentures. The surface of the model is then hardened with wax and resin and painted with rose pink and oil. The block is repeatedly applied, and the high spots cut away until the denture fits. A second model is used when the first has lost its sharpness. Robinson mentions the machine invented by Tomes in 1845 but says it is not very satisfactory owing to the difficulty of producing undercuts. He then apparently painted a patient's gum with red paint and tried the plate in the mouth. He used springs only when the alveolus was shallow, since the firmness and steadiness of the plate depended entirely upon the accuracy of the fit. The methods and formulæ for baking porcelain teeth are given, Robinson saying they have always remained a profound secret in England, and he quotes from the American textbook of Goddard and Parker, 1844 [20]. French textbooks had given formulæ for many years. He gives instructions for baking several teeth in blocks, and this may be important in the dating of a porcelain denture, since a poorly fired example of *c.* 1850 may bear some resemblance to the work of de Chémant of *c.* 1800.

In the fifties a number of new materials were tried as bases for artificial teeth; I have mentioned Harrington's tortoiseshell process, but in addition there was gutta-percha first patented by Truman in 1848, buffalo horn, aluminium, the "cheoplastic" metal of Blandy, and of course vulcanite.

An important lecture by Robert Hepburn at the London School of Dental Surgery in 1864 shows the position of mechanical dentistry at that time. He says that metallic and vegetable substances were gradually superseding bone work. He evidently was convinced that ivory still had an important part to play, especially for lower dentures, for orthodontic plates and for temporary dentures. He says that ivory was still much used for side blocks, and that there were practitioners in London and Paris who still used no material as a base but bone. It was usual to send hippopotamus tusks to grinding mills, where the enamel was ground off at a cost of from two and sixpence to five shillings each. Mineral teeth may be cemented on their pins with sulphur. He gives a formula for staining gums pink, and states that the denture must be placed in the boiling solution for a few minutes, the parts to remain white being protected with plaster of Paris [21].

The identification of the particular ivory used may be difficult owing to the smallness of the specimen or the amount of destruction of the surface that has taken place. There is a very wide colour variation, ranging from almost black through every shade of yellow and brown to almost pure white. The colour, therefore, is of no value in identification, as it appears to depend on the smoothness of the denture originally, the care with which it was cleaned and the action of the saliva.

I have examined a total number of 473 dentures from various sources, either consisting entirely of ivory or containing a substantial proportion, and

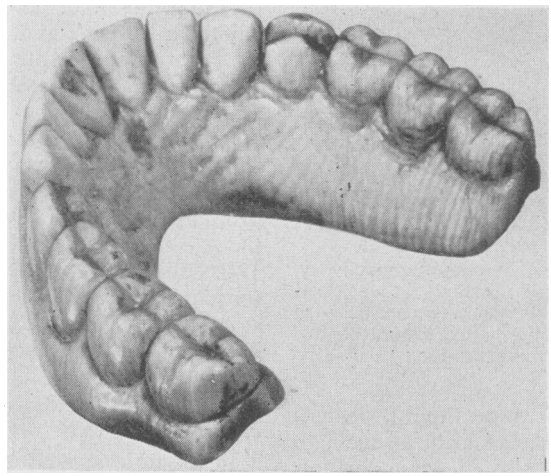

FIG. 6.—Upper denture, elephant ivory with typical striations.
(The Museum of the British Dental Association.)

of this number 269 were made of hippopotamus, 146 of walrus, 5 possibly of elephant, and 22 doubtful. I have also seen 4 wooden and 27 porcelain dentures.

The materials of choice when an ivory denture was to be made were elephant ivory, hippopotamus ivory, sperm whale, walrus ivory, and bone, and it is necessary to be able to distinguish them. If the denture is small, say one or two teeth, this may be a matter of considerable difficulty or even impossibility, since it is a necessity that the identification must not damage the denture in any way, otherwise a microscopic examination of a small fragment would be decisive. The denture examined must be cleaned and slightly polished and a lens of about six magnifications is suggested. The method employed is to obtain specimens of various ivories, cut and polished so that three planes can be examined. The reason for this is that each ivory possesses a definite structure which is visible on sometimes one only of the cut surfaces and it is thus possible to identify the material of the denture under examination by comparison.

Elephant ivory.—The form and size of the elephant tusk is too well known to require description. A longitudinal section shows an apparently structureless outer layer of cementum perhaps $\frac{1}{8}$ in. in depth, known to ivory workers as the rind. Next there is a layer of denture marked by longitudinal lines which become more indefinite as the centre of the tusk is approached. Finally the lines tend to disappear towards the centre and the ivory appears to be structureless. In transverse section the cementum appears to be structureless, but the outer layers of the dentine present a very typical criss-cross appearance which is difficult to describe but enables a denture made of elephant ivory to be identified with certainty (Fig. 6). The "lines" described no doubt indicate the periodicity of deposition of calcific material of varying density.

Hippopotamus ivory.—The canines were usually the teeth used, and normally the lower. The upper canines are comparatively small and only a small portion is erupted, while the lower are very large and weigh from $2\frac{1}{2}$ to 10 lb. The outer surface of the tusk is covered with enamel, the rest being covered by cementum. A longitudinal section in one plane shows no apparent structure, but the longitudinal plane at right angles to this shows a series of longitudinal lines which apparently diminish as the centre of the tusk is approached. A transverse section also shows these lines parallel to the surface and hence concentric. They are narrower and more closely packed than in the elephant, and there is absolutely no suggestion of the "criss-cross" appearance. Robinson states that if natural or mineral teeth are to be inserted in the piece, the tusk must be applied horizontally to the model. On the occlusal surface, therefore, the lines would not be apparent, but would be visible on the buccal surface (Fig. 7). Occasionally dentures of hippopotamus tusk are seen with the enamel on the labial surface of the artificial teeth. The enamel is usually "crazed," that is showing very numerous cracks, and is often of a curious blue colour (Fig. 8). Robinson (among other authors) notes this and considers that the enamel covering is best left on the sides of the denture for this reason. When the enamel is retained the tusk is

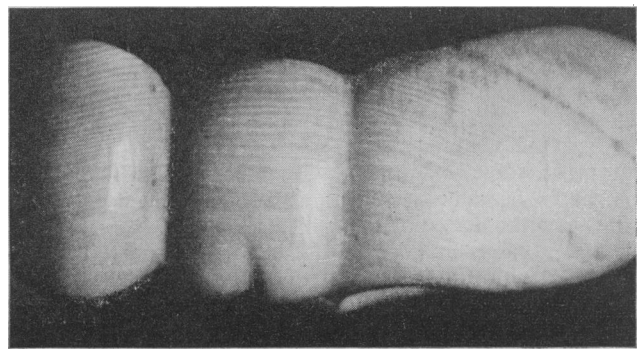

FIG. 7.—Partial upper denture, hippopotamus ivory, buccal view showing typical striations. × 3 approx. (The Fauchard Museum, Paris.)

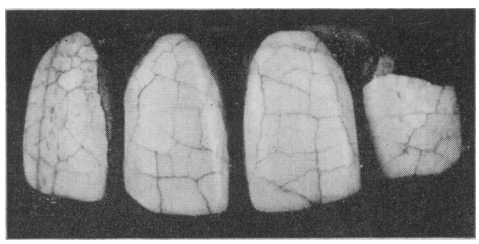

FIG. 8.—Partial upper denture, hippopotamus ivory with enamel on labial surface. Retained by silk ligatures, *c.* 1800. (The John Humphreys Odontological Museum, University of Birmingham.)

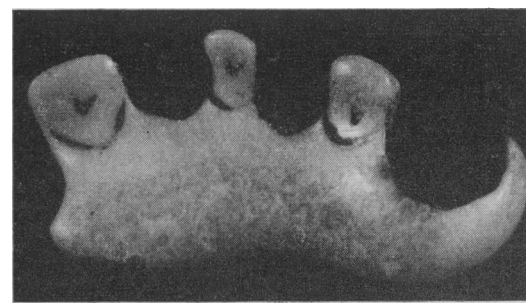

FIG. 9.—Upper denture, walrus ivory showing secondary dentine. Made in Leamington, *c.* 1870. (Collection of the author.)

cut transversely and consequently the lines are visible on the occlusal surface.

Walrus ivory.—This is obtained from the enormously developed upper canine teeth. A transverse section of a walrus canine shows a layer of cementum which is structureless, a layer of dentine which is structureless and a mass of secondary dentine which has a very typical appearance and enables ivory of this animal to be identified. This secondary dentine occupies a great part of the body of the tooth, even when the tooth comes from a young animal, and appears to be more translucent than the true dentine, consisting of rounded masses set in the whiter dentine. A large number of dentures have been identified as having been made from this ivory, and in each case identification is possible because fragments of the secondary dentine are seen (Fig. 9). Nasmyth (1839) says "This substance . . . is the cause why only the outer shell of the canine teeth of the walrus is applicable for finer bone-work." [22.]

Sperm whale—The teeth of this animal are of poor colour, and a transverse section shows secondary dentine of a very dense type, quite different in appearance from that of a walrus. Hepburn says "As the teeth of the whale and the tusks and teeth of the wild boar have fallen into disuse, I need say nothing about these animals." He goes on to say that he has frequently used the small grinding teeth of the boar for side blocks and found they were very satisfactory. I have not seen any dentures constructed from a whale's tooth.

Bone.—This appears to be structureless when examined, and a tentative identification of this material can only be made when the preceding materials are eliminated.

In an effort to obtain a more scientific and precise method of identification than slight magnification of the surface, I endeavoured to obtain the specific gravity of elephant ivory, hippopotamus ivory, walrus ivory and bone from the hock of a cow, the results being elephant

ivory 1·78, hippopotamus 1·97, walrus 1·92, bone 2·08. Several specimens were tested in each case and these figures represent the average. Two small hippopotamus dentures were tested and the specific gravity proved to be 1·92 in one case and 2·03 in the other, so that it would appear that though the figures are somewhat inconclusive, the method might be of value in some cases, the first necessity being the determination of the specific gravity of a large number of specimens of different ivories, using perhaps more precise methods than I have been able to employ. If the denture to be identified is small and presents no recognizable features in the way of striations, it must be confessed that the material of which it is composed cannot be identified without microscopic examination.

When I began investigations on the specific gravities of ivories I was not aware that any previous worker had had the same idea but in 1849 Alexander Nasmyth published tables showing the specific gravity and chemical composition of various sorts of ivory and of enamel. The actual chemical work involved was done by Thomas Thomson, Regius Professor of Chemistry at Glasgow, and his nephew, R. D. Thomson. The specific gravity of elephant ivory was 1·728–1·794, walrus 1·909, hippopotamus 1·866 [23]. I am not aware of any more recent work along these lines, but since these men were expert and experienced chemists, it may be assumed that these figures are accurate. The figures approximate my own results and it would appear that while the specific gravities of different ivories can hardly be used as a basis for identification, it is a matter which requires further research before a certain conclusion can be reached.

From the middle of the nineteenth century the dental supply houses advertised hippopotamus, walrus and whale teeth. Messrs. Claudius Ash have kindly given me some information relating to the period 1851–1875. During that period they offered hippopotamus teeth at 3/6 to 14/- per lb., blocks with enamel ground off 3/- to 25/- each, walrus tusks 2/6 to 4/- per lb., blocks 1/- to 7/- each. I understand that Messrs. Claudius Ash supply hippopotamus teeth to some dental schools for practice in the cutting of cavities, and thus hippopotamus is the oldest material in present use, having been used certainly from the end of the seventeenth century.

From the earliest times retention of removable dentures was by gold or silver wire, or silk or flax thread. As I have shown, the dentures illustrated by Paré are so retained, and a similar method is shown in the works of Fauchard [12], Bourdet [13], de Chémant [15], Gariot [16], Delabarre [24], Maury [18] and many others. Gariot's work of 1805 [16] was translated into English in 1843, and a footnote by the editors states "the practice of fastening one or more artificial teeth with ligatures to the adjoining teeth has long since been done away with." Lefoulon, writing in 1841, considered that ligatures are undesirable. It would be reasonably safe to say that a denture needing ligatures for retention would date before about 1825, although Robinson says in 1846 that the ligatures frequently employed to fasten dentures soon loosen the adjoining teeth.

Bands and wires round teeth are illustrated by Campani [25], by Delabarre [24] and most of the later authors. The wire bands and cribs of De la Fons [26] are a great improvement. There are considerable difficulties in attaching satisfactory gold bands or wires to ivory dentures, and this has been surmounted in a most ingenious way in a denture in the Odontological Museum of the Royal College of Surgeons, the band being in two parts, each separately inserted into the denture.

Another method of retention was by means of wooden pegs driven into the side of the artificial tooth to wedge it in place. This appears to be rare and I am able to show a specimen by the courtesy of the Director of the Fauchard Museum, Paris (Fig. 10).

Campani [25] illustrates three dentures replacing a number of upper incisors which appear to be retained by a pair of clips which fit over the alveolus.

Complete dentures were always retained by springs and in the eighteenth century these were usually flat and were inserted in the posterior surface of the denture behind the last molar tooth. Campani [25] and Arroyo [27] illustrate this. Laforgue [28] illustrates this type, but also an upper denture attached to a lower frame on

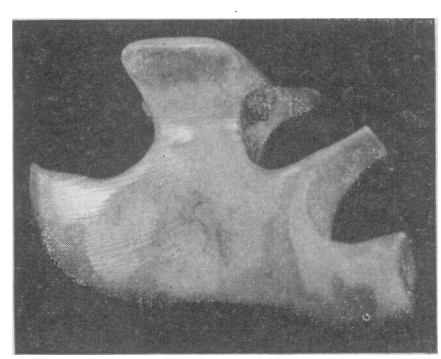

FIG. 10.—Upper denture, hippopotamus ivory, retained by two wooden pegs. (The Fauchard Museum, Paris.)

which the springs are fastened at the side of the molars (Fig. 11), and henceforth springs are shown in this position. It would appear, therefore, that springs fastened behind the last molar tooth would indicate an eighteenth century date. Fauchard says that a complete upper denture can be held by the sole support of the cheeks and lower teeth, but it is only intended for ornament and pronunciation. However, it can be used for eating as he has seen.

The use of springs declined from about the middle of the last century, when more accurate impressions were obtained, but they continued to be used occasionally until very recently.

The dating of carved dentures may present great difficulties. If porcelain incisors are used dating is much simplified, because the teeth used are either tube teeth with gold or platinum tubes and consequently *c.* 1837 or later, or facings which cannot be earlier than 1808 when Fonzi introduced separate porcelain teeth. It is when the dentures are carved from one piece or when human incisors are used that the greatest difficulty arises. Early writers from Albucasis onwards mention the use of animals' teeth and ox bone, presumably for the incisors only; dentures of this type are rare, but when found they may well be assumed to be dated before about 1750, and possibly much earlier.

The value of a denture whose date can be determined within 25 years or so is immense, and if any such dentures exist in a museum they should be accurately labelled. In this connexion the dentures excavated at St. Bride's and preserved in the Odontological Museum of the Royal College of Surgeons are valuable.

Rath [29] illustrates upper and lower dentures stated to be from a Swiss tomb of *c.* A.D. 1500 and made from the femur of an ox with a strip of tin to act as a spring between the dentures. The molar portions are joined to the incisal block with wire. Presumably the date is correct, but it is hardly possible that tin would be used as a spring since it is so soft a metal. And in this connexion I would plead for a really accurate description of a denture used as an illustration, stating the material, whether the pins are gold, platinum, silver or base metal, and whether the post is smooth or threaded. If all the incisor teeth are present this information can be obtained by an X-ray which would also show if the pins fitted accurately or whether silk thread was used as a packing. Finally, if a tentative date is assigned, the reasons should be given.

It is tempting to believe that the cruder the workmanship, the earlier the denture, but this view may lead to difficulties and errors. It is possible to date certain dentures with some accuracy, either because it is known who made them, or for whom they were made: these can serve as models from which other examples can be dated, but it is essential to record as many as possible of such accurately dated specimens.

When springs or bands are present they may give valuable clues as to the date of manufacture by comparing them with illustrations from text-

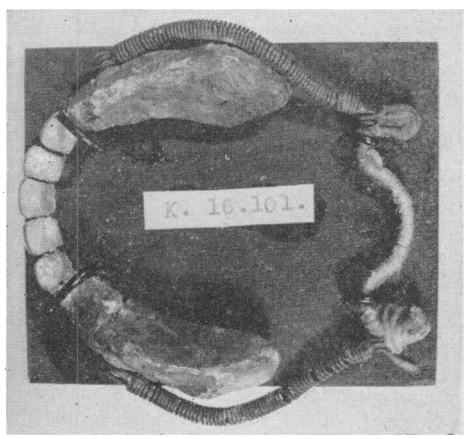

FIG. 11.—Upper denture, spiral springs attached to a curved, padded piece of metal which presumably fitted behind the lower incisors. The teeth are not human and the molar region is built up with resin or mastic. Late eighteenth century. (The Odontological Museum of the Royal College of Surgeons.)

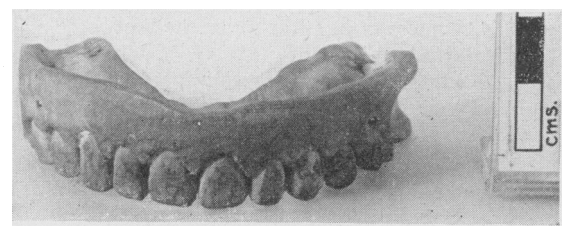

FIG. 12.—Upper denture, grey porcelain, unglazed, *c.* 1820? (The Wellcome Historical Medical Museum, No. R.28370.)

books of various periods. Swivels may be hand-made or shaped in a press and it may be assumed that the former are the earlier.

Dating of porcelain dentures presents difficulties also. As I have said, de Chémant made all-porcelain dentures and the materials from which he made them are given in his patent of 1791. But the position is complicated by the fact that from about 1820–1850 many dental practitioners experimented with porcelain in France, in this country, in Ireland and in America, many textbooks giving formulæ (Fig. 12). As a matter of interest I have in my collection a copy of a letter written by John Parish of Bath dated 1812 in which he thanks de Chémant for his "Ratellier" [set of teeth] and says they "answer perfectly." He also sends a remittance of forty guineas.

If the denture is made of some unusual material, say tortoiseshell or gutta-percha, the dating is simplified, but it must be emphasized that almost all writers from Fauchard to Robinson stressed the usefulness of hippopotamus tusk over other materials, and therefore, in the absence of datable features, the date of construction of a hippopotamus ivory denture may well be a matter of conjecture.

[The lecture was illustrated by specimens, photographs, lantern slides and photostats of English patents relating to artificial teeth 1791–1863.]

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