FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

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PREFACE

This Thesis is the culmination of the authors interest in forensic odontology over a period of ten years. The author is a general dental practitioner whom the Police have consulted over that period on problems of identification by dental means.

The research studies were initiated while the author was a part time research assistant on Scottish Home and Health Department Grant K/MRS/32/C16 awarded to Dr. D.G. MacDonald, Senior Lecturer in Oral Medicine and Pathology to investigate "Forensic Studies of Bite Marks in Food".

The work of the Thesis was undertaken partly in the Department of Oral Medicine and Pathology, in Glasgow Dental Hospital, partly in the author's surgery and home and partly in Strathclyde Police Headquarters in Ayr.

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FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

1.1 INTRODUCTION

Forensic odontology as yet hardly recognised as possessing the basic requirements necessary to a scientific discipline is hopefully emerging from the almost non investigated cocoon stage and moving towards the full flourish of scientific acceptance. However, little actual research is actively conducted with a view to solving particular problems and providing a sound base from which to advance and on which other workers can build. This is certainly true of bite mark investigations which tend to be almost primitive, lacking a scientific foundation on which to base ultimate conclusions. It has been said that most knowledge is open to a degree of doubt, but somewhere along the line there is a point where scientific credibility and probability are compatible and it was with such thoughts in mind that the studies presented in this thesis were undertaken.

Tooth characteristics have been extensively studied at the Glasgow Dental Hospital and School (MacDonald, MacFarlane and Sutherland, 1973) and these characteristics have been used to establish the probability of a given dentition having made a particular bite. Which of these characteristics are likely to be found with any degree of certainty in flesh bites is not known and the difficulties of studying large numbers of bites in living subjects are obvious. However, the police report many instances of bitten foodstuffs being found at scenes of crime and it seemed to the author a logical step forwards to examine bite marks in foodstuffs in an attempt to bring a degree of credance to this branch of forensic dental knowledge.

1.2 BITE MARKS AS EVIDENCE

That the science of bite mark investigation is still a neglected field of dentistry in general, and forensic science in particular was recognised by Fearnhead (1961) who stated "that the need for a transfusion of dental research into forensic science is only too apparent when one considers the doubtful reliability of the deliberations given by so called expert witnesses"; yet today it is normal for skilled witnesses to be heard on an amazing range of scientific and technical subjects on which the Courts could not be expected to have informed themselves (Brownlie, 1976).

Sherlock Holmes is given credit for acting as a catalyst in the evolving of the modern investigation. He made the study of tobacco and tobacco ash a hobby and also came to conclusions from tooth marks on the tips of cigars (Berg, 1971). Speaking on the subject 'Crime and the Dentist', Simpson (1970) stated that where a victim had been bitten by an assailant, the criminal might just as well have left his visiting card or signed his name. Bite marks to those who had skill in this field were proving to be as good as fingerprints.

The idea that dental features may be characteristic of an individual and the use of routine procedures with meticulous attention to detail, in order to relate a particular individual's dentition to a bite mark has not always been accepted in Courts. A report in "Justice of the Peace" (1960) describes a novel kind of evidence, namely the marks of teeth in a piece of cheese, and at the trial an expert witness expressed the opinion that tooth marks were in the same category as fingerprints, and as conclusive. The Deputy Chairman of the London Sessions, however, directed the jury that it would be utterly unsafe to convict on this evidence alone, although he agreed that in time the science of tooth mark identification might be developed so as to become sufficient evidence. More recently Lord Grant (1968) summing up in the "Biggar Murder" Trial (H.M. Advocate v. Hay, 1968) said that there must be a first time for everything and the Law must keep pace with science.

In many criminal cases bite mark evidence has not been used other than as part of the indictment and it has been the author's own experience that where he has been cited by the prosecution to give dental evidence, in no instance has the defence introduced a defence expert in an attempt to refute the evidence. This is probably due to the fact that not many dentists have studied the application of scientific techniques designed to provide technically acceptable, yet comprehensive evidence which can be understood by both legal experts and lay jurors.

Relatively few workers have carried out experiments in this field although according to Gustafson (1966) it is clear that a scientific approach could give more information about bite marks, their occurrence and their value from a criminological point of view, and Fearnhead (1961) is of the opinion that experts need to be trained and research into the dental aspects of forensic problems initiated.

Figures illustrating the numbers of apple bites found in criminal cases at nine British population centres (Table 1.1) have been published by Marshall, Potter and Harvey (1974) and these indicate only limited success in the gaining of convictions in Court. The author has personally found that failure to provide evidence is more often due to lack of suspects than lack of dental details in bitten foodstuffs.

It appears that many instances of bite marks in flesh and in inanimate objects such as foodstuffs have gone unnoticed, or have not been used as evidence because investigating police officers have not recognised them at the time as being bite marks, or have not been aware of the investigation techniques which are available for the analysis of bite marks and the possible matching with, or the elimination of suspects. Walls (1974) suggests that identification of hungry burglars could be made more frequently if investigating officers were more 'vigilant' in collecting discarded apple cores and the like.

The present author has been asked to investigate alleged bite marks, in both flesh and foodstuffs, days after the bites had been made, when either the injury was healing or the foodstuffs had decomposed to the point of being useless.

A reliable method of proof in the use of bitten apples as evidence is called for by Marshall, Potter and Harvey (1974) and much quoted in forensic literature is the view of Fearnhead (1961) who writes that evidence involving bite marks in foodstuffs should be examined extremely critically and that evidence which involves the identification of a person by toothmarks left as bruises in flesh should never be admitted. "Often quoted however, Keiser-Nielsen (1967) states that any more comprehensive marks may well lead to direct identification and this view is supported by Schaidt (1974); Svensson and Wendell (1955); Sabata (1963); Ström (1963) and many others" (Harvey, 1976).

The application of specialist dental knowledge to the investigation of criminal problems is a comparatively modern development and as yet not many references to the use of bite mark evidence have been published in recognised English literature. It is interesting to note that since 1966, six major text books on forensic odontology (Gustafson, 1966; Furuhata and Yamamoto, 1967; Cameron and Simms, 1974; Lundtz, 1975; Harvey, 1976 and Sopher, 1977) have been written in or translated into English. Gustafson (1966) has most to say on the subject of bitten foods but his observations are unfortunately scattered through out the chapter on bite marks. Harvey (1976) devotes just over one page to the subject but this is largely historical in content, while Sopher (1977) mentions food bite marks as part of one sentence in his bite mark chapter, in which he claims to provide insight into the most controversial area of forensic dentistry!

1.3 THE OCCURRENCE OF BITE MARKS IN FOODSTUFFS

In the criminal field bite marks have been found in flesh, foodstuffs, and a variety of objects such as wooden cabinets, (Pedersen and Keiser-Nielsen, 1961) a pipe, (Oshikane, 1931) pipe stems and musical instrument mouthpieces (Harvey, 1976) a tube of rat poison (Inoue and Sasada, 1950) a bottle cap (Kashitani and Yamamoto, 1961), but the commonest of all bite marks found in criminal cases are bite marks in foodstuffs left at the scene of a crime. Bites have been described in cheese, chocolate, apples, oranges, cucumber and biscuits (Harvey, 1976). Simon, Jordan and Pforte (1974) describe the case of a bitten bread and cheese sandwich.

"Fruit and cheese seem to be the most popular foodstuffs that exhibit bite marks that are left at scenes of crimes" (Cameron and Simms, 1974).

These authors also say that "of fruit the most common is the apple, although the variety is not specified nor is the type of cheese".

The father of food bite mark investigations in the United Kingdom was Humble (1933) who described in much detail a case of larceny at which bite marks had been found in a piece of cheese. In 'Justice of the Peace' (1955) another case of larceny was illustrated in which a man was convicted as a result of his having left bite marks in cheese.

Among the more bizarre examples of food bite marks reported, is the incident in which an artificial soap apple was bitten by a burglar who was unaware of the nature of the material until it was too late and he had already made the bite (Euler, 1929). A Danish newspaper (1921) described the case in which a conviction was obtained in Scandinavia as a result of the criminal being identified from tooth marks in a piece of roast pork.

1.4 FOOD BITE MARKS AND SERIOUS CRIMES

While many cases of bitten foods have occurred during acts of burglary, the evidence of the forensic odontologist investigating food bite marks has been crucial in more serious crimes.

In a murder hunt a suspect was apprehended because he left at the locus, a portion of meat and potato pie which contained his bite mark (Furness, 1971). Furuhata and Yamamoto (1967) describe a case in which a murderer and rapist was caught because of his tooth marks in a piece of cucumber found at the scene. More recently Sperber (1978) reported what he believes to be the first case in which chewing gum proved to be an essential part of the evidence leading to a conviction for murder. One of two female suspects was proved to have been at the locus because certain of her dental characteristics could be related to the chewing gum which had been found. In particular the mark of a lingual cavity in an upper incisor was reproduced in the chewing gum.

A case of arson was solved when a bitten apple, which remarkably survived the fire, was found in a drawer and the bite marks were sufficiently clear to prove that the accused person had been on the premises (Furness, 1977, personal communication).

Furness (1979) also aided the Court in a case of double murder by demonstrating that photographs of plaster casts of the accused's dentition exactly matched the bite marks on an apple found in an orchard which was the locus of the crime. This identification placed the accused at the scene, although he claimed in his defence that he had been out of the country at the time when the murders had occurred.

Similarly Jacobsen (1971) describes the case of a burglary in a supermarket in North Jutland at which a portion of cheese containing nine bite marks was found. Two suspects were arrested in the south of the country, but they denied ever having been in the north, or to have had any connection with the burglary. A dentist examining the evidence stated that there was 'a very high degree of probability' that the bite marks had been made by one of the accused and this evidence resulted in a confession to both the burglary and a number of other crimes.

In the last three years the author has investigated four cases of bites on apples, one bitten pear, and a bitten piece of cheese. In the most recent instance a bitten apple was found at a break-in in a supermarket and it was believed by the police that identification of the biter could help to solve a number of similar crimes which had occurred in the same district. However, a particularly brutal murder was committed a few nights later and a massive search was conducted to find the killer, including an effort to fingerprint the entire male population of the town. During this fingerprinting process the supermarket burglar voluntarily confessed to various crimes including biting the apple, rather than be implicated in the murder!

1.5 THE MATCHING OF BITES AND BITERS - MATERIAL AND METHODS

The available knowledge on the interpretation of bite marks in foodstuffs and the matching of bites and biters comes largely from single case histories. There has been a tendency to use methods which have been developed for other purposes albeit with some success. No previous study has been reported which is designed both to classify bite marks in foodstuffs and to simplify the technique of investigation such that a standard approach to the subject might be developed. The first published report of a bite mark case was that of Sörup (1924) who described 'odontoscopy'. The models of the suspect's teeth were coated on the incisal edges with printers ink. Moistened paper was then placed on the inked surfaces and the print transferred to a gelatine transparent paper. A life sized photograph of the bite mark was obtained and the transparent paper was then placed over the photograph and compared with it. This technique has been criticized as being unnecessarily complicated, but other workers in this field have used modifications of the Sörup technique.

Morgen (1943), painted his models with black paint except for the incisal edges of the teeth. The photographed models showed the white incisal edges against a black background. The film negatives of both the model and the bite marks were then superimposed one upon the other for comparison. Ström (1963) coated the incisal edges of articulated models with lipstick and used the models to make bite marks on a phantom model or on a living subject before carrying out a photographic comparison.

Working with bites in various foodstuffs, Humble (1933) found that in a number of experiments with apples, oranges and cake, that to 'record well' the bite must be made very carefully and often several attempts were necessary to obtain a mark which could be identified as a tooth mark. Nickolls (1963) states that it would be foolish to think that all bite marks will yield sufficient information to enable an identification to be made.

Kuwana and Suketoshi (1971) had 90 biters make bites on small sections of cheese. Plaster models were made of the bite marks and of the biters dentitions, the models were divided into ten groups and three experienced dentists were asked to find corresponding sets of bite mark models and dentition models. They could match less than half of the models and bites.

Many of the earlier attempts to match bite and biter have involved the making of simulated bites on similar materials to the original bitten specimen or sometimes dental materials such as paraffin wax have been used to obtain bites for comparison purposes. However, if a felon takes a bite from an apple there seems little point in asking him days or weeks later to bite another apple as there are so many uncontrolled variables to be considered. It is not possible to guarantee the same texture of fruit or the application of the same biting technique. The force applied in making the bite cannot accurately be determined and it is not known how the size of the fruit influences the ultimate bite marks.

Experimenting with bite marks in foodstuffs Yamamoto (1955) had his biters bite into a 'moderately hard' bean jelly which was then copied in plaster of paris. The same author states that toothmarks on sticky food or chewing gum do not show 'their right impression' this being due to adhesion of the material to the incisal edges of the teeth.

Gustafson (1966) favours the use of plasticine to obtain simulated bites because it offers "no resistance". Berg and Schaidt (1954) used plasticine to obtain 5,000 such simulated bites from 100 biters in an effort to find a criteria for making positive identifications. They employed a film projector to superimpose the photographed simulated bites on photographed bite marks. Only in the correctly paired bite marks and simulated bites was there complete correspondence.

Simulated bites were taken by the police in a composition material in a case of burglary described by Nickolls (1963), and plaster of paris positives were constructed from them. These positive casts were compared with tooth marks in butter, margarine and cheese which had been found at the scene of the crime and were stated to "correspond exactly in size, position and absence of teeth" with the positive obtained from one of two suspects.

Paraffin wax was used by Simon, Jordan and Pforte (1974) to obtain a simulated bite, and this was photographed and compared with the photograph of a bite on a sandwich. The attempt was not successful but a successful conclusion was reached by comparing the photographed bite mark with a laterally transposed negative of a photograph of a silicone model of the suspect's dentition.

In another crime at which bitten cheese was found Layton (1966) obtained simulated bites, by having the suspects bite into a further portion of the same cheese. Because the material used for the simulated bites was smaller than the original piece, the mechanism of the biting action was altered. It was reported that the marks which were produced contained none of the 'sliding characteristics' which were seen in the original bites.

1.6 PLASTER OF PARIS MODELS OF BITERS AND BITES

The problem of the simple inspection of a bite mark on foodstuffs and its comparison with a plaster model is highlighted by Fearnhead (1960). In an experiment with bite marks in apples it was found that a colleague was able 'without much difficulty' to discover among a collection of plaster models kept for record purposes, a model of a female aged fifteen years which fitted the bite marks made by a male aged eighteen years, just as perfectly as the jaws that made them.

Glaister (1915) describing a case of larceny which occurred in Carlisle in 1906 states that plaster models of the suspect were shown in court and these 'fitted' the bitten cheese. (A pointer perhaps to the concordance used by the legal profession is the fact that this case was referred to by Lord Grant (1968) in the murder trial (H.M. Advocate v. Hay, 1968). Possibly a wider field of reference would have revealed other instances of forensic odontology.

The technique of fitting plaster models into bites seems to be the one used most often. Part of the evidence in a case described by Kerr (1977) included the fitting of a plaster cast of the suspect's dentition into the photographed outline of a bite mark on an apple. Susuki (1970) also used plaster models to demonstrate how the suspects teeth fitted into a plaster of paris replica of a bitten apple.

A variation on the technique of fitting plaster casts directly into the bite marks is reported by Harvey (1976). Artificial teeth of a similar size to the tooth marks in an apple, were waxed into the apple, which had been preserved in formalin thus building up a picture of the biter's dentition. The accused confessed.

1.7 SCRATCH MARKS

Dental peculiarities such as sharp pointed or fractured teeth, restorations, and simply teeth which lie at different levels within the dental arch may cause marks other than the actual tooth imprint. The most frequent of these is a scrape or scratch across the bitten material, which has occurred during movement of the teeth. Recognising this, Nickolls (1963) is of the opinion that the whole method of examination of tooth marks is identical with examination of the more customary type of instrument mark, and investigators must regard the teeth as instruments. Dentists may have difficulty in divorcing their minds from the idea that teeth are teeth, but must consider them as instruments. Comparing scratch marks, with irregularities in the incisal edges of teeth Nickolls (1963) claims successful matchings in butter, margarine and cheese.

The buttered cracker biscuit (Fig. 1.1) shows clearly the scratch mark of a faulty gold inlay in the biter's upper right central incisor.

Both scratch marks and impression marks made by the anterior teeth on a variety of foodstuffs have been examined by Sölheim and Leidal (1974) who utilized scanning electron microscopy for the comparison. Only the impression marks caused by the defects on the incisal edge were of value in identifying the biters, using this very detailed technique.

1.8 ARCH CURVATURE

The comparison of the curvature of the dental arch in a bite mark, with the curvature of the dental arches of a suspect has been attempted by some workers using an updated version of the method described by Sörup (1924). The author has not found any instance of such a comparison being applied to bitten foodstuffs such as the bite mark on an apple.

Furness (1968) has described his method of comparing arch curvatures in flesh bite marks and this could be adapted for use in cases of food bite marks. Following upon a rough check of the model against the bitten substance, the incisal edges of the teeth on the model are marked with printers ink, and photographed from the labial aspect, and the incisal edges are photographed with the camera angled from the molar region. When the negatives have been printed on the same scale as the previously photographed bite marks they are mounted on plain white cards. The curvature of teeth in the mark and the arch curvature are compared and measured, as are the incisal edges and gaps between the teeth. Finally lines are projected to show the similarities. This technique seems complicated and difficulty may be experienced in identifying the inked incisal edges because of the black shadows which are produced in the photograph on the lingual aspect of the teeth (Fig. 1.2).

Musich and Ackerman (1973) have described the use of the catenary curve which utilises a cord or chain hanging freely from a sliding scale to compare arch curvature. This comparison has been applied in flesh bite marks and could be used also in food bites. The catenary curve is an even curve however, and the author has not found this to be a regular feature of the average dental arch as seen in bite marks.

1.9 CHARACTERISTIC FEATURES IN BITE MARKS

At the present time the author has been much impressed by the efforts issuing from the Glasgow Dental Hospital and School which in the last decade has built up a wide and special experience in the interpretation and analysis of flesh bite marks (MacFarlane, MacDonald and Sutherland, 1974).

In Glasgow the basic idea of physically relating replicas of a particular dentition to records of a bite mark obtained by a variety of means has largely been superseded as the principle method of identification of a suspect, by a procedure designed to examine and analyse the characteristic features which are known to occur in bite marks, and comparing these with the characteristic features in the dentition of an alleged biter. In addition such characteristic features in a dentition can now be compared to the known frequency of occurrence of these features in a known population sample, thus answering the question - 'what is the likelihood of another individual having the same tooth characteristics as a given suspect'? According to Ström (1963) the important point is to find characteristic details which will establish that the bite marks, when compared with a suspects dentition, are of such a type that there can be no doubt as to their identity. MacDonald (1976) states that what is required is to be able to demonstrate distinctive features in the bite mark and corresponding features in the teeth of the alleged biter.

The forces and mechanism applied in making the bite mark and the textures and thickness of the bitten material all appear to influence the ultimate mark, and clearly emphasis must be placed on individual characteristics rather than on an expected mirror image of the teeth making the bite. Attempting to identify a suspect from a bite mark in cheese Layton (1966) states that an evenly arranged, regular perfect set of teeth may leave a bite mark showing no particular identifying features and may be shown to have been produced by many different people; but MacFarlane, MacDonald and Sutherland (1974) are of the opinion that using present day techniques involving a complete analyses of a bite mark such factors as incisor edge lengths, tooth gaps and exact angulations, would probably combine to show that even two dentitions which appear to be identical would produce unique bite marks.

1.10 THE NUMBERS AND TYPES OF CHARACTERISTICS NECESSARY FOR BITE MATCHING

Bite marks can be characterised by positive or by negative features which indicate either the presence of particular teeth together with variations in shape and position, or the absence of a particular tooth or teeth. The characteristic details of a dentition may not all appear in a bite mark, as in the case of a tooth the incisal edge of which is short of that of the adjacent teeth. The details and characteristics are more important than the number of teeth involved. In the Biggar murder trial

(H.M. Advocate v. Hay, 1968) Lord Grant in his summing up address to the jury stated that as he understood the evidence "It is not so much the number of marks, as the quality, the definition, the uniqueness or the unusual features which they (bite marks) have, that matter".

There has been a tendency in the forensic dental investigation to follow the example of fingerprint comparisons. Some workers have suggested analagous numbers of points of comparison to the accepted 16 to 18 points of comparison required in the fingerprint investigation, while others have been more concerned with particular details of individual teeth.

Sörup (1924) believes the identification of three or four teeth within a bite mark to be sufficient for positive identification, but four or five adjacent teeth should correspond exactly, in the view of Berg and Schaidt (1954). Imprints of the lower anterior teeth in a bitten apple were less well recorded than the marks of the upper teeth in a case described by Kerr (1977). Yamamoto (1955) reports that upper and lower central incisors are the most useful in identifying tooth marks, while Furness (1968) has found that the lower anterior teeth are most commonly involved.

Keiser-Nielsen (1968) considers that only a very limited number of teeth are found in bite marks. The corresponding characteristics in food bite marks and a suspects dentition have been described by several authors in reports of criminal cases. Simon, Jordan and Pforte (1974) were able to show eleven corresponding tooth features in the case of a bitten sandwich. Twenty different dental 'peculiarities' in one dental cast were 'exactly similar' to twenty dental peculiarities found in two other casts in the case of bitten cheese reported by Layton (1966). The unique features of a 'great line of peculiarities' (Korkhaus, 1955) and the imprint of gingival margins (Keiser-Nielsen, 1947) have aided Court proceedings as did two small hypoplastic pits (Euler, 1929) which were found on the incisal edge of a lower central incisor.

1.11 THE USE OF STATISTICS IN BITE MARK COMPARISONS

Statistical methods have only recently been applied to bite mark analysis and at the present time little work has been published on the value of statistical bite mark findings as evidence. Many expert witnesses on being asked what is the likelihood of another set of teeth having produced a given bite mark, have replied with subjective answers, such as 'one in a million' or 'almost impossible', because despite apparent agreement between marks and models no matter which technique in involved, it cannot be stated with certainty that a particular individual has made a particular bite mark. An absolute standard of measurement to evaluate the findings of the analysis of a bite mark and its comparison with a dentition is not as yet forthcoming but the assessment of the degree of probability of occurrence of certain tooth characteristics can now be calculated. In a survey of teeth characteristics reported by MacFarlane, MacDonald and Sutherland (1974) a random sample of the population of the Glasgow area was studied. The six anterior upper and lower teeth were analysed in terms of tooth status, relationship to arch form, and tooth rotation. The study concentrated on positive characteristics only. The results of the survey have provided an assessment of the frequency with which these dental characteristics occur in the over sixteen years of age population of the Glasgow area. Tables have now been computed giving the probabilities attached to all possible subsets and combination of arch positions and also rotations for upper and lower jaws (Aitken and MacDonald, 1979).

The use of statistics has been accepted in the Courts on a number of occasions and was first demonstrated by Dr. D.G. MacDonald of Glasgow Dental Hospital and School in a murder case (MacDonald and Laird, 1976).

1.12 THE PRESENT POSITION

The forensic dental expert is asked to pronounce on a variety of matters relating to the matching of dental features with a given individual. In the science of bite mark interpretation there is no absolute guide line of approach to the problems. Each case tends to be almost unique because of the different characteristics in the dentition and because of the varying circumstances and conditions which affect the making of the bite. It does not seem unreasonable to expect a technique to evolve for bite mark examination and interpretation which would prove beyond doubt that a particular bite mark on flesh or foodstuffs had been made by a particular individual. Polson and Gee (1973) state that "fortunately the majority of bite marks requiring identification occur in foodstuffs, and these, as Ström said, are a much easier task to handle". It is this author's view that the interpretation and analysis of bite marks in foodstuffs is more difficult than the investigation of flesh bites. At present it is not known how many characteristics of a dentition are reproduced in bitten foodstuffs. It is not known whether or not characteristic dental features are reproduced each time a bite is made. The effect on the reproduction of the characteristics by the same biter biting different materials has not been adequately shown. The flesh bite mark is made mainly by the incisal or occlusal surfaces of the teeth, but it has not been shown which part of the tooth is responsible for the marks found in various bitten foodstuffs.

1.13 AIM AND DESIGN OF THE PRESENT STUDY

With the foregoing in mind the aims of this study were to examine the possibility of developing a reliable technique for the investigation of bite marks in foodstuffs. In particular it was intended to look at the accuracy of the identification of tooth characteristics in such marks, and a number of questions were formulated.

1. What is the best method of recording bite marks in food and how should the bitten foods be preserved for study and Court presentation?
2. What types of tooth marks are found in bitten foodstuffs and how do these relate to the mechanism of biting?
3. Which features of teeth are recorded in bite marks in food and how accurately can the characteristic features of a dentition be identified in such marks?
4. How should comparison of bite marks in food and the teeth of the alleged biter be made and how can the results of such comparison be presented in Court?

The study is reported in six chapters (Chapters 2-7) which aim to answer the research questions progressively, advancing from first principles to a study of the accuracy of reproduction of characteristic tooth features found in experimental food bites. In Chapter 2 preservation methods of bitten materials for both study and possible Court production were examined. The recording of bite marks and the use of photography and duplication of perishable bitten foods employing silicone rubber for the purpose is described in Chapter 3. The findings of Chapters 2 and 3 were utilised for a series of preliminary experiments carried out by two persons repeatedly biting samples of cheese, chocolate and apples. From these experiments an evaluation of the accuracy of reproduction of characteristic tooth features was made and is reported in Chapter 4.

The techniques of analysis used in Chapter 4 were subjective and as only two persons had taken part, the bites and characteristic tooth features became familiar. Chapter 5 describes a much larger and more detailed range of experiments to study bites made by 30 dental student volunteers. This Chapter includes a double blind analysis of the bite marks and dentitions using plaster models, to which 20 additional sets of models were added from students who had not taken part in the experiments. A classification of bite marks on foodstuffs is presented in Chapter 6, which also includes an assessment of the difficulties in the interpretation of bite mark features in the foods studied.

In the final Chapter possible aids to matching bitten foodstuffs and alleged biters are examined, and a mock case is presented to illustrate how the author believes the forensic dental report should be prepared for Court presentation. The outlook for the future is also discussed.

Cases of Bitten Apples 1962-1974

Source	Number of cases	Convictions
Aberdeen	4	2
Chester	1	1
Dundee	1	0
Edinburgh	0	0
Glasgow	0	0
Inverness	3	1
Perth	1	0
Sheffield	0	0
Stirling	1	1
	11	5

TABLE 1.1: Numbers of bitten apples found in criminal cases at nine British population centres.

Fig. 1.1 A very distinctive bite on a buttered cracker biscuit. The scrape mark made by a faulty gold inlay is shown at 'A'.

Fig. 1.2 The Furness technique may be complicated when shadows mask the inked incisal edges.

FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

2 THE PRESERVATION OF BITTEN MATERIALS FOR STUDY

2.1 INTRODUCTION

As indicated in the available literature and police reports, the foodstuffs most commonly found bitten at scenes of crime are cheese, chocolate and apples. It was therefore decided to study bite marks in these three materials.

Fresh foodstuff is obviously subject to deterioration due to temperature change, bacterial action, evaporation and exposure to light. These changes have caused problems for other workers in this field and various observations and attempts to preserve bitten food specimens have been reported.

Nickolls (1963) divides bitten foods into two categories; namely those which dry out and those which do not. The former he states should be kept in a moist chamber the water of which should have a 'preserving agent' such as formalin in it, to stop mould formation. Other materials should be placed in a dry chamber and stored in a refrigerator.

The distortion of bitten foods is discussed by Cameron and Simms (1974) who assert that keeping a bitten apple under normal conditions of refrigeration does not preserve the original shape of the apple nor prevent brown oxidation change. Sölheim and Leidal (1974) in scanning electron microscope experiments were able to obtain reliable replicas of bitten cheese specimens two hours after bites had been made on them, but after three days distortion was of such a degree that the bitten samples were of no value. The same authors report that only two types of chocolate 'remained unchanged' after three days exposure to the environment at room temperature. Although not stated the reference to change presumably was that shown by the electron microscope technique, as the present author has not been able to demonstrate any naked eye visual changes in bitten chocolate exposed to room temperature in Scotland over a period of three days.

Such factors as dimensional permanence, the retention of tooth characteristics in bitten food and the need to preserve specimens for both experimental investigations and possible later Court production posed questions at the onset of this study. It was clearly desirable to discover what changes occur in bitten foods and to examine food preservation techniques in an effort to find a means of preserving bitten materials, which would not interfere with any investigation or analysis.

2.1.1 Chemical Preservation of Apples

The use of chemical methods for the preservation of bitten apples has been attempted and the results reported. Hobson (1970) from his observations on 14 cases found that bitten apples can be preserved in a solution of formaldehyde 5 ml, glacial acetic acid 5 ml and alcohol 90 ml.

An unsigned article in the Police Journal (1955) makes the observation that once the 'juices' of an apple have evaporated any impression of the teeth will become distorted. The writer suggests that plaster of paris replicas of bitten apples should be made in criminal cases, and thereafter the original apples should be immersed in a solution of 50 per cent sulphur dioxide in half a pint of water. Apparently "no swelling or shrinkage takes place".

Marshall, Potter and Harvey (1974) describe 16 methods of chemical preservation of apples. Among the materials studied were buffered formal saline, alcohol, citric acid, acidified copper sulphate, and fruit preserving tablets (Campden tablets) which contain 52 per cent sulphur dioxide. The condition of the bitten areas after preservation for three to four months was studied and it was noted whether or not there was any change in the dimensions within the marks and whether or not the bite mark characteristics could still be recognised. The best results were obtained using a solution of 5 per cent acetic acid and 40 per cent formaldehyde in a ratio of 5:1. With this solution no change in the apple core sizes could be demonstrated after 16 weeks, and the bite areas were described as good (Table 2.1).

In the cases where the results were unsatisfactory, softening, and swelling and rotting of the core occurred and the bite areas suffered from blackening and distortion of the bite mark characteristics. In some cases the characteristics of the bite could be recognised despite discolouring of the bitten food.

The author has successfully preserved three bitten apples in solutions of four Campden tablets in 200 ml of water for a period of three months. The apples showed slight overall swelling and the bitten areas became bleached. The characteristics of the bites however, remained perfectly obvious, until the end of the preserving time (Fig. 2.1).

2.2 THE SHORT TERM PRESERVATION OF BITTEN FOOD

Consideration of the preservation of bitten specimens involves two distinct elements. There is firstly the problem of preservation prior to the recording of bite marks by methods such as photography and the making of models. Secondly the possibility of long term preservation for possible Court presentation required to be examined. Senior members of the staff of the Glasgow College of Food Technology were consulted and they recommended several text books on food preservation (Davis, 1963; Desrosia, 1970; Matz, 1962). Unfortunately little of direct benefit to the study was derived from these sources. Much of the text book content on food preservation is devoted to long term stability of the ingredients rather than to the effect of exposure of the finished products to external influences. Refrigeration and exposure of foodstuffs to extremes of temperature are discussed and clearly refrigeration was a factor to be considered.

It was felt that if bitten food samples could be initially preserved for up to 24 hours and retained for 3 days that this period of time would be sufficient for the investigation and recording of details in a criminal case. For experimental purposes in the studies reported in this thesis it was calculated that no more than 4 hours would be required to carry out the necessary procedures, each time a series of bites was made.

Although chemical preservation might be suitable for apples, for short term preservation purposes it would be advantageous to find one method applicable to all three materials. The use of non-chemical methods such as wrapping the bitten foodstuffs in aluminium foil or placing them in plastic containers within a refrigerator were considered.

In order therefore to assess short term preservation methods, experiments were devised to answer two questions.

1. What dimensional change occurs in bitten foodstuffs not subjected to preservation methods over a period of 72 hours?
2. Can a short period of refrigeration delay the onset of deterioration such that bitten foodstuffs can be accurately studied and any tooth characteristics which are present be evaluated before dimensional or other change occurs?

2.2.1 Material and Methods

Five small sections of 'supermarket' cheese, five sections of chocolate and five apples were bitten and photographed with a scale included, at intervals of 30 minutes, 1 hour, 2 hours, 4 hours 24 hours and 72 hours. The specimens were kept in daylight at room temperature and no attempt was made to protect them from the immediate environment.

As it was intended to measure the effect on the bitten areas of their exposure to the atmosphere, two fine steel needles were place in each specimen. The needles were ordinary disposable cartridge syringe needles, guage 27, the hubs of which had been broken off (Fig. 2.2). These needles were inserted at random along the edge of the bitten areas exactly 25 mm apart. The position of the needles was varied such that they were not placed at any particular point on the bitten surfaces (Figs. 2.3 and 2.4). Photographs were taken at the intervals described, and the specimens were weighed at the same time intervals.

A second series of bites was made and the individual specimens were stored in plastic 'lunch type' boxes within a refrigerator. In order to counteract possible moisture loss and collapse of the skin along the bitten edges of the apples, small sections of damp cotton wool or Kleenex type tissue were placed along the edges of the apple skins (Fig. 2.5).

As before the specimens were weighed each time they were photographed. The resulting prints were measured to show any change in distance between the needles in order to demonstrate dimensional change in the bites.

An unbitten specimen of food was included in each series and this was used as a control to evaluate the effect of the bite on the foodstuff.

The results were noted over a period of 24 hours and every bitten food was retained for 3 days when final weighing and measurements were carried out.

2.2.2 Results

As might have been expected the bitten specimens of cheese, apples and chocolate each reacted to the environment in a different way.

In the case of the non refrigerated cheese samples slight dimensional change was found in three bites after 24 hours. The measured distance between the needles was reduced by 1 mm in each case (Table 2.2) but in the remaining two bites no alteration could be demonstrated. Every bite showed change after 72 hours and in one specimen (Fig. 2.6) there was a surprising reduction of almost 3 mm.

These unwrapped non refrigerated cheese specimens produced an oily film on their surfaces within an hour of being exposed to the atmosphere and as Table 2.3 shows after 24 hours a weight loss of about 4 per cent was found. By the third day the oily film had largely disappeared and slight cracking developed in some sections of cheese as they dried out. As can be seen in Table 2.4 the weight loss on average was just over 9 per cent. The characteristics of the bites remained evident throughout the 24 hour period and despite the shrinkage and weight changes the bite marks could still be accurately analysed at the end of the experiment (Fig. 2.7).

The refrigerated cheese bites showed a significantly less tendency to both dimensional change and weight loss. No dimensional change was measureable up to 24 hours and in the two cases in which shrinkage did eventually occur this was only 1 mm (Table 2.2). Refrigeration appeared to reduce oil loss from cheese and no cracking developed. The weight loss after 24 hours was 1.6 per cent (Table 2.3) and by the third day this loss was still only an average 3.4 per cent (Table 2.5). The data in this table and in Table 2.4 was interesting in that there did not appear to be any correlation between the commencing weights of the specimens and the ultimate weight loss. The largest refrigerated section of cheese (42.37 grammes) lost only 3.68 per cent of its weight while a reduction of 5.2 per cent was found in a specimen more than 10 grammes less in weight. The characteristics of the bite marks remained evident in the refrigerated samples for the 72 hour period.

The control cheese samples behaved in the same manner as the bitten sections, in that weight reduction was found more so in the room temperature experiments then in the refrigerated cheese.

Non refrigerated apple bites underwent change in outline form after only two hours at room temperature, and because of drying out along the skin edge two bitten areas showed a folding inwards of the skin. Despite this the features of the bite marks could still be recognised (Fig. 2.8). No change in the distance between the needles was evident in any specimen up to 4 hours, but by 24 hours in three apples a reduction of 1 mm was demonstrated, (Table 2.6) and every bite showed shrinkage after 24 hours.

Weight loss occurred steadily in every specimen and an average loss of 6.8 per cent could be shown after 24 hours (Table 2.7). This had almost doubled by the third day and Table 2.8 illustrates the gradual weight reduction in the five bitten specimens. The bite mark characteristics could not be relied upon by the end of day three but in all but one case successful analysis of the features was possible for 24 hours.

As in the case of the cheese bites the refrigerated apples did not show measureable shrinkage during the first 4 hours and only one apple with a 1 mm reduction was found after 24 hours. Reference to Table 2.6 shows how little change was found after 72 hours. In no case was a reduction of more than 1 mm encountered and two specimens showed no change at all. Weight loss was also reduced and a maximum reduction of 5.74 per cent is shown in Table 2.9.

Slight browning of the apple flesh occurred rapidly in the room temperature specimens but this did not alter the ability to recognise the bite mark features. Refrigeration did not prevent the browning effect as pointed out by Cameron and Simms (1974) but it was found that the discolouration took place much more slowly and was much less severe.

The control unbitten apple exhibited a very slight weight loss and a just visible wrinkling of the skin.

Bitten chocolate did not show any measureable dimensional change at any point during the 72 hours either in or out of the refrigerator and the bite mark features did not alter. A very slight weight loss was found after 24 hours at room temperature (Table 2.10).

The refrigerated chocolate attracted condensation on its surface (Fig. 2.9) and this caused an apparent weight gain in some samples Table (2.11). One chocolate specimen was kept in the refrigerator for 6 months and as Fig. 2.10 shows the bite mark characteristics were still obvious after this prolonged storage time.

2.2.3 Aluminium Foil

This material did not prove to be satisfactory for the purposes of these experiments. It was found that damage occurred on some of the bitten edges during the wrapping and unwrapping process, and no further consideration was given to it's use.

2.3 DISCUSSION

Within the scope of these experiments on food preservation techniques it has been shown that short periods of refrigeration are not detrimental to the exposed or bitten areas of cheese, apples and chocolate. Apart from one refrigerated apple the bite mark characteristics could be recognised in each foodstuff up to 72 hours despite some linear change and weight loss. In apple bites it was found helpful to keep the skin edge moist with dampened cotton wool.

Every non refrigerated specimen retained bite characteristics for up to 4 hours and in most cases for 24 hours, which in a criminal case would still allow the evidence to be usefully anâlysed.

The changes in weight which occurred did not appear to be related to the fact that the specimens had been bitten, but simply that they had been exposed to the atmosphere. This was particularly so in cheese samples where the unbitten control sample reacted in the same fashion as the bitten cheese. The size of the apple bites appeared to influence the amount of evaporation from the surface and the largest weight reduction was found in the specimen with the largest piece removed from it, although this was not the biggest apple used.

The fact that shrinkage was found in most specimens of bitten cheese and apples suggests that the technique of attempting to physically fit plaster casts of a suspect's dentition into bites in these materials would not always be accurate. If such a comparison was contemplated using replicas or photographic prints the experiments have shown that it would be necessary to carry out the photography or construction of the replicas as soon as possible, and preferably within 4 hours, unless the bites had been kept in a refrigerator. Bitten apples could not be accurately analysed after 3 days exposure to the atmosphere, but chocolate bites retained their characteristics well in excess of this period.

The experiments have indicated that bitten foodstuffs can be successfully preserved for short periods without loss of bite mark detail but should be analysed as soon as possible. The fact that change does occur adds support to the concept that the analysis of the features within the bite mark and comparison with the details of a dentition is to be preferred to attempts to fit plaster models of a suspect's teeth into bitten materials.

	Method of Preservation	General Condition of fruit (after fixation)	Colour	Core Size	Duration	Bite-Area
1.	10% Buffered Formal Saline	Good	Loss/Brown	Unchanged	19 weeks	Good
2.	Judah I	Good	Loss/Brown	Unchanged	19 weeks	Swollen
3.	Formaldehyde/ Alcohol/ Glacial Acetic Acid (Stoddart) (equal parts)	Good/ Gross	Slight Loss	Increase	15 weeks	Swollen
4.	Formaldehyde/ 5 ml: Glacial Acetic Acid 5 ml: Alcohol 90 ml	Good/ Gross Swelling	Slight/ Brown	Increase	15 weeks	Swollen
5.	Formaldehyde/ 1 part 3% Citric Acid 3 parts	Poor/ Softening	Unchanged	Unchanged	14 weeks	Good
6.	10% Formalin Glacial Acetic Acid Alcohol	Good/ Slight Swelling	Slight/ Brown	Slight Increase	11 weeks	Fair
7.	Kahle's Fluid (= 4) (Vacuate Dessicator	Good/ Slight Swelling	Brown	Unchanged	9 weeks	Swollen

	Method of Preservation	General Condition of fruit (after fixation)	Colour	Core Size	Duration	Bite-Area
8.	Acidified Copper Sulphate	Very Poor	Loss	Doubtful (Gross Shrinkage of Skin)	12 weeks	-
9.	5% Acetic Acid 5 parts Formaldehyde 1 part	Good/ Very Slight Softening	Slight Loss	Unchanged	16 weeks	Good
10.	5% Acetic Acid	Very Poor	Brown	-	1 week	-
11.	Citric Acid/ Campden Store 4°C in Minigrip	Very Good	Unchanged	Increase	9 weeks	Loss
12.	Citric Acid/ Campden Store 4°C covered cling film	Good	Unchanged	Increase	9 weeks	Loss
13.	Formaldehyde/ Sod Hydro Sulph (4°C)	Very Poor	Loss	Gross Shrinkage	12 weeks	Loss
14.	Acetic Acid/ Formaldehyde + Campden	Very Poor	Loss	Shrinkage	12 weeks	Loss

	Method of Preservation	General Condition of fruit (after fixation)	Colour	Core Size	Duration	Bite-Area
15.	Snap-Freeze $-70^{\circ}C$ (Store $-20^{\circ}C$)	Very Good	Unchanged	Unchanged	6 weeks	Loss
16.	Gradual Freezing $-20^{\circ}C$	Good	Unchanged	Change: External - Increase Internal - Decrease	6 weeks	Loss

TABLE 2.1: The effect of chemical preservation on 16 bitten apples over a period of from 1 week to 19 weeks.

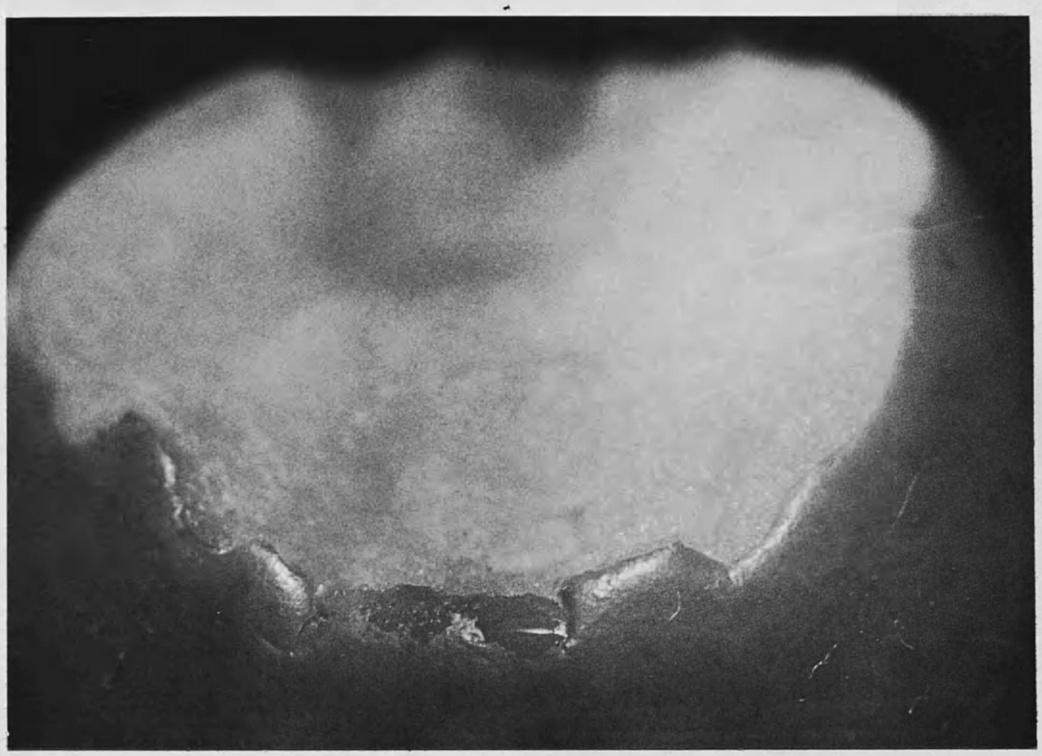


Fig. 2.1 Apple preserved in Campden solution for 3 months.

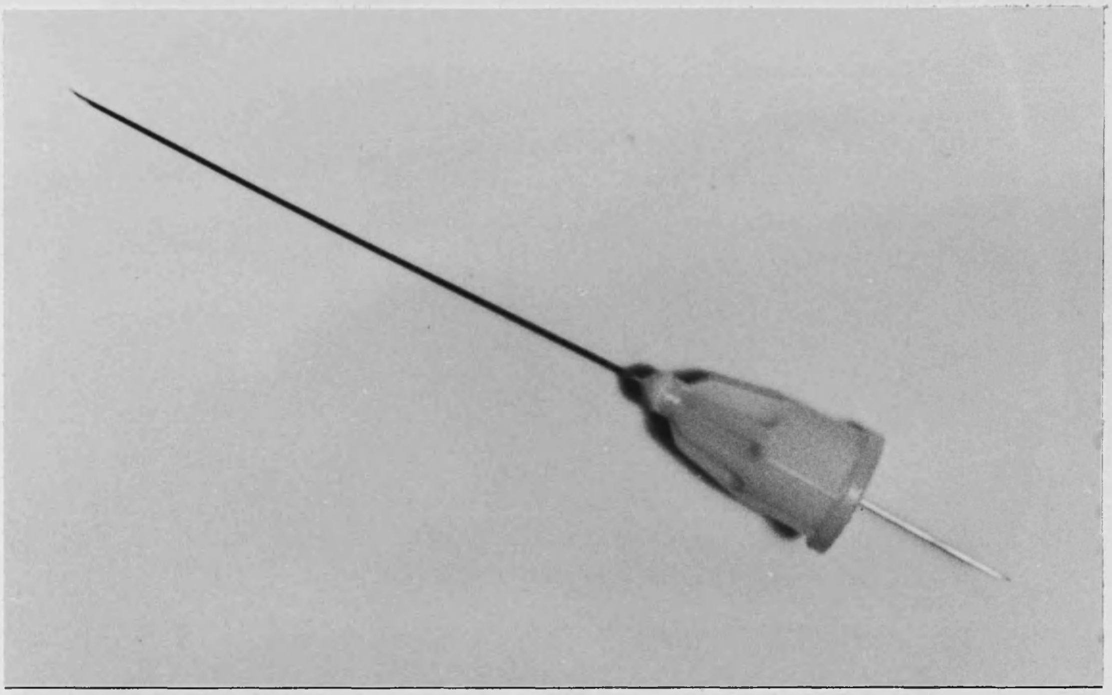


Fig. 2.2 Disposable cartridge syringe needle. The hubs were removed before being inserted into the bitten foods.

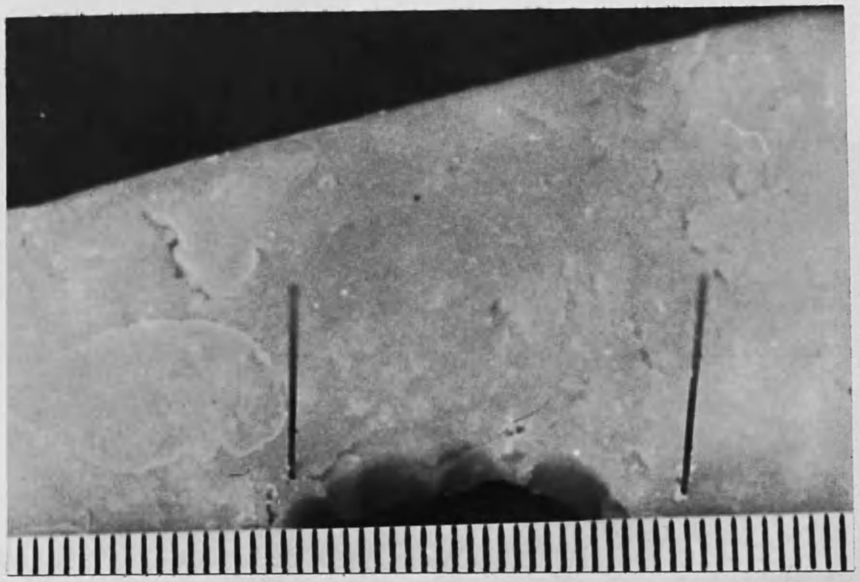


Fig. 2.3 Needles set 25 mm apart in bitten cheese.

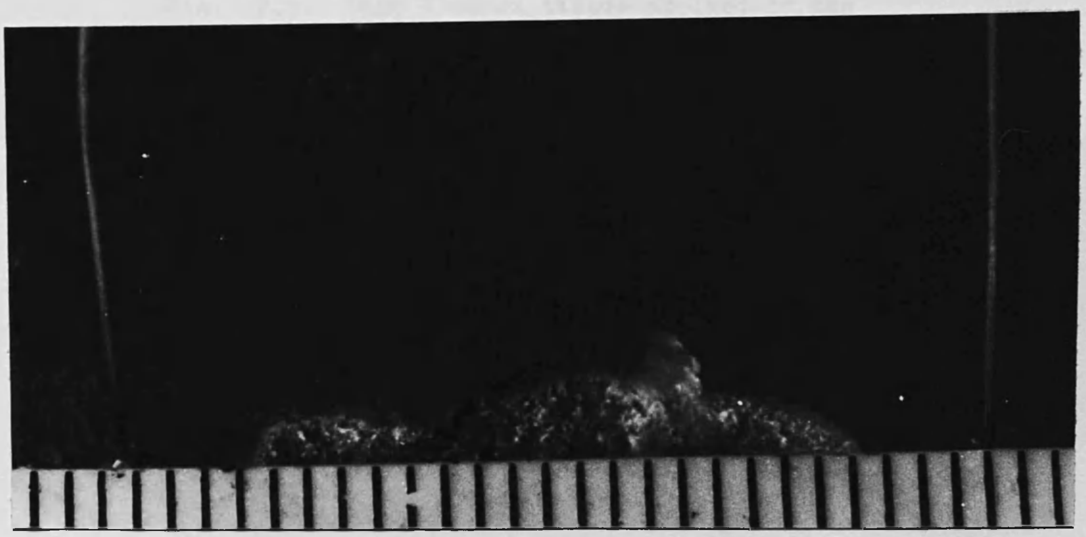


Fig. 2.4 Needles set 25 mm apart in bitten chocolate.

Fig. 2.5 Damp Kleenex tissue applied to the skin edge in a bitten apple.

CHEESE BITES (NON-REFRIGERATED)

Time in Hours	1	2	3	4	5
24	24 mm	24 mm	24 mm	25 mm	25 mm
72	23 mm	23 mm	22 mm	23 mm	23 mm

CHEESE BITES (REFRIGERATED)

Time in Hours	1	2	3	4	5
72	25 mm	24 mm	25 mm	25 mm	24 mm

TABLE 2.2: The measured distances between needles placed 25 mm apart, in cheese bites. No change could be demonstrated in refrigerated samples up to 24 hours.

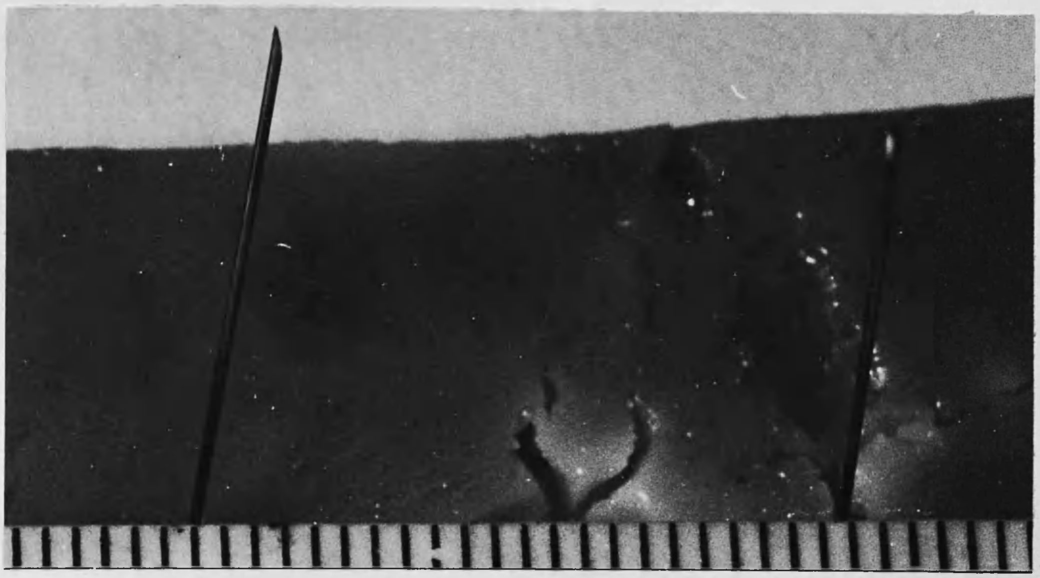


Fig. 2.6 Needles in a cheese bite after 72 hours. The measured distance is only 22 mm.

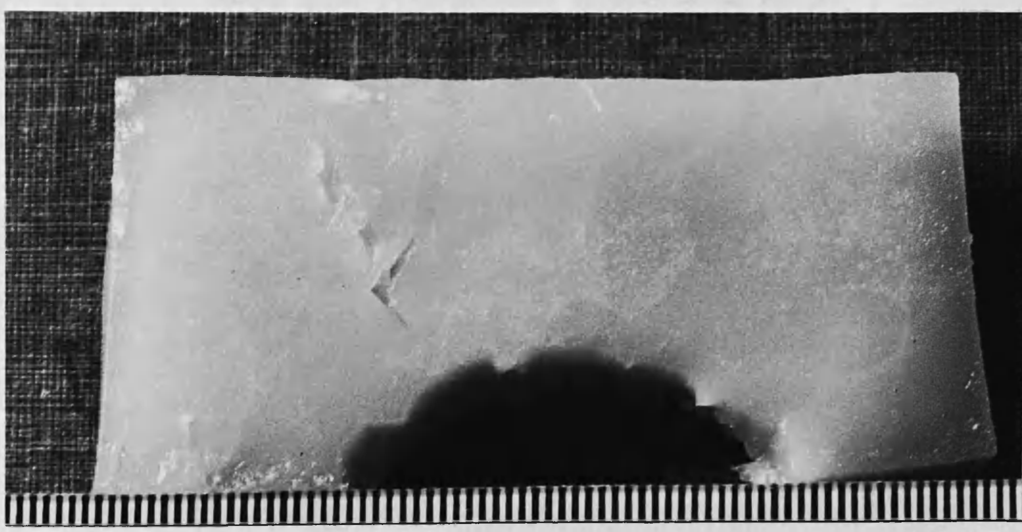


Fig. 2.7 A cheese bite after 72 hours. The characteristics can be recognised despite shrinkage and weight loss.

	Control	1	2	3	4	5	Average
I	3.7	4.2	5.0	4.2	4.8	4.5	4.4

	Control	1	2	3	4	5	Average
II	1.7	1.2	0.4	1.2	3.3	2.1	1.6

TABLE 2.3: Percentage weight loss of 5 bitten cheese specimens after 24 hours

I. Non-refrigerated

II. Refrigerated

WEIGHT IN GRAMMES

Time in Hours	Control	1	2	3	4	5	Average
0	32.73	28.54	24.12	36.51	24.80	25.33	27.86
.5	32.73	28.51	24.10	36.46	24.78	25.31	27.83
1	32.72	28.36	23.96	36.28	24.63	25.14	28.67
2	32.69	28.23	23.84	36.14	24.52	25.02	27.55
4	32.66	27.82	23.44	35.59	24.12	24.73	27.14
24	31.59	27.33	22.90	34.99	23.59	24.17	26.59
72	29.98	26.40	22.11	32.18	22.56	23.22	25.27
Loss %	8.40	7.49	8.33	11.85	9.03	8.33	9.06

TABLE 2.4: Weights of five samples of bitten cheese after storage at room temperature.

WEIGHT IN GRAMMES

Time in Hours	Control	1	2	3	4	5	Average
0	36.66	42.37	35.04	28.38	31.66	28.45	33.18
.5	36.65	42.36	35.04	28.37	31.66	28.45	33.17
1	36.63	42.35	35.03	28.36	32.63	28.40	33.15
2	36.60	42.35	35.01	28.33	31.60	28.40	33.13
4	36.56	42.33	35.01	28.31	30.89	28.10	32.92
24	36.01	41.86	34.91	28.28	30.61	27.84	32.70
72	35.26	40.81	34.29	28.04	30.01	37.07	32.04
Loss %	3.81	3.68	2.14	1.19	5.20	4.85	3.41

TABLE 2.5: Weights of five samples of bitten cheese after refrigeration.

APPLE BITES (NON-REFRIGERATED)

Time in Hours	1	2	3	4	5
24	25 mm	24 mm	25 mm	24 mm	24 mm
72	23 mm	23 mm	23 mm	22 mm	23 mm

APPLE BITES (REFRIGERATED)

Time in Hours	1	2	3	4	5
24	25 mm	25 mm	24 mm	25 mm	25 mm
72	25 mm	24 mm	24 mm	24 mm	25 mm

TABLE 2.6: Measured distances in bitten apples of needles placed 25 mm apart.

	1	2	3	4	5	Average
I	5.9	8.1	6.4	7.7	5.8	6.8

	1	2	3	4	5	Average
II	3.9	2.2	3.4	2.7	3.8	3.2

TABLE 2.7: Percentage weight loss of bitten apples after 24 hours

I. Non-refrigerated

II. Refrigerated

The weight loss in the unbitten control specimen was not significant

WEIGHT IN GRAMMES

Time in Hours	Control	1	2	3	4	5	Average
0	112.13	100.12	106.67	104	97.30	110.61	103.74
.5	112.13	99.86	106.36	103.77	96.99	110.12	103.42
1	112.13	99.68	106.09	103.46	96.60	109.72	103.11
2	112.13	97.70	103.43	101.27	94.49	108.56	101.09
4	112.13	97.48	103.09	100.88	94.10	107.71	100.65
24	112.11	94.16	97.98	97.27	89.77	104.11	96.82
72	112.03	82.56	96.34	96.33	85.40	100.94	92.31
Loss %	.09	17.53	9.68	7.67	12.23	8.74	11.17

TABLE 2.8: Weights of five bitten apples stored at room temperature.

WEIGHT IN GRAMMES

Time in Hours	Control	1	2	3	4	5	Average
0	95.08	108.41	98.66	101.04	105.64	117.50	106.23
.5	95.09	108.32	98.61	100.97	105.63	117.40	106.18
1	95.09	108.24	98.53	100.86	105.44	117.36	106.08
2	95.08	107.76	98.02	100.30	104.99	116.95	105.60
4	95.08	106.09	97.31	99.75	104.46	116.38	104.79
24	95.08	104.10	96.45	97.64	102.82	113.02	102.80
72	95.08	102.51	93.80	96.22	99.73	110.75	100.60
Loss %		5.40	4.92	4.77	5.50	5.74	5.26

TABLE 2.9: Weights of five refrigerated bitten apples

WEIGHT IN GRAMMES

Time in Hours	Control	1	2	3	4	5	Average
0	31.16	23.42	23.50	21.57	22.79	19.05	22.06
.5	31.16	23.40	23.47	21.57	22.79	19.04	22.05
1	31.16	23.38	23.47	21.55	22.76	19.02	22.03
2	31.16	23.38	23.46	21.53	22.74	19.01	22.02
4	31.16	23.37	23.46	20.87	22.74	19.01	21.89
24	31.15	23.35	23.44	20.84	22.62	18.88	21.82
72	31.10	23.29	23.20	20.80	22.39	18.52	21.64

TABLE 2.10: Weights of five sections of bitten chocolate stored at room temperature.

WEIGHT IN GRAMMES

Time in Hours	Control	1	2	3	4	5	Average
0	32.31	22.13	24.64	21.07	18.81	20.38	21.40
.5	32.31	22.13	24.64	21.07	18.81	20.38	21.40
1	32.32	22.13	24.64	21.07	18.81	20.40	21.41
2	32.32	22.14	24.62	21.07	18.81	20.41	21.41
4	32.32	22.13	24.62	21.07	18.81	20.39	21.40
24	32.31	22.13	24.61	21.05	18.81	20.37	21.39
72	32.32	22.12	24.61	21.04	18.79	20.37	21.38

TABLE 2.11: Weights of five sections of refrigerated bitten chocolate.

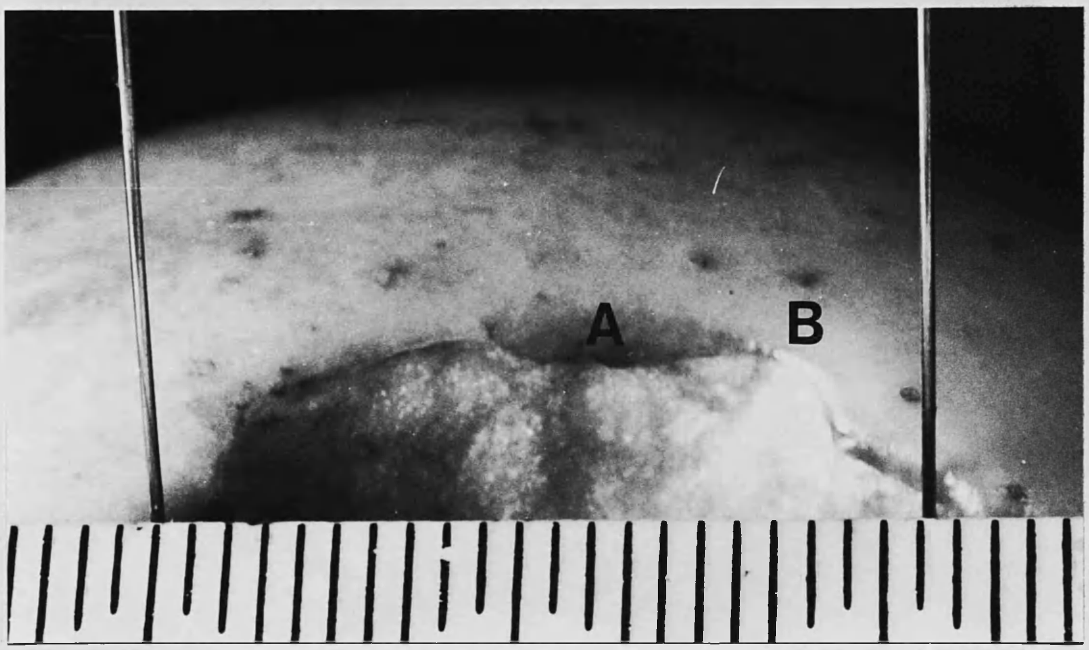


Fig. 2.8 Skin collapse in a bitten apple. Some indication of the tooth features remains. 1/ appears to be mildly rotated in the mesio-lingual direction (A). 2/ may be rotated mesio labially (B).

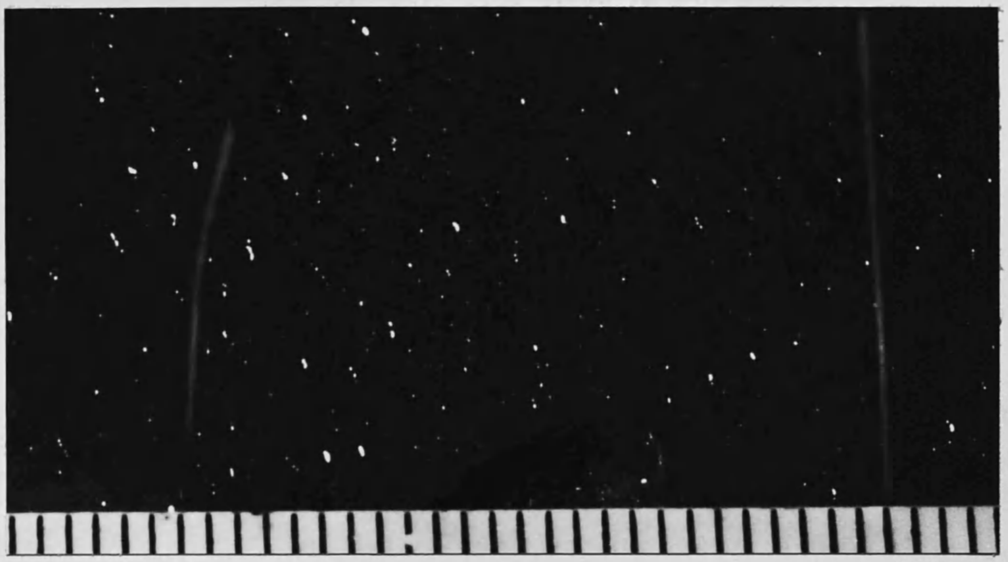


Fig. 2.9 Condensation on refrigerated chocolate which caused apparent weight gain.

Fig. 2.10 Refrigerated bitten chocolate after 6 months. The characteristics of the bite are still obvious.

FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

3 THE RECORDING OF BITTEN MATERIALS FOR STUDY AND COURT USE

3.1 INTRODUCTION

Because of the nature of the materials being studied it has been shown that food bite specimens eventually lose the characteristics of the bite marks such that they become useless for both study and possible Court production at a later date. Not only is it necessary to compare the characteristic tooth features in a bite with a suspect's dentition, it is necessary to accurately record characteristics until the time when the police can produce a suspect. In addition records will be required in Court at some indeterminate time in the future.

While it is possible to retain a refrigerated bitten section of chocolate for a lengthy period in the laboratory, the handling of the evidence by Court officials, the jury and others would quickly show such an arrangement to be quite unsatisfactory and open to many criticisms. A bitten apple could perhaps be chemically preserved in a container, but the demonstration of the tooth features to the Court would be difficult if not impossible.

In order to overcome these problems it was necessary to find a method of permanently recording the details and characteristics of bite marks in foodstuffs. The use of photography seemed obvious for the recording of the dental data, but it was felt that there could also be some advantage for both experiment and Court use if a stable replica of a bitten specimen could be exhibited, which would show all the characteristic tooth features. Accordingly it was decided to examine both photographic techniques and methods of producing replicas of bitten foodstuffs.

3.2 THE USE OF PHOTOGRAPHY

It is normal Court practice to use photographs to provide a permanent record of evidence. The reasons for this are two fold. Firstly, exhibits which require laboratory tests to be carried out upon them can be photographed before any alteration in appearance can occur due to testing techniques, and in the present studies deterioration, because of the unstable nature of the specimens. Secondly, by the use of a good photographic technique details may be revealed which are not readily appreciated by the naked eye. Not only are the photographed exhibits of value to the investigator, they are also essential for the eventual Court production.

In the criminal cases seen by the author, bitten foodstuffs were usually photographed in colour by the police, with the resulting delay in obtaining the finished colour prints, during which time the specimens had deteriorated to the point of being useless. The light source for colour photographs was 'ring' flash in all cases. The photographs often lacked detail and were seldom taken life size, nor was a scale always incorporated (Fig. 3.1).

If a photographic technique is to be used, the incorporation of a scale within the photograph is essential in order that accurate comparison and perhaps measurements in the bite mark and ultimate models can be made, although Korkhaus (1955) believes that it is impossible to make accurate measurements on bite marks. The scale should be placed above or below the bite mark in the 'same plane' as the bite mark, with the film plane parallel with both (Butler, 1976).

Experiments of the nature proposed were clearly one of, and trial and the correction of errors was necessary. The development and inspection of the photographic results had to be rapid in order that if repeat photographs with altered lighting and exposures were required, they could be made during the period of stability of the specimens.

While modern 35 mm cameras such as the single lens reflex types with through the lens light metering and close up lenses can be used to obtain high quality photographic results, there are never-the-less some disadvantages. Colour film is usually processed in a photographic laboratory with some delay before the finished prints are obtained. If flash lighting is employed the effect is not known until the film has been processed, by which time the bitten food may have become distorted. Similar difficulties arise if black and white film is used.

The essentials for both the experiments and criminal cases were simplicity, variable lighting, and quickly obtained quality results. Accordingly it was decided to study two types of equipment which would satisfy these requirements.

3.3 MATERIAL AND METHODS

3.3.1 Polaroid Photography

Tests were made with an SX - 70 Polaroid land camera and the complete available accessory range, and it seemed that this apparatus would be ideal for obtaining quality coloured prints in a matter of a few minutes. Without the use of an accessory lens, half life size prints were obtained at a distance of $10\frac{1}{2}$ inches. Small subjects such as the bite area on bitten foods were photographed life size using the accessory lens from a distance of 5 inches.

The lighting of the subjects was either by daylight or from the flash bar designed for the apparatus. Difficulties were experienced because of the problem of shadows masking some of the details within the bite marks.

The photographs were taken immediately after bites had been made and refrigeration of the bitten specimens was not found to be necessary as the whole process was carried out rapidly.

3.3.2 Large Format Apparatus

Having decided against using a 35 mm camera for the reasons already stated it seemed that a large format plate camera could overcome the problems and a number of experimental photographs were therefore carried out. The principal advantages of the plate camera were that each individual photograph could be set up and the lighting arranged visually, before any exposure was made, and the plates could be developed more or less instantly.

Equipment

A Linhof Karden 4" x 5" plate camera with a 150 mm F5.6 symnar S lens and copal shutter was employed, with two photax photoflood lights, and Kodak process sheet film, No. 4147. This film is mostly used for making line negatives from black and white sketches, drawings, maps etc.

A table was constructed on which specimens could be placed, and which allowed the camera mounted on a tripod to be placed above them (Fig. 3.2).

Lighting

The risks of heat damage and distortion using photographic lamps have been noted by Svensson and Wendel (1955) especially in relation to bitten foodstuffs. Attempting to set up photographs the author found that the heat from the photoflood lamps caused melting of chocolate specimens and rapid browning and skin edge collapse in apples. Cheese specimens were also affected, in that the previously noted oily exudate quickly appeared on the surface. An ordinary 60 watt lamp was therefore used and the photoflood lamps were only introduced for final checking and exposure of the plates.

One lamp was placed in front and above the subject, and the second lamp was usually placed low down almost on a level with it, but just above and to one side, such that the bitten surfaces were thrown into relief. Gustafson (1966) found details to be best observed using oblique lighting but he did not indicate what his light source was. In the case of cheese and chocolate bites a number of photographs were taken with the specimens placed on an x-ray viewer thus providing light from beneath.

3.4 RESULTS

3.4.1 The Polaroid Apparatus

The coloured life size polaroid prints varied considerably in detail (Figs. 3.3 and 3.4) and this was apparently mostly due to lighting problems, but the relatively small size lens did not provide definition or depth of field. With daylight exposures the colour balance was good, but the prints lack fine detail. The flash light source could only be directed in the same plane as the lens because the flash pack clips into the camera just above the lens and is not adjustable and this caused shadow effects. In order to overcome the shadows a great deal of expensive experimentation using reflectors placed around the specimens would have been necessary and this was not felt to be justified in view of the quality of the detail shown in the prints, and the high cost of each print.

Although great care was used in the setting up of the apparatus it was extremely difficult to measure the suggested focussing distance of 5 inches from lens to subject. The resulting prints were seldom exactly 1:1 as measured against a mm scale and where the measurement was exact this appeared to be due to chance.

3.4.2 Large Format Apparatus

Initial experimental photographs were poor. Problems were again experienced with shadows, and in the case of apple bites the curvature of the apples was not always apparent. The early photographs were taken with the specimens placed on a white card as a background, but this was unsatisfactory. The backgrounds were varied and cheese specimens were placed on a black non reflecting matt surface, apples on a green matt surface and chocolate on a white background. By varying the position of the lower photographic lamp it was possible to eliminate the shadows and bring the characteristics of the bite marks into relief. While the introduction of light from the x-ray viewer placed underneath the specimens was advantageous in helping to high light the bitten areas, even the gentle heat caused slight melting or distortion of the specimens and this was not repeated.

The fact that an exposed plate could be developed immediately was of considerable advantage, allowing repeat photographs to be exposed when this was found to be necessary. With 30 minutes washing time and a similar drying period for an exposed plate, contact prints could be obtained within one hour. This was well within the times which had been previously noted before change could be expected in bitten specimens not refrigerated and exposed to room temperature.

3.5 REPLICAS OF BITTEN FOODS

It has been stated (Gustafson, 1966) that with the ever present risk of distortion of any material, that all bite marks should be recorded as soon as possible by means of photographs or impressions. Methods of 'lifting' bite marks from flesh have been described. The author is not convinced of the need for replicas of flesh bite marks although Stoddart (1972) has suggested that it may be necessary for the purpose of legal identification to provide a replica of a bitten specimen. Furuhata and Yamamoto (1967) state that it is advisable to take impressions of bites with a 'precise' rubber base impression material but do not offer reasons why this should be done.

A method of recording bite marks using free flowing syringe type silicone is described by Luntz (1973) who also says that models and photographs of the suspects teeth are compared to photographs of the bite mark and to the silicone impression, if indentations were present in the bite mark. In the opinion of Harvey (1976) the only value of an impression of a bite mark is as a museum specimen, because tissues begin to swell immediately after a flesh bite and may continue to do so for a period of 5 days, part of which time the bite will be covered by the setting impression material. In the food bite, compression, or other distortion may occur during the making of a replica, which would render the replica less than totally accurate.

Despite the foregoing there is some justification for the idea of taking impressions of food bites. If a replica of the bitten material can be made this could be of value when comparing the teeth of a suspect with the bite mark. It may be possible on some occasions to place or fit the plaster model of an accused person into the bite mark or a replica of it or to demonstrate points of coincidence. In addition a stable replica of a bitten foodstuff which shows all the characteristic tooth features could be of help in the Court's understanding of the analysis of the bite mark, or for the purposes of the experiments proposed.

As an aid to the studies it was decided to examine methods of making food bite replicas.

3.6 MATERIALS FOR IMPRESSION TAKING

Various authors have discussed materials for the taking of impressions of flesh bite marks. Each writer examined the most suitable materials available at the time of writing. Stoddart (1973), Jarvie (1973) and Jarvie (1976) have described techniques for the duplication of bitten foodstuffs using a silicone rubber (Silcoset) for the purpose. Experiments were therefore carried out using this material to obtain models of bitten foodstuffs from which the dental details could be examined and analysed.

3.7 MATERIALS AND METHODS

3.7.1 Silcoset

Silcoset is a silicone rubber (Manufactured by I.C.I. Limited) which cures at room temperature. It is used in a wide variety of industrial processes where high fidelity moulds are required with the maximum reproduction of surface details. These rubbers contain no solvents and have a linear shrinkage of 0.2 per cent to 0.5 per cent.

In the form used in these experiments 'Silcoset 105' is a pourable paste to which drops of a hardening agent are added. This allows a setting time of around 20 minutes. Because of the pourable nature of Silcoset no pressure is necessary which avoids the possibility of distortion to the bitten food surface. The mix is spatulated with a wooden spatula, avoiding the trapping of air bubbles within it.

A white perspex box was constructed for the making of models, and this was held together by small panel pins which fitted into previously drilled holes, in order that the box could be taken apart after the material had set (Fig. 3.5).

The bitten samples were placed inside the box with the bitten surfaces uppermost and the prepared Silcoset poured in, until the specimens were completely covered. When hardening was complete the box was dismantled and the cube of rubber removed with the bitten substance inside. By cutting carefully across the mould away from the bite surfaces, the rubber was opened up, the food was taken out and the resulting space filled with dental stone plaster, which was removed from the Silcoset mould when setting had taken place (Fig. 3.6).

3.7.2 Results

Replicas of bitten apples, chocolate and cheese were constructed using the methods described (Figs. 3.7 and 3.8). No attempt was made to check the mathematical accuracy of the replicas, but in every case the known tooth characteristics were compared and found to have been faithfully reproduced in the stone models.

The models have the disadvantage that they are not coloured and are not life like. Observers could not always identify models of cheese or chocolate. Although the Silcoset flows freely tiny particles of foodstuffs particularly in cheese bites did break off and this could make the reproduction of some features inaccurate.

A valuable use of Silcoset was discovered. That part of the rubber which had been in contact with the bitten surfaces gave a labial view of the tooth surfaces, such that confirmation of their relationship to each other could be established (Fig. 3.9). This situation is analagous to that of photographic prints and negatives; while all the detail of a photograph may be present in the negative it is much easier to interpret the print.

3.8 METAL SPRAYING OF BITTEN FOODS

A technique for producing metal surfaced dyes in crown and bridge techniques has been described by Friend and Barrat (1965), and this can be used to make metal surfaced replicas of bitten foods. Holt (personal communication 1975) states that spraying cheese and chocolate and even cloth are quite satisfactory.

A 'Swift' spray gun and Cerrocast metal which is an alloy of bimuth and tin is used to spray the bitten areas on foodstuffs, which are then backed with cold cure acrylic resin. A base can be added in dental stone plaster. This rather bulky apparatus was not given further consideration as the Silcoset method was adequate for the purposes which were proposed.

3.9 DISCUSSION

Because the materials being studied deteriorate at varying rates with loss of bite mark outline form it is necessary to record the details exhibited within the bite marks for further study and Court use.

Early workers in this field have been handicapped by the lack of suitable materials. Modern fast films and developing and printing techniques, including the Polaroid type of camera have simplified the obtaining of repeat photographs if these prove to be necessary. While the Polaroid photograph may lack fine detail it could be of value at the locus of a crime as a complement to other photographic techniques, especially if a delay is likely to occur in the examination of photographic results.

Food bite photographs were found to be satisfactory for experiment purposes if taken with a large format camera. This apparatus is particularly valuable because the single exposure can be developed immediately and contact prints can be obtained rapidly. As even apples could be relied upon to maintain the characteristics of the dentition for four hours at room temperature repeat photographs can be taken before deterioration occurs.

Long term preservation of bitten foodstuffs is not necessary because all the detail can be recorded photographically, but replicas can be obtained using the Silcoset method.

The argument against making replicas of bites is the searching cross examination which could result in Court on the subject of the physical properties of the materials used in the manufacture of the models, also the risk of artefacts appearing in the models exists. A bitten foodstuff is distorted or destroyed in the process of making a replica, and there is no second chance to overcome flaws in the ultimate model.

The point in time when the impression of the bitten food is made may also be critical. It has been shown that while the characteristics of the bite may still be recogniseable in some foods after 3 days, there is often a weight reduction, and linear shrinkage has been demonstrated. While a replica may exhibit the characteristics of a bite the shrinkage might make it impossible to fit a model of the dentition alleged to have made the bite into it.

The true value of Silcoset is the demonstration of the labial view of the teeth and their relationship to each other.

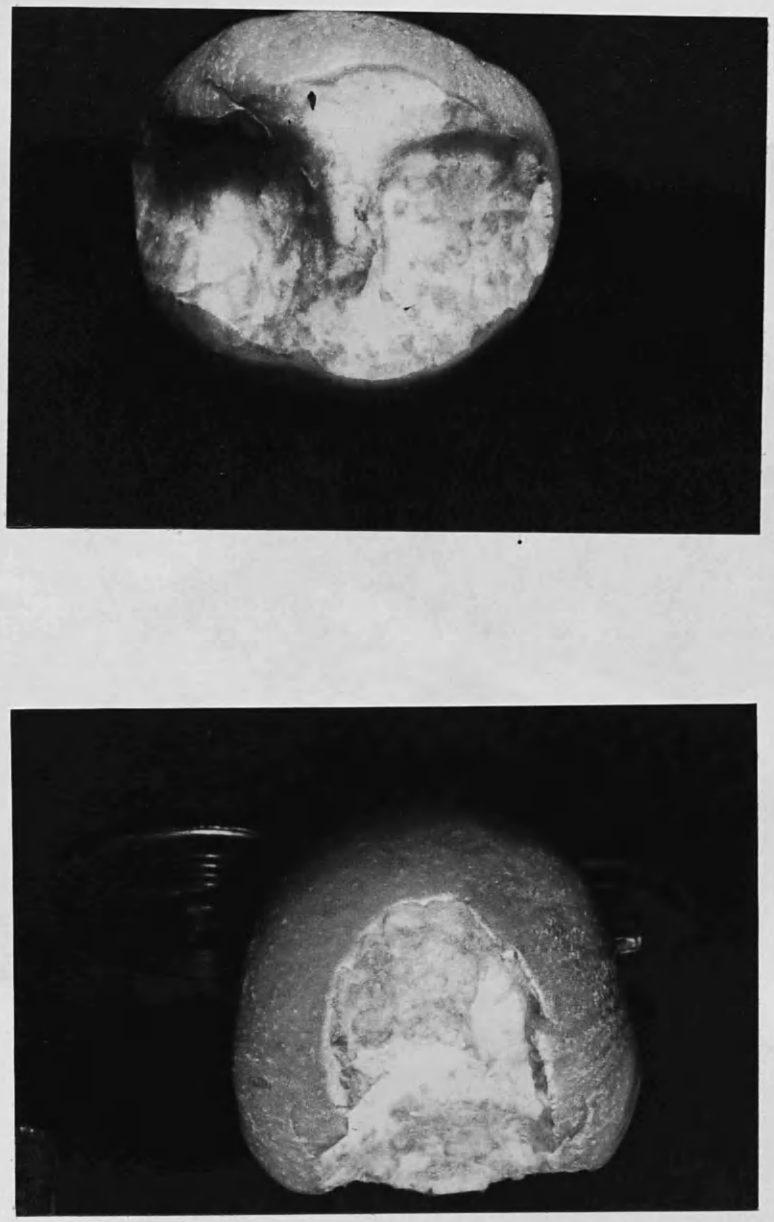


Fig. 3.1 A bitten apple found at a burglary. The police photographer has not included a scale and the bite mark detail is indistinct.

Fig. 3.2 The large format apparatus used for much of the experimental work.

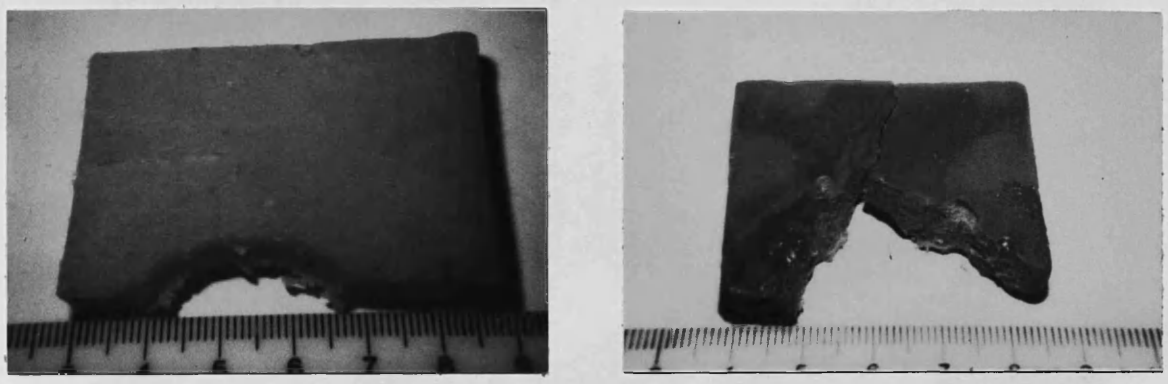


Fig. 3.3 Polaroid prints of cheese and chocolate bites.

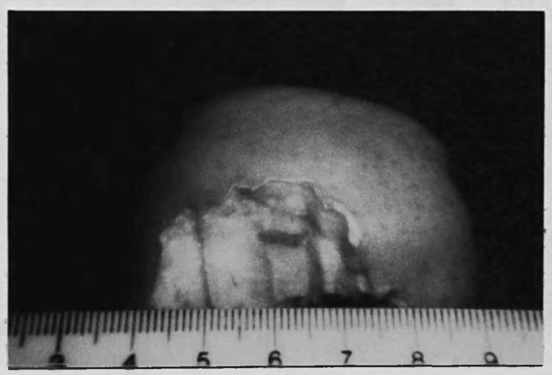


Fig. 3.4 Polaroid print of an apple bite.
The detail is acceptable.

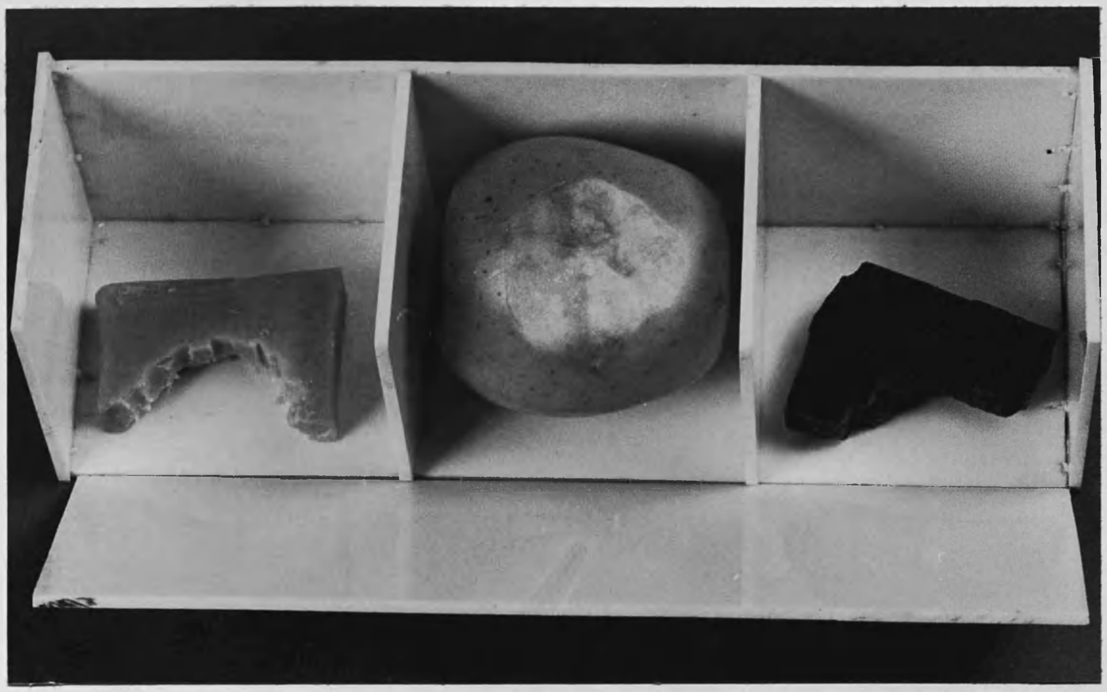


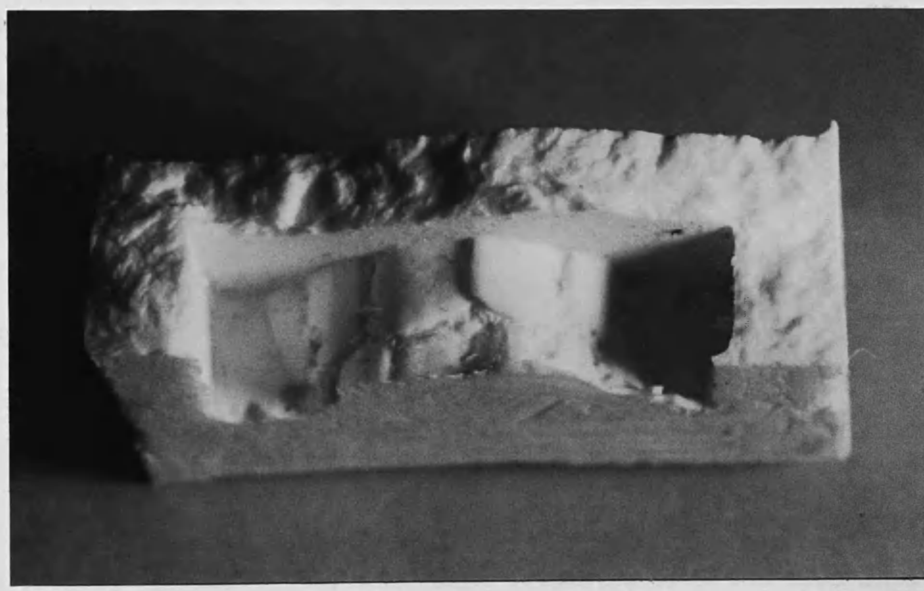
Fig. 3.5 The perspex box used to construct replicas of bitten foods.

Fig. 3.6 The Silcoset mould after being opened up.

Fig. 3.7 Stone plaster replicas of bitten apples and chocolate.

Fig. 3.8 Two examples of bitten cheese replicas made from Silcoset moulds.

A



B

Fig. 3.9 The Silcoset mould reveals the labial view of the teeth in
(A) an apple and,
(B) a cheese bite.

FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

4 PRELIMINARY BITE MARK STUDIES

4.1 INTRODUCTION

The experiments described in Chapters 2 and 3 were concerned with the preservation of specimens for study, and the recording of bite marks for analysis. During the experimentation it was noted that certain tooth features were recorded when a bite was made, but it is pertinent to ask whether or not the particular features of various dentitions are constantly reproduced in bitten foodstuffs. According to Keiser-Nielsen (1967) bite marks in flesh can never be taken to reproduce the dental conditions of the originator, but whether or not this statement could be applied to food bite marks was not known.

During the investigations into preservation and recording of food bite marks, numbers of people were asked to bite samples of cheese, chocolate and apples and known characteristics in the dentition's of the biters were sought in the bite marks made by them. This allowed ideas to be formulated on the possibility of establishing the consistency of reproduction of tooth characteristic in food bite marks. It was noted that very evident features such as rotated incisor teeth, and teeth displaced from the arch in a labial or lingual direction caused particular types of bite marks (Figs. 4.1 and 4.2). Comparison of particular dental arches and the bite marks made by them had also suggested that there might be a mathematical discrepancy between the intercanine distances in a dentition as measured on plaster models and the apparent similar distances measured in the bite marks.

The earlier experiments had also shown that quite exaggerated tooth imprints could be found in some bites in the sense that the tooth marks bore no resemblence in linear width to the width of the teeth known to have made the marks. Accordingly a series of investigations was designed to answer the following questions.

1. What types of tooth marks are found in bitten foodstuffs and which characteristic features are recorded?
2. How consistently can the characteristic features of a dentition be identified in bite marks in food?
3. Can measurements made in food bite marks be accurately compared to the dentitions which made the bites?

4.1.1 Material and Methods

Two individuals with known distinctive dentitions, each made thirty bites (10 in each of the materials to be studied). The resulting marks were recorded photographically using the 5" x 4" plate camera and the methods previously described. Lighting was obtained from two photoflood bulbs and Kodak sheet film No. 4147 was employed throughout. Impressions of the teeth of both biters were taken in an alginate impression material (Zantalgen) and from these stone plaster models were constructed (Figs. 4.3 and 4.4). It was felt that to aid interpretation of the photographed bites slight enlargement of the photographed bitten surfaces would be helpful and these were therefore printed $1\frac{1}{2}$ times life size.

The specimens were kept inside plastic lunch boxes in a refrigerator. Silcoset replicas of one specimen each of cheese, chocolate and apples were constructed.

4.1.2 Materials for Experimental Bites

Cheese:

Preliminary investigations and reports of criminal cases have described bites in several types of cheese. For the purposes of this study bites were made in the varieties of cheese which might be found in the average household in the United Kingdom and were the most likely to be bitten by an intruder. It was established that rubbery types and processed cheeses produced marks most clearly and consistently, and the edges did not break or crumble readily. The Cheddar type was adopted.

The shape for specimens presented difficulty also. The right angled shaped wedge of cheese (Fig. 4.5) is an exhibit bitten in a supermarket robbery in Glasgow which provided some excellent tooth marks, but did not seem likely to be the shape of cheese which would be purchased pre-packaged for domestic use. In a choice between right angled wedge shapes and oblong sections it was found that the latter, cut in sizes of approximately 50 x 30 x 20 mm were convenient. They were large enough to record the marks of the anterior teeth, but were small enough to handle, and economical from a cost point of view. Furthermore less Silcoset was required when models of the bites were being made.

Apples:

According to the national apple register there are just over 6,000 registered apple varieties. The choice for experiment was based on availability and medium sized fruit was used. 'Golden Delicious' is a firm apple, which gives a clear bite and the skin is of uniform colour, usually green or yellow, which was advantageous from a photographic standpoint. The experiments of Marshall, Potter and Harvey (1974) describe 16 apple varieties which were subjected to chemical fixation and they report blackening of the bite area in Golden Delicious apples with loss of skin colour. Despite these findings, bites were usually clearer and easier to interpret than bites on other types and this fact influenced the final decision.

Chocolate:

A seemingly endless choice of names, consistencies, flavours, thicknesses and patterns were available and many experimental bites were made. Personal taste coupled with convenient size led to the adoption of Bournville plain chocolate as the most suitable material. This chocolate is patterned on one side only. The size of specimens used for biting was two of the marked sections approximately 50 x 30 x 5 mm.

4.2 EXPERIMENTAL BITE MARKS

4.2.1 The Biters

The two individuals who made the bites had intact arches of contiguous teeth in both jaws. In the case of biter No. 2 the upper lateral incisors were absent and the upper canine teeth occupied the position of the lateral incisors within the upper arch (Fig. 4.3). It could be expected that this dentition would give a very characteristic bite mark.

4.2.2 The Recording of the Experimental Bite Marks

Each bite mark was photographed. In the case of cheese and apples three views were obtained. These were a view to show the outline of the upper teeth marks; a view of the outline of the lower teeth marks, and a view of the body of the bite to show what have been designated tooth scrape marks. The chocolate specimens were photographed to show the upper and lower outline tooth marks only as the area of the scrape marks was very small and did not give useful detail (Figs. 4.6, 4.7 and 4.8).

4.2.3 Evaluation of Features in Bite Marks

As it was intended to place emphasis on characteristic tooth features a list of these was prepared. MacDonald, MacFarlane and Sutherland (1974) examined particular features of dentitions which might give characteristic bite marks in flesh. Because of the problems in obtaining large numbers of experimental flesh bite marks these writers studied teeth or models of the teeth. The present study afforded the opportunity to evaluate the characteristic features in actual bite marks.

Four features, that is tooth presence, forwards and backwards displacement and tooth rotation were sought (Table 4.1). It was first noted whether or not a mark had been made by each individual tooth. MacDonald (1976) found that generally the presence of a particular characteristic is more valuable than a missing characteristic. The presence of a mark in a particular tooth position is strongly indicative of the presence of the tooth itself. The absence of a mark does not necessarily indicate a missing tooth however, as the absent mark may be due to a short or fractured tooth (Fig. 4.9 and 4.10).

Distinctive characteristics of positional abnormalities forwards or backwards, and any degree of rotation were evaluated by relating the individual teeth to the arch form. This was the method adopted by MacDonald, MacFarlane and Sutherland (1973) who assessed the mean curvature through the canines and the incisors, assuming that the canines lay on the curve. Each bite mark was examined for these features which were recorded as present or not present (Table 4.1).

4.2.4 Measurements in Bite Marks

Gustafson (1966) expresses the view that in cases of curved surfaces there is no hope of depicting exactly the distance between tooth marks, and Korkhaus (1955) felt that it was impossible to make accurate measurements in bite marks. It is presumed that these observations referred to flesh bite marks and it was therefore felt that measurement of individual tooth mark widths and the measurement of intercanine distance should be attempted in the present experiments.

Intercanine distances were measured on the models of the biter's dentitions as being the distance from the most prominent part of the incisal tip of the canine tooth on one side to the same point on the canine tooth on the other side of the arch. Individual tooth widths were taken at this time as being the width of the incisal edges of the central and lateral incisors.

4.3 RESULTS

4.3.1 Characteristic Features in Food Bite Marks

The sixty photographs of the bites were analysed. Tables (4.2 and 4.3) show a summary of the frequency with which the characteristics of the biters dentitions could be distinguished in the marks. A histogram (Table 4.4) was prepared to provide visual recognition of the positive features observed in the sixty bites.

What was somewhat surprising was the number of bites in which it was not possible to identify marks of six upper and six lower teeth. In particular, bites in apples showed these in only 70 per cent of cases. This was noted in both biters for both upper and lower teeth. Six marks were found in 82.5 per cent of the cheese bites and in over 90 per cent of the chocolate bites. In general, features of positional abnormality could be recognised more readily in the case of the lower teeth although this was marginal, the difference being only 5 per cent. The reproduction of known characteristics was remarkably even for both biters, in terms of positional variations and rotations, but surprisingly the rotations seen in the marks made by the dentition of the second biter which were rather more gross in character were in fact less well identified in the bite marks, and a difference of almost 6 per cent between the biters was demonstrated for this feature.

No false positive results were recorded, but distinctive features known from model analysis to be present were not always discernible in the bite marks. Bitten chocolate in particular because it fractures, tended to do so before distinctive features could be recorded.

Certain characteristics in the dentitions of the biters were found to cause particular types of food bite marks. Teeth displaced lingually from the arch sometimes caused a wedge shape to be produced in the mark (Fig. 4.11). Overlapping teeth (Fig. 4.12) were also distinctive. The points at which the incisal edges of the teeth meet the mesial or distal surfaces were found to cause prominent marks in food bite marks (Fig. 4.13) and each of these three characteristics is examined fully in Chapter 5.

4.3.2 Measurements in Food Bite Marks

In these experiments attempts were made to measure individual tooth widths and intercanine distance in the bite marks. Evaluation of the distinctive characteristics in food bites was found to differ slightly from the corresponding assessment in flesh bite marks. In the latter there is frequently a mark in the skin of the whole biting edge whereas in food bite marks what was available for study was usually the residue after a piece had been bitten out. Accordingly the assessment had to be made on an impression of the labial surfaces of the teeth and not on the whole biting edge. This caused difficulty in the attempts to measure the widths of individual incisor teeth, and Table (4.5) shows the considerable variability which was found in the measurements. As the measurement of individual tooth widths in the mark varies with the depth of tooth penetration into the material, it was not possible to find a common reference point from which to standardise measurements. The width of each of the four upper and four lower incisor teeth was therefore taken as being the measurement of distance between the most mesial and most distal aspects of each tooth crown recorded.

Due to the variable depths of tooth penetration, in no instance could it be stated for certain that the outline mark of a tooth in the food bite marks was the outline of its incisal edge. Pedersen and Keiser-Nielsen (1961) have warned against the use of tooth widths in bite marks, as they 'cannot be indicative of the original teeth'.

Tables (4.6 and 4.7) show the variable results of the attempt to relate intercanine distance in the arch to the apparent intercanine distances in the bite marks. Chocolate proved to give the most accurate results but even in that case only 6 out of a possible 20 bites gave a correct measurement for both upper and lower dentitions. The intercanine distance in apples could only be found to match once in both jaws and in cheese four times. Individual distances in one jaw only, could be related to the models slightly more often, and in general the measurements were found to be more accurate for the maxillary tooth marks.

4.4 DISCUSSION

The results of this first series of experiments indicated the frequency with which specific tooth characteristics could be distinguished in food bite marks. The fact that in apples it was not possible to identify marks of six upper and six lower teeth in more than 70 per cent of cases had indicated that reliance in bite mark identification should only be placed on positive characteristics which are identifiable within the mark.

Analysis of positional abnormalities revealed that lower teeth characteristics were more frequently recorded than upper teeth features, yet in both jaws distinctive features known from model analysis to be present, were not always discernible in the bite marks. Bitten chocolate which tends to fracture, often did so before distinctive features could be recorded.

The fact that no instance of false positive recording of features occurred was interesting, but in a very subjective study of bites from only two individuals with known dental characteristics, such features might have been missed. In addition as experience in analysing and recording features was gained it is likely that prior experience was applied to interpret doubtful points.

Attempts were made to measure both intercanine distance and individual tooth widths in the bites. It was felt that the variability in the measurements was due to the fact that it was frequently impossible to say which part of the tooth had caused a given part of the mark, nor was it possible to be certain that the two elements of a mark had been made at the same moment in time. If movement of the bitten material had occurred between the making of the mark of one canine tooth and that of the other canine tooth in the same jaw, then the apparent intercanine distance could be quite different from the true measurement in the mouth as recorded from the models, and the conclusion was that no reliance could be placed on the measurement of intercanine distances. Some marks could be measured accurately, but it was considered that chance played a part and that such accurate measurements as were found, probably related to quite individual conditions, such as the care exercised in producing the bite or the texture and shape of the material being bitten.

The measurement of individual tooth widths suggested that these are also unreliable in food bite marks and are not suitable for identification purposes. The data given in Table (4.5) shows errors of as much as 3 mm in the measurement of the upper central incisor in some cheese bites, and an extreme variation of 4 mm in an apple bite (Figs. 4.14 and 4.15).

Measurement of the same teeth making bites in different materials also varied and this was felt to be due mostly to the type of material bitten and to the mechanism of biting adopted for each material. Tooth widths measured in chocolate bites gave the most accurate results, probably because of the limited depth of tooth penetration and to the hardness of the material. The variability of measurements in cheese bites appeared to be due partly to the depth of tooth penetration and partly to the rubbery consistency of the cheese.

Photographic recording of bite marks proved to be accurate and satisfactory, but the making of models of the bitten foods may be of dubious value and open to criticism if the models were to be used for Court presentation. Silcoset impressions of the bite do allow some features of the biter's teeth to be more readily interpreted.

These first studies have suggested that the main effort should be placed on the recognitition of distinctive features in bite marks and the larger definitive experiments to be described in Chapter 5 were designed to concentrate on this aspect. No further study was carried out on food preservation methods as the short term methods devised to limit distortion prior to detailed photography, together with the use of Silcoset models and impressions appeared to have fulfilled the criteria necessary for the purposes of experiment and Court presentation.

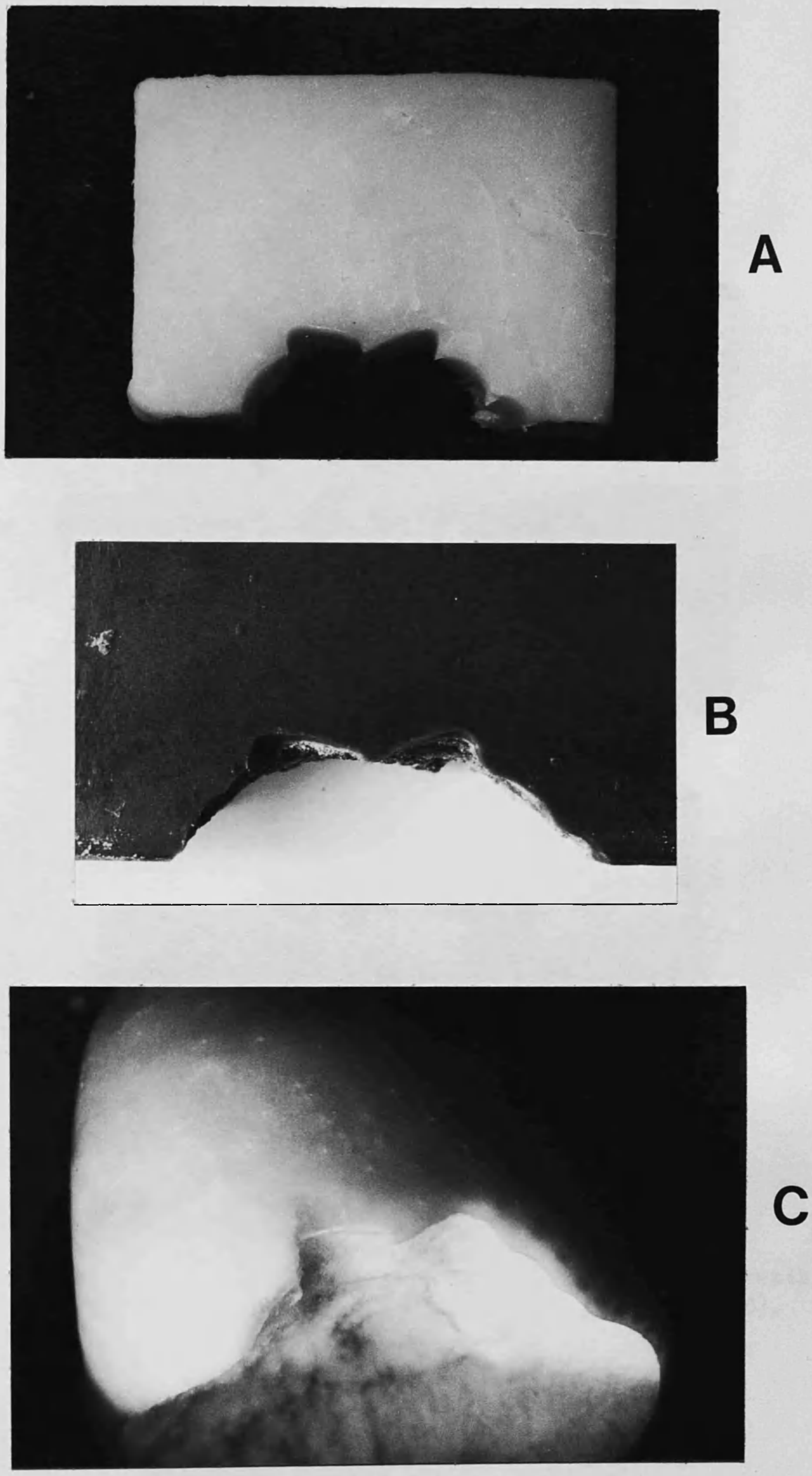
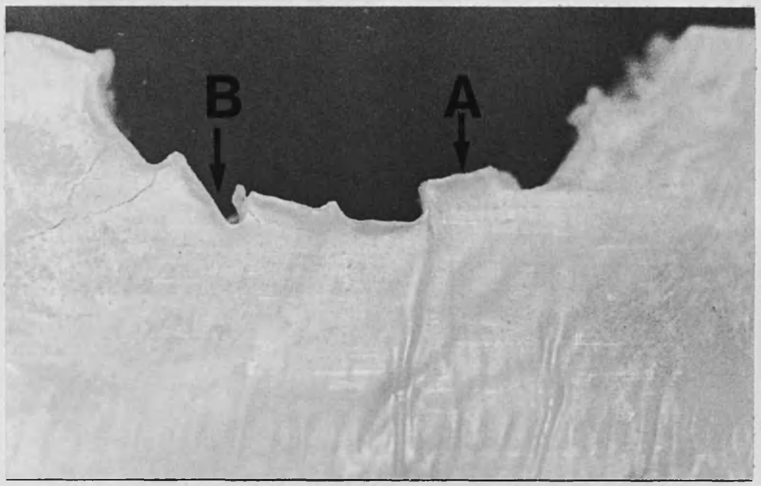


Fig. 4.1 Upper central incisors rotated mesio lingually in cheese (A), chocolate (B) and apples (C).



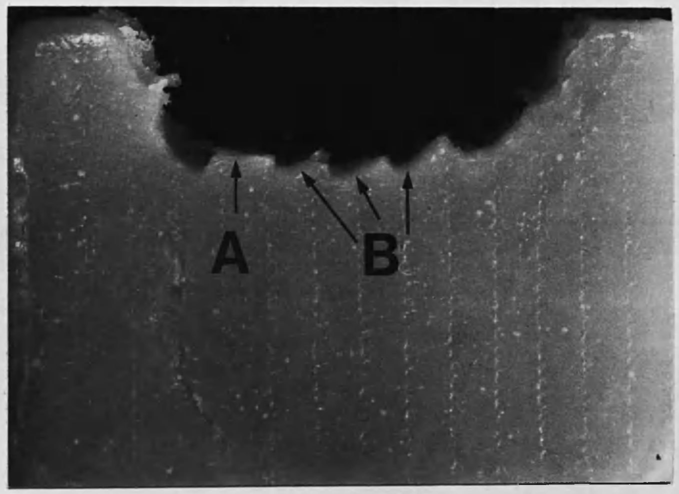


Fig. 4.2 Cheese bites illustrating the effect of teeth displaced from the arch (A) and rotated teeth (B).

Fig. 4.3 Models of the teeth of biter No. 2.

Fig. 4.4 Models of the teeth of biter No. 1.

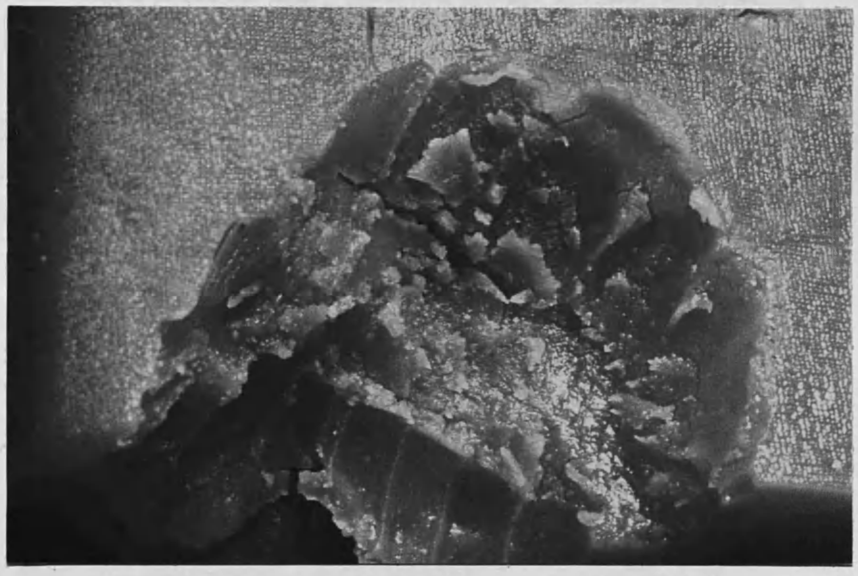


Fig. 4.5 Block of bitten cheese found at a supermarket robbery.

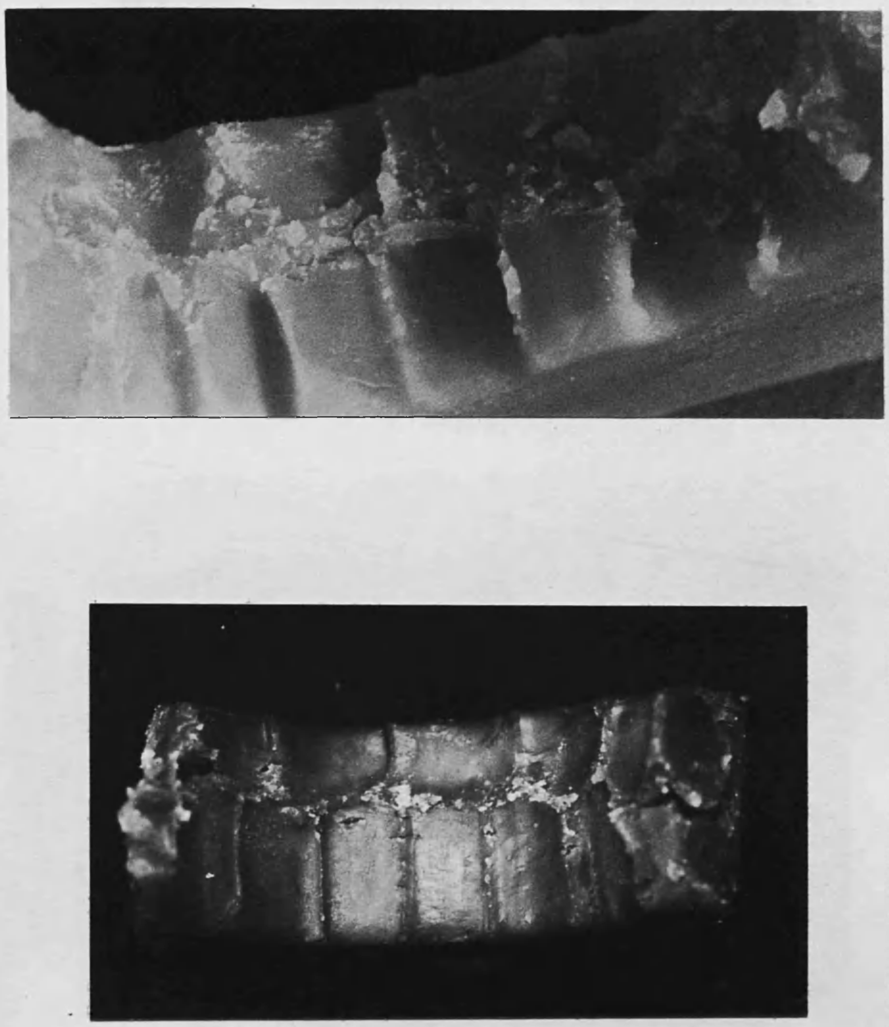


Fig. 4.6 Scrape marks in cheese bites.

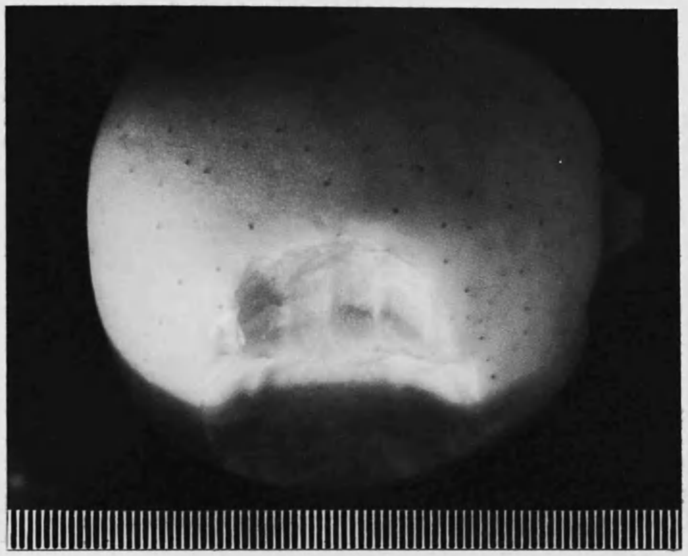


Fig. 4.7 Scrape marks in an apple bite.

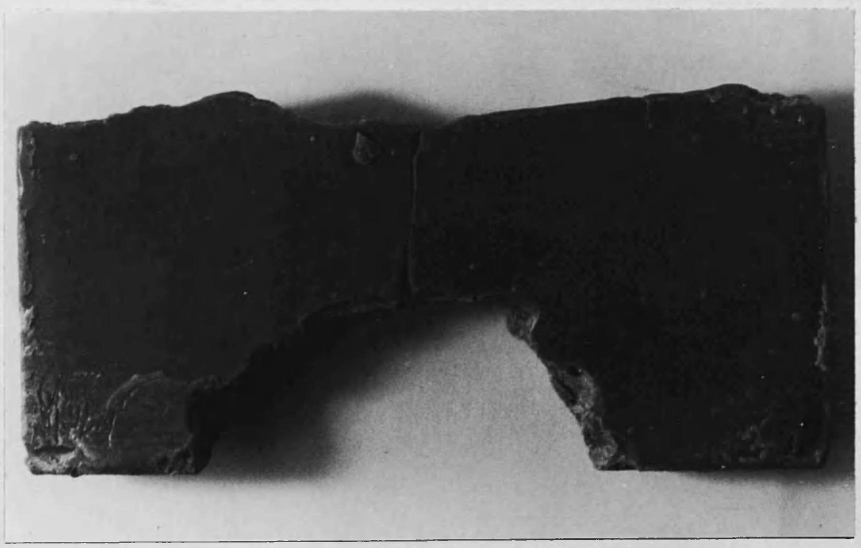


Fig. 4.8 The area of scrape marks does not give useful detail in chocolate bites.

Series One (Cheese Bites)

	Bite No.					
	1A	1B	2A	2B	3A	3B
Tooth presence	x	x	x	o	x	o
Displacement forwards	x	x	x	x	x	x
Displacement backwards	x	x	x	o	x	o
Tooth rotation	x	x	x	x	x	o

TABLE 4.1 Preliminary data to evaluate features in bitten foods.

A = Lower bite mark

B = Upper bite mark

x = Feature present

o = Feature absent

Fig. 4.9 1/ is missing and 2/ (A) occupies its position. Hence the small tooth mark.

Fig. 4.10 Both lateral incisors are short and have not been recorded.

BITER NO. 1

	CHEESE		APPLES		CHOCOLATE		AVERAGE		
	A	B	A	B	A	B	A	B	A+B
Six teeth marks present	80	80	70	70	100	90	83.4	100	81.7
Positional abnormality present	100	100	100	100	100	100	100	100	100
Positional abnormality - forwards	100	90	100	90	90	100	96.5	93	94.5
backwards	-	-	-	-	-	-	-	-	-
overlap	-	90	-	90	-	80	-	86.5	86.5
rotation	100	90	90	100	100	80	96.5	90	93.4

TABLE 4.2: Percentage of positive features for 60 bitten surfaces (30 bites).

A = Lower teeth features

B = Upper teeth features

\- = Feature not present

BITER NO. 2

	CHEESE		APPLES		CHOCOLATE		AVERAGE		
	A	B	A	B	A	B	A	B	A+B
Six teeth marks present	90	80	70	70	95	90	85	80	82.5
Positional abnormality present	100	100	100	100	100	90	100	96	98
Positional abnormality - forwards	95	95	100	95	85	70	94	87	90.5
backwards	100	-	90	-	90	-	94	-	94
overlap	100	85	100	85	50	80	84	83	83.5
rotation	100	95	95	90	75	70	90	85	87.5

TABLE 4.3: Percentage of positive features for 60 bitten surfaces

A = Lower teeth features

B = Upper teeth features

\- = Feature not present

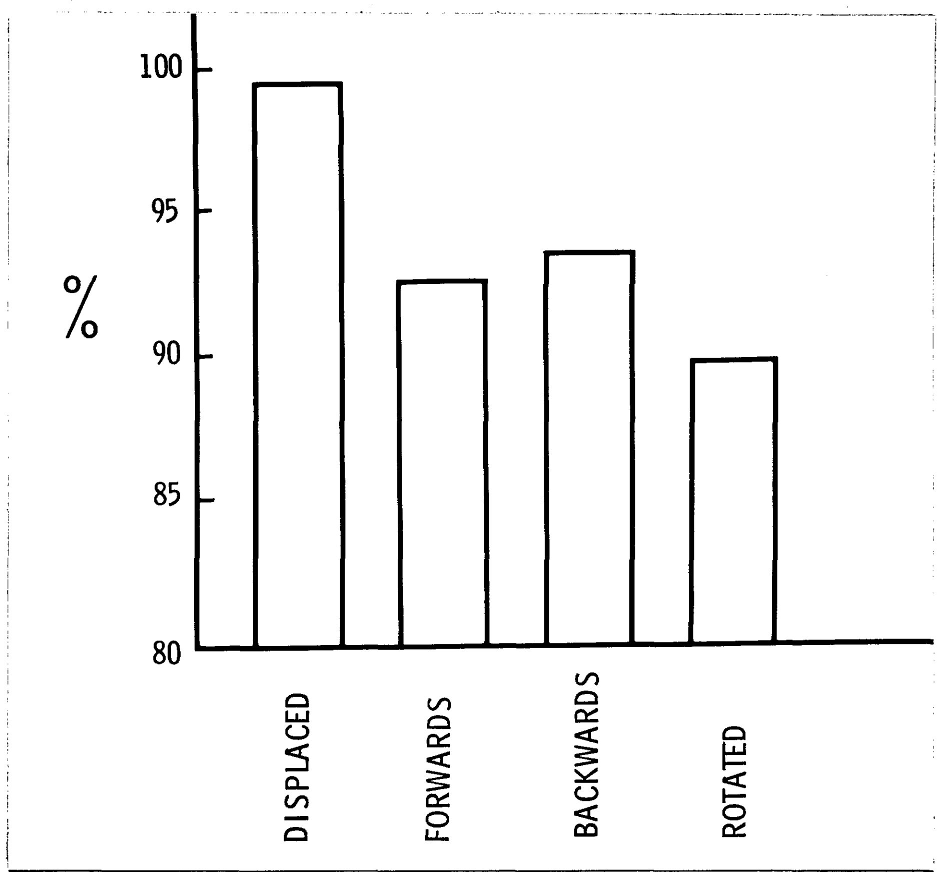


TABLE 4.4: Positive features observed in 60 bites.

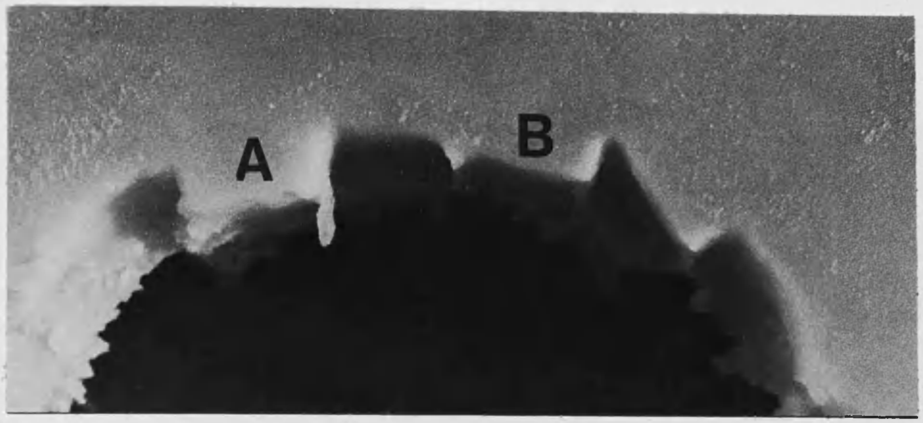


Fig. 4.11 Tooth wedge marks in a cheese bite (A) and (B).

Fig. 4.12 Overlapping central incisors in a cheese bite.

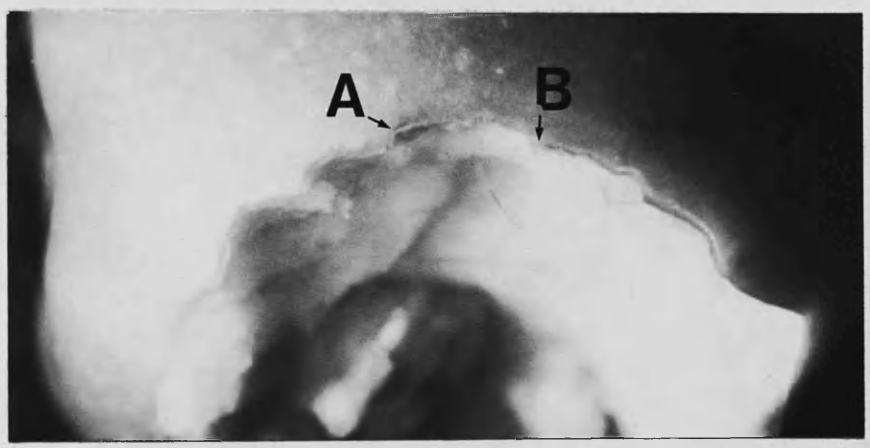


Fig. 4.13 Tooth prominences in an apple bite mesial prominence (A) distal prominence (B).

Tooth Width	Cheese	Chocolate	Apples
8 mm	8	9	12
	9	9	9
	11	8	9
	10	9	10
	10	8	9
	8	9	10
	11	9	10
	10	8	8
	10	7	8
	9	8	11

Upper Central Incisors

Tooth Width	Cheese	Chocolate	Apples
5 mm	6	6	4
	6	6	6
	5	6	6
	6	5	6
	5	6	6
	4	5	5
	5	6	6
	6	6	4
	6	6	6

Lower Central Incisors

TABLE 4.5: Individual tooth measurements for 10 bites in bitten cheese, chocolate and apples.

BITER NO. 1

BITE NO.	MODEL A	MODEL B	CHEESE A	CHEESE B	APPLES A	APPLES B	CHOCOLATE A	CHOCOLATE B
1	44	50	43	50	44	50	43	-
2			43	51	48	52	44	50
3			-	-	-	53	44	48
4			42	50	45	-	44	51
5			45	48	47	50	45	50
6			44	50	-	-	45	48
7			45	-	46	48	43	-
8			44	50	-	-	47	50
9			-	49	43	51	44	50
10			44	51	43	50	44	50

TABLE 4.6: Measurement of intercanine distance (mm) x $1\frac{1}{2}$.

A = Lower bite surface

B = Upper bite surface

- = No measurement possible

The measurements shown are $1\frac{1}{2}$ times life size as the photographic prints were enlarged by this amount to aid interpretation of the bite mark details.

BITER NO. 2

BITE NO.	MODEL A	MODEL B	CHEESE A	CHEESE B	APPLES A	APPLES B	CHOCOLATE A	CHOCOLATE B
1	36	35	-	36	-	35	36	35
2			33	36	35	35	37	37
3			35	37	38	-	37	-
4			36	35	36	36	38	37
5			-	33	-	37	36	35
6			36	-	36	37	36	-
7			38	-	33	-	37	35
8			36	33	35	-	36	35
9			36	35	-	-	37	36
10			34	35	35	37	-	35

TABLE 4.7: Measurement of intercanine distance (mm) x $1\frac{1}{2}$

A = Lower bite surface

B = Upper bite surface

- = No measurement possible

The measurements shown are $1\frac{1}{2}$ times life size as the photographic prints were enlarged by this amount to aid interpretation of the bite mark details.

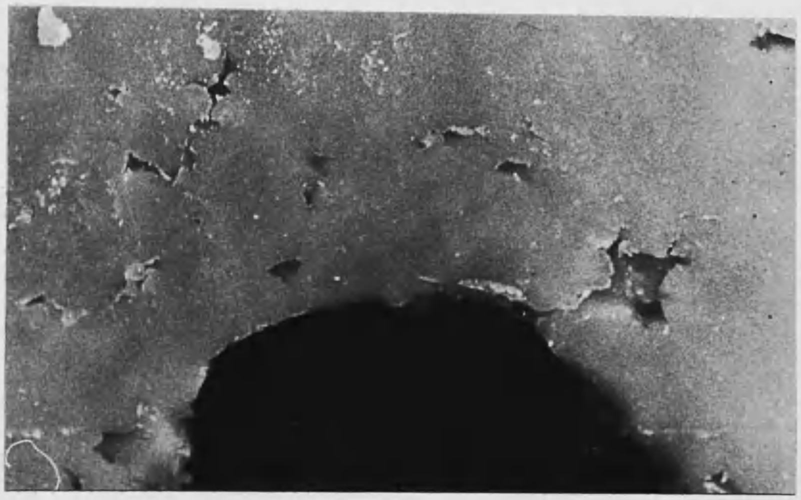


Fig. 4.14 A much enlarged central incisor in a cheese bite.

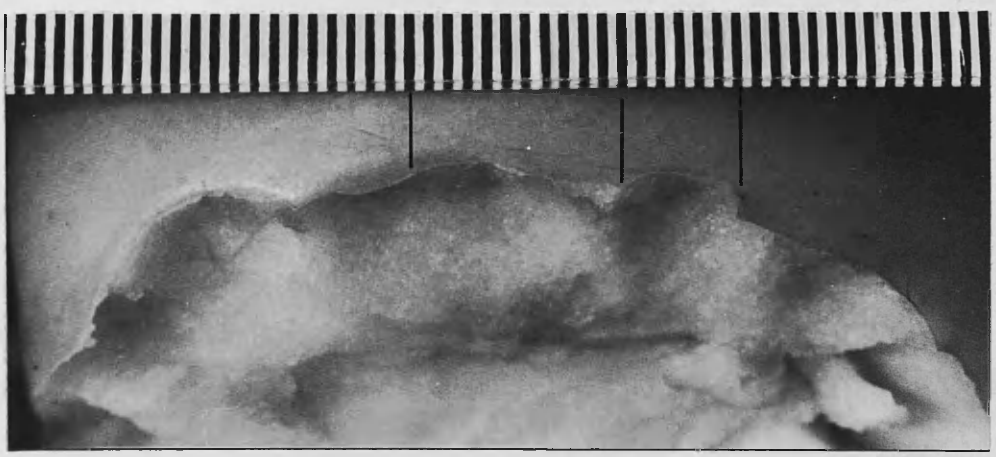


Fig. 4.15 The mark made by the central incisor is 4 mm wider than the adjacent tooth.

FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

5 FURTHER BITE MARK STUDIES

5.1 INTRODUCTION

Having studied the techniques for investigating food bites in the preliminary experiments, by analysing 60 bites made by two individuals on each of three foodstuffs, it was felt that the results might not necessarily be reliable. A distorted picture could have been obtained because the investigator learned to recognise the bites of these individuals and may have unconsciously interpreted features according to his prior knowledge, gained from experience.

A much larger series of experiments is reported in this Chapter. The bites of 30 individuals were studied in each of three foodstuffs, in an attempt to provide more reliable data on the types and frequency of tooth characteristics seen in bite marks, furthermore, this allowed an evaluation of the incidence and nature of apparent false positive features seen in bite marks.

5.2 MATERIAL AND METHODS

5.2.1 Bites

Thirty, third year dental students of Glasgow University Dental School were asked to take one bite each in samples of cheese, chocolate and apples. In practice, because of the requirements for accurate photography within a short period of the bite, it proved optimal to study only three students on each occasion.

The bites were taken in the same manner as in the first experiments with one slight modification, that the brand of chocolate was changed to Cadbury's Dairy Milk to suit the student taste!

5.2.2 Photography

The bitten materials were photographed in the same fashion as before, using a different background for each material. While one specimen was being photographed the remainder were stored inside 'lunch type' boxes in a refrigerator.

The apples were photographed first because they showed the quickest distortion on drying, with a previously noted tendency for the bitten skin margin to fold inwards. To counteract this the apples were, as before covered with moist paper tissue or cotton wool while awaiting photography.

Prints were prepared of the 90 bites and because it was again felt that slight magnification would assist the analysis, these prints were enlarged to 1.5 times life size.

5.2.3 Analysis of Bites and Models

The photographed cheese bites were random numbered from 0 to 29, chocolate from 30 to 59, and apples from 60 to 89.

The 90 bites were analysed as described below. A proforma was devised for the analysis of 72 tooth characteristics in the bites and in the models as shown in Table 5.1.

The individual features studied were as follows (Table 5.2):

Tooth status: In the bites, the presence of a mark in a given anterior tooth position was noted and it was recorded whether or not this mark was of the usual size and shape for that position in the arch. Deficiencies of the incisal edge were recorded. If no tooth mark was seen in a given position this was coded as 6. The models were similarly analysed. If a tooth was missing from the arch or if only a root was present projecting not more than 2 mm above the gingival margin this was coded as 5. Teeth forming part of a prosthesis were coded in the same manner as natural teeth.

Arch position: The arch form of the anterior teeth were assessed subjectively by imagining the best arch form upon which lay the canine teeth and one or both of the central incisors. The incisal edge of each incisor tooth individually was then scored as being on this arch, in front of, or behind the arch.

Rotation: Rotation of individual incisor teeth was noted with respect to the arch curvature described above. A mild rotation was of less than 45^{o} whereas marked rotation was of more than 45^{o} from the mean arch curvature.

Examples of coding for the features of arch position and rotation are illustrated in Figs. 5.1, 5.2 and 5.3, and these show the various combinations which may be encountered.

In the earlier experiments it was noted that the distinctive tooth features could be represented in other ways. Accordingly these were analysed to discover if they might provide more reliable data than was achieved by the study of arch positions and rotations.

Tooth prominences: It had been noticed that bite marks in food recorded mainly the impression of the labial surfaces of the teeth and that the resulting imprint often showed distinctive areas at the mesial and distal edges of each tooth mark. These were designated as tooth prominences, and could be either labially or lingually displaced from the arch (Fig. 5.4).

Tooth overlaps: It had also been noted that marks made by teeth which were malpositioned with overcrowding and consequent overlapping of teeth, reproduced a pattern in the bitten material sometimes recognisable as overlapping teeth (Fig. 5.5).

Bite wedges: Teeth displaced from the arch especially lingually tend to produce a wedge of bitten material which may be quite distinctive. This also was coded as a separate feature (Fig. 5.6).

The assessment of the features of tooth prominences, and bite wedges in the models differed fundamentally from the assessment of the features of arch position and rotation. In the latter cases what was available for study was a model of the dentition from which, by applying the criteria laid down in the coding key, a specific answer was obtained. Either a tooth was rotated or it was not rotated. In the case of the prominences, and tooth wedges the models were examined for an expected bite mark feature. There is, for example no such tooth characteristic as a bite wedge, but bite marks may show this feature. In the same way a tooth prominence may be present in a bite mark, but the teeth on the model do not show this and an assessment had to be made as to whether or not the teeth would cause a prominence in the bite mark. To aid this assessment, and where doubt existed, the incisor teeth on the models were pressed gently into plasticine and the resulting imprints were studied to show whether or not the feature had been recorded.

5.2.4 Models

Models were obtained from third year dental students. These models were made available by Professor A.R. MacGregor of the Department of Prosthodontics. The students were required to obtain impressions of each others mouths as part of their normal instruction and the fabrication of duplicates for this forensic study was made a part of their training.

Models of the 30 biters were selected and in addition models of a further 20 students were added to give a series of 50 models which were allocated random numbers from 90 to 139. The 50 sets of models were analysed in the same manner as the bites.

5.2.5 Measurement in Bite Marks

Measurement of the intercanine distance of both upper and lower teeth was made from every second set of student models, providing that the canines had been recorded in the bites to give a series of 15 upper and 15 lower measurements. The distance was taken from the most prominent point of the tip of the canine on one side to the same point on the tooth on the opposite side. This measurement was made using dividers and transferred to a mm scale. In the same fashion the apparent intercanine distances in the bite marks were measured from the photographs and adjusted because the bite mark prints had been enlarged to $1\frac{1}{2}$ times life size.

Individual tooth widths were recorded from the models as being the width of the incisal edges, and the teeth measured were the upper and lower central incisors.

5.3 THE METHOD OF MATCHING BITES AND MODELS

Prior to the breaking of the random numbered codes an attempt was made to match the models and the related bites by comparison of the coded data. This was undertaken manually and it would clearly have been extremely tedious to examine every feature for each bite.

Accordingly the features of arch position and rotation, 16 features in all, were noted in each bite and the sheets of the 50 sets of models were scanned for corresponding coded features.

If there was a match of arch position features in three of the four upper teeth and three of the four arch position features of lower teeth, this was accepted as a possible identification. If the rotations showed a similar degree of correspondence of features of the bite and the model, this supported the probable identification of the appropriate model. Where more than one model showed possible correspondence of features, examination of the tooth prominences allowed the single most likely model to be selected. When a model has been deemed to be identified, the scoring sheet was not taken out of the analysis as it was not known if several dentitions would show similar coded features.

Following this preliminary comparison the random numbered codes were broken and a detailed analysis was made of correctly matched and mismatched tooth features.

5.4 RESULTS

5.4.1 Matching of Bites and Models

The initial comparison of the bite coding sheets and the model coding sheets allowed positive matching of 76.6 per cent of cheese bites, 50 per cent of chocolate and 43.3 per cent of apple bites. No instance of a wrong matching was encountered within these groups. This identification of the models was achieved using the suggested key and no attempt was made at further break down using a combination of all coded teeth features to increase the percentage of successful matchings.

5.4.2 Analysis of Tooth Features

Six teeth marks were found in only the following percentage of cases: cheese 75 per cent, chocolate 55 per cent and apples 65 per cent and the histogram (Table 5.3) illustrates this tooth status data for both the first experiments and the present larger study. In the majority of cases the teeth which failed to leave recognisable marks were once again the canines.

The coding sheets were studied to determine if any teeth missing in the models had been recorded as present in the bites. Only one missing tooth (code 5) was noted in the 30 models. This was correctly identified in the cheese and chocolate bites, but in the apple bite a tooth was coded as being present in that arch position (Figs. 5.7, 5.8 and 5.9).

The value of coding the wrongly shaped teeth and fractures appeared debatable. Mesial and distal fractures (codes 2 and 3) were not noted in the bites whereas abnormally shaped teeth (code 1) or combined mesial and distal fracture (code 4) were considerably over-recorded in the bites.

The percentage of correctly identified arch positions and rotations for each anterior tooth is shown in Table 5.4. The details of the upper teeth were better identified than the lowers. In the case of the feature of arch position, the upper left central incisor and upper left lateral incisor were correctly recorded and identified in every cheese bite, and the upper left lateral was also found in every apple bite. Lower bite marks did not record this feature in more than 96 per cent of the bites and it was again the teeth on the left side of the arch which provided the most consistent results, particularly in the bitten cheese.

The tooth rotation data (Table 5.4) shows that in none of this series of bites were all the rotations noted, but of the lower incisor teeth the lower left lateral gave the poorest result for each material bitten. It was not possible to identify more than 70 per cent of rotations of this tooth in the chocolate bites, and the results in general for chocolate bites indicate that these marks are less well recorded.

The wrongly coded features of arch position in the bite marks were analysed to determine the number of missed features and the number of false positive features. These results are summarised in Table 5.5 and the data in this table shows that the most frequent error in recording arch positions was for a displacement from the arch not to be noted in the bite. False positives occurred where teeth apparently displaced from the arch in bites were in the arch in the models or where apparent displacement in the wrong direction was recorded in the bite. The total error in each line of the table is out of a possible 120 observations (30 bites with four teeth).

When the wrongly coded features of tooth rotation were similarly examined (Table 5.6) it was found that the most frequent error was for a specific rotation seen in the model not to be evident in the bite. There were also several instances where apparent tooth rotation was seen in the bite, but was not present in the model. The instances where a rotation was present in the model and a wrong rotation was noted in the bite were all cases in which the direction of rotation had been correctly interpreted from the bites, but the degree of rotation had been wrongly assessed.

The percentages of correctly identified tooth prominences are presented in Table 5.7. Comparison of this table with Table 5.4 indicates that the analysis of tooth prominences was less accurate than either of the analysis of arch position or rotation. This was particularly so in chocolate and apple bites. The recording of the mesially placed prominences was found to be slightly more accurate than the distal aspect, for both upper and lower teeth and the upper prominences were recorded more consistently than the lowers.

The data in Table 5.8 indicates that the most frequent error found was for an apparent prominence in the model not to be found in the bite mark. Instances occurred in which these had not been scored as being present in the model. In the cases where a prominence was noted as being present in the model and a wrongly identified prominence was noted in the bite, in each instance the feature was present but the direction of the prominence had been wrongly assessed. For each type of prominence cheese gave the least number of errors and chocolate the most (Tables 5.9 and 5.10).

The recognition of overlapping teeth in bite marks was found to be very variable. The tendency with cheese bites was to overscore overlaps especially in the upper teeth. In chocolate and apple bites overlaps were missed in about 40 per cent of cases (Table 5.11).

The recognition of bite wedges was inaccurate in the same manner as for the overlaps. There was over estimation in cheese bites and under-recording in chocolate and more especially in apples (Table 5.12).

5.4.3 Measurement in Bite Marks

Attempts to relate the measurement of intercanine distance of the student models to the apparent intercanine distance in the bite marks gave poor results. Table 5.13 shows the measurements which resulted. In the bites in which the canines had been recorded correct measurements were found in 55 per cent of chocolate bites, 50 per cent of cheese bites and only 40 per cent of the apple bites. Of the incorrect intercanine measurements, the distance was increased in 88 per cent of the apple bites and 73 per cent of cheese bites (Table 5.14).

Table 5.15 shows the results of the attempts to measure individual tooth widths. The measurements on the models had been taken as the widths of the incisal edges of the teeth concerned, but it was not possible to say that the tooth mark in the bite was that of the incisal edge as this depended on the depth of tooth penetration; while chocolate bites often exhibited accurate individual tooth width measurements in no case in any of the bites in the 3 materials studied, did the 4 upper and 4 lower tooth widths exactly compare with the 8 teeth which had made the marks.

5.5 DISCUSSION

The experiments described in this part of the study have in general confirmed and extended the data from the preliminary studies. There is support for the concept of placing most effort on the positive features which can be identified in bites. A major part of the analysis has been an attempt to assess the reliance which may be placed upon apparent recording of specific features in food bites and also to try and assess the false results recorded to provide information on what might be incompatible inconsistencies between models and bites.

The tooth status data showed that teeth present in the mouth do not always give marks in bites. Thus the absence of evidence of an expected tooth in a mark is not an incompatible inconsistency. The recording of abnormal tooth shapes and incisal fractures proved to be variable, but such features could still be of value in individual cases.

The analysis of arch positions of the incisor teeth proved to be the single most reliable tooth feature and the results confirmed the findings of the earlier experiments. A few false positive results were obtained suggesting that apparent lack of complete correspondence of tooth displacement in models and bites should not necessarily constitute an incompatible inconsistency. In support of this view is the fact that no instance of a displacement in the wrong direction was noted.

Tooth rotations were slightly less accurately recorded in bites than were arch positions and there were several instances of false positives. In no case, however, was an apparently wrong direction of rotation seen in the bites.

It is clear from the results that for the 4 upper and 4 lower incisor teeth the features of tooth status, arch position, and rotation are accurately recorded in most food bite marks. These are the features which have been studied to determine their occurrence in the Glasgow population (MacFarlane, MacDonald and Sutherland, 1973) and that data has been presented in Court in cases of flesh bite marks. The present study indicates that it could also be used in food bite mark presentations.

The value of assessing tooth prominences in bite marks as a general rule, is debateable, due to the difficulty of forecasting some prominences. They may well be of value in particular cases, as a complement to the analysis of the other features within the mark. In a similar way bite wedges may be useful as back up evidence, but marks made by overlapping teeth were missed or misinterpretated to such an extent that their use in food bite mark interpretation is clearly dubious.

In these studies attempts to relate the intercanine distance measured on the student models to the apparent intercanine distance in the bites were largely unsatisfactory, and the measurements in apple bites were the least accurate. The inaccuracy appeared to be due to the fact that considerable difficulty was experienced in finding the correct point in the tooth marks from which to make the measurements. The texture of the bitten materials also appeared to influence the measurements as the increased distances were found mainly in cheese and apples which tended to produce gouge type marks rather than clear cut tooth marks. These problems are discussed fully in Chapter 6.

The results have shown that no reliance can be placed on apparent individual tooth widths in food bite marks. This is due to the fact that the incisal edges on the models were taken as representing the tooth width whereas the widths of the marks in the bites depended on the depth of penetration of the individual teeth. In both cheese and apple bites teeth rotated out of the arch tended to give marks which were in excess of their true measurement. The crumbling of the edges in bites in all 3 materials caused difficulty and in only a small number of the bite marks could every tooth mark be measured.

By the time the complete analysis of every feature in the bites had been completed, the author had become convinced that the decision to print the photographed marks $1\frac{1}{2}$ times life size was wrong. The enlargement rather than clarify the marks tended to mask them, and although this view has been obtained in the light of experience it is suggested that experience in the analysis of tooth characteristics in bite marks could have been gained more quickly if the study had been carried out using 1:1 photographic prints.

The features which were correctly identified in the bites were marginally better scored in the marks made by the upper teeth, but it is the author's opinion that this information is of no great value. The reproduction of the tooth characteristics depends to a large extent on the consistency of the material being bitten and on the mechanisms of the biting action. It is the knowledge that a feature is present in both the bite and the dentition which is important, and not which dental arch is involved. In the same way the number of teeth involved is less important than the demonstration of positive characteristics in both bite and biter.

Because the studies have clearly indicated that the characteristics of arch position and tooth rotation are consistently recorded in food bite marks and can be accurately compared to the dentitions which made them, and because measurements in bite marks have been found to be largely inaccurate, doubt must be expressed about the method of fitting plaster casts into bitten materials. Fearnhead (1961) has shown that the wrong model can be made to fit. Using the methods of analysis which have been described in these experiments no instance of a wrong matching occurred due to the severe elimination process, and it is worthy of note that not one of the additional 20 upper and lower models of the students who did not participate, was encountered.

CODING SHEET

Bite Marks in Food

SUBJECT NUMBER

1	2	3

TOOTH STATUS

CODES 0 - 6

	4	5	6	7	8	9	
R							L
	10	11	12	13	14	15	

ARCH POSITION

CODES 0 - 6

	16	17	18	19	
R					L
	20	21	22	23	

ROTATION

CODES 0 - 6

	24	25	26	27	
R					L
	28	29	30	31	

TOOTH PROMINENCES (MESIAL EDGE)

CODES 0 - 6

	32	33	34	35	36	37	
R							L
	38	39	40	41	42	43	

TOOTH PROMINENCES (DISTAL EDGE)

CODES 0 - 6

	44	45	46	47	48	49	
R							L
	50	51	52	53	54	55	

TOOTH OVERLAPS

CODES 0 - 6

	56	57	58	59	60	61	
R							L
	62	63	64	65	66	67	

BITE WEDGES

CODES 0 - 6

	68	69	70	71	
R					L
	72	73	74	75	

TABLE 5.1: Proforma used to score tooth features in bites made by 30 dental students.

<u>TOOTH STATUS</u> <u>CODES 0 - 6</u>

<u>CODE FOR EACH TOOTH</u>

3 2 1	1 2 3
3 2 1	1 2 3

0 : Tooth present, normal shape for arch position

1 : Tooth present, abnormal shape for arch position
e.g. wrong tooth

2 : Tooth present, mesial incisal defect, cavity, filling etc.

3 : Tooth present, distal incisal defect, cavity, filling etc.

4 : Tooth present, mesial and distal incisal defect

5 : Tooth missing from arch - model

6 : Tooth mark not present in bite

\- - - - - - -

<u>ARCH POSITION</u> <u>CODES 0 - 6</u>

<u>CODE FOR EACH TOOTH</u>

2 1	1 2
2 1	1 2

0 : In arch

1 : In front of arch

2 : Behind arch

5 : Tooth missing - model

6 : Tooth mark not present in bite

\- - - - - - -

<u>ROTATION</u> <u>CODES 0 - 6</u>

<u>CODE FOR EACH TOOTH</u>

2 1	1 2
2 1	1 2

0 : Normal

1 : Mild mesio-labial/disto-lingual rotation

2 : Marked mesio-labial/disto-lingual rotation

3 : Mild mesio-lingual/disto-labial rotation

4 : Marked mesio-lingual/disto-labial rotation

5 : Tooth missing - model

6 : Tooth mark not present in bite

\- - - - - - -

<u>TOOTH PROMINENCES</u> <u>CODES 0 - 6</u>

<u>CODE FOR EACH TOOTH</u> $\frac{3\,2\,1 \mid 1\,2\,3}{3\,2\,1 \mid 1\,2\,3}$

I. <u>MESIAL EDGE</u>

0 : No prominence

1 : Mesial anterior prominence

2 : Mesial posterior prominence

5 : Tooth missing - model

6 : Tooth mark not present in bite

\- - - - - - -

II. <u>DISTAL EDGE</u>

0 : No prominence

1 : Distal anterior prominence

2 : Distal posterior prominence

5 : Tooth missing - model

6 : Tooth mark not present in bite

\- - - - - - -

TABLE 5.2: Analysis of bite marks in foodstuffs coding key.

Fig. 5.1 Arch position coding 0 0 | 1 0
Rotation coding 0 0 | 0 3

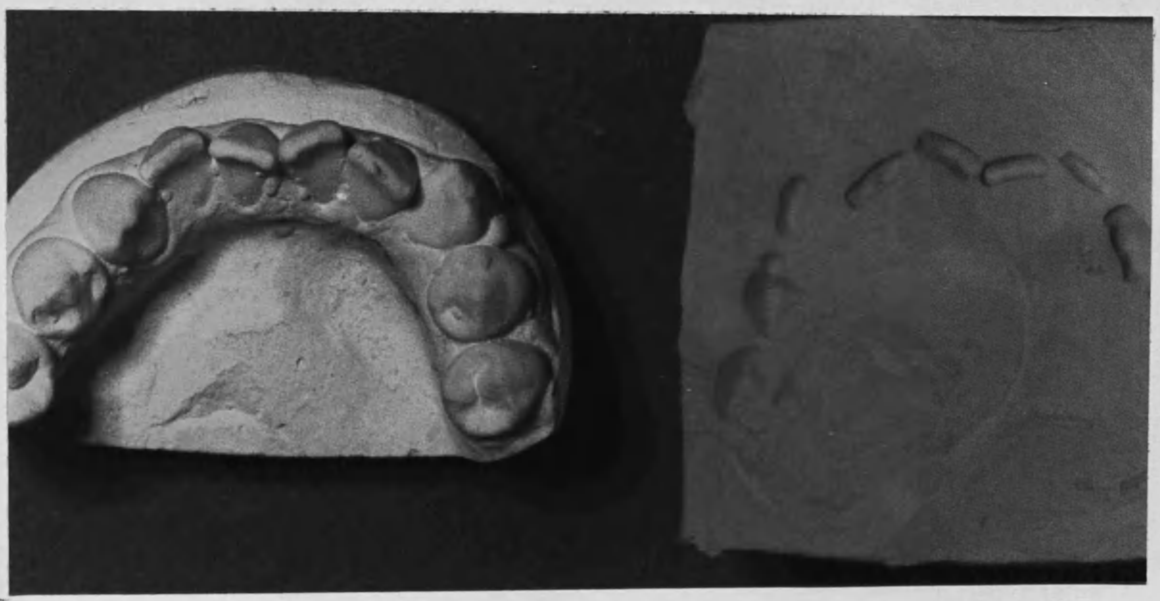


Fig. 5.2 Arch position coding 2 0 | 2 0
Rotation coding 0 3 | 3 0

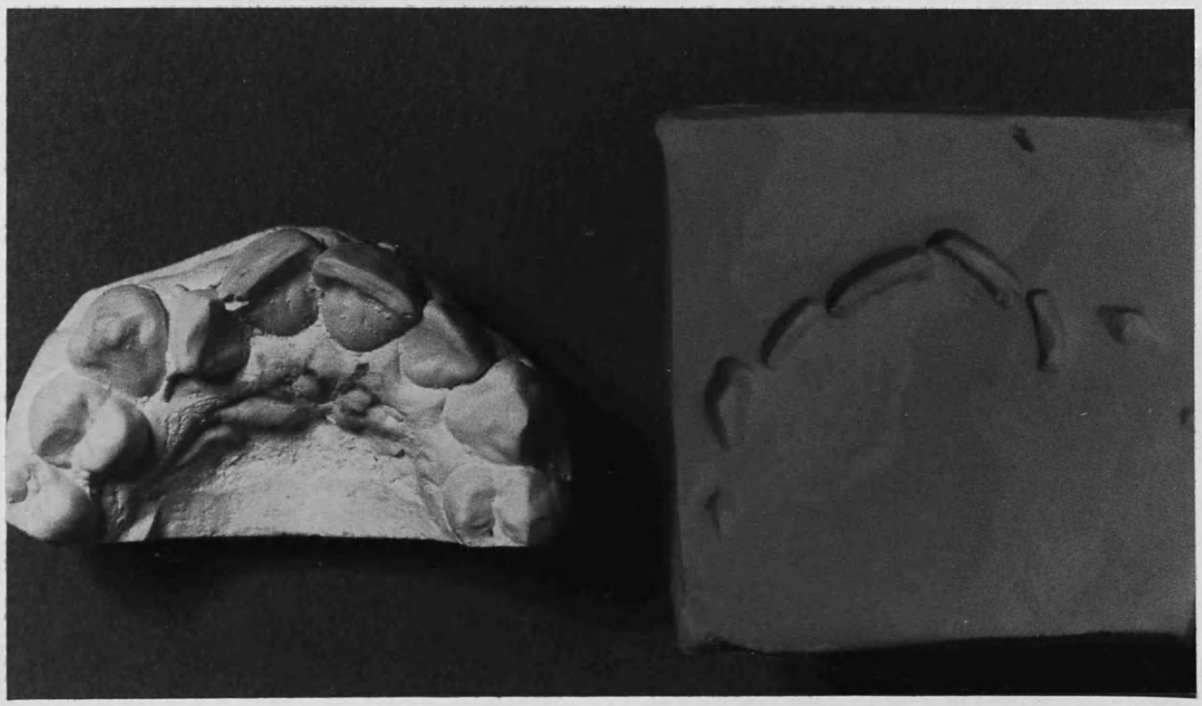


Fig. 5.3 Arch position coding 0 0 | 0 2

Rotation coding 1 0 | 3 4

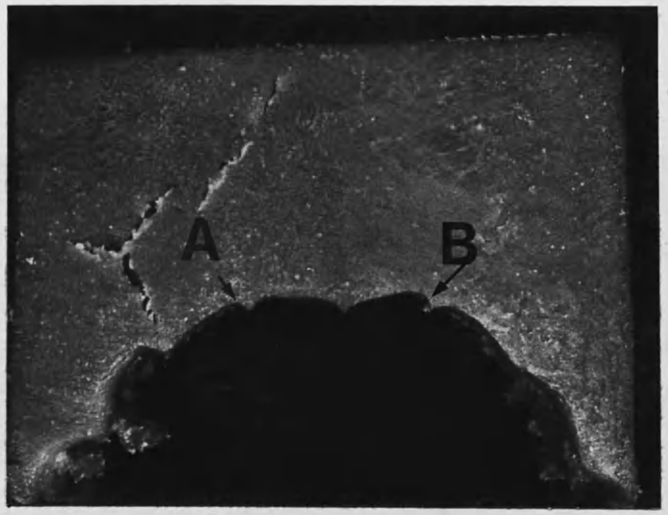


Fig. 5.4 Tooth prominences in a cheese bite.
(A) Mesial prominence.
(B) Distal prominence.

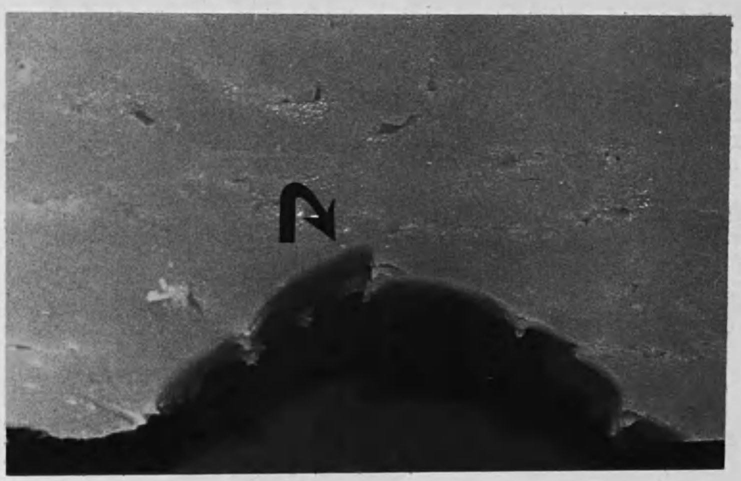


Fig. 5.5 Overlapping central incisors.

Fig. 5.6 Bite wedges made by the same biter in cheese and an apple. The lower lateral incisors are displaced lingually.

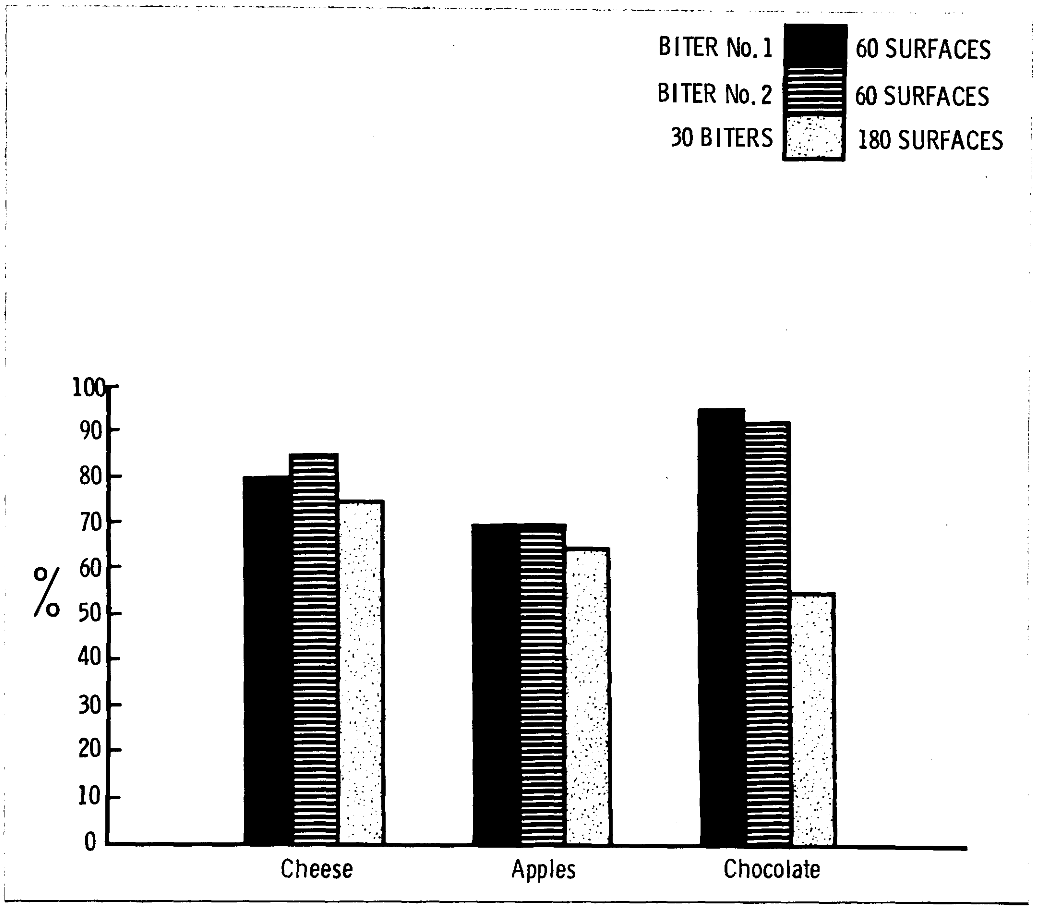


TABLE 5.3: Percentage of bites in which six teeth marks were recorded.

Fig. 5.7 The missing upper central incisor was correctly coded in this cheese bite.

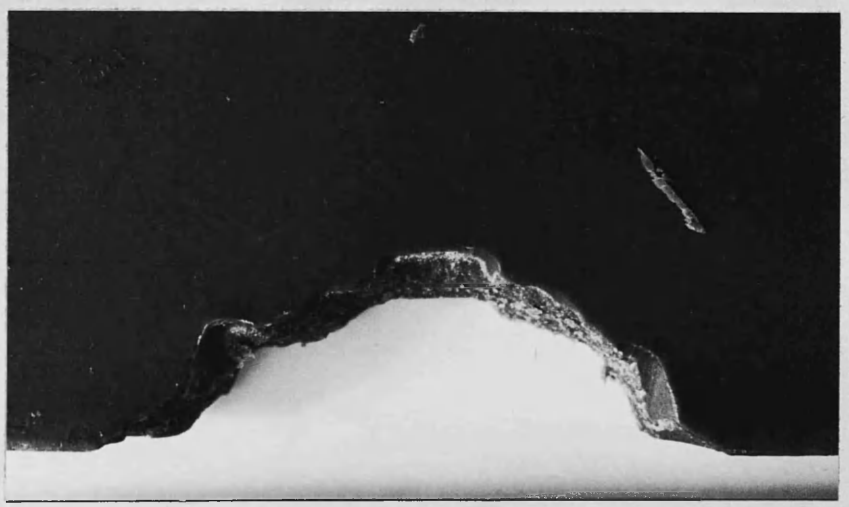


Fig. 5.8 The missing incisor was correctly coded in the chocolate bite.

Fig. 5.9 A tooth was coded as being present in this apple bite although it was missing from the dental arch.

	ARCH POSITION								ROTATIONS							
Tooth	$\underline{2/}$	$\underline{1/}$	$\underline{/1}$	$\underline{/2}$	$\overline{2/}$	$\overline{1/}$	$\overline{/1}$	$\overline{/2}$	$\underline{2/}$	$\underline{1/}$	$\underline{/1}$	$\underline{/2}$	$\overline{2/}$	$\overline{1/}$	$\overline{/1}$	$\overline{/2}$
Cheese (30)	96	100	96	100	93	83	96	96	86	86	86	93	93	93	90	76
Chocolate (30)	90	93	93	90	70	83	86	86	76	83	90	73	80	83	70	73
Apples (30)	90	93	100	100	93	86	83	83	80	83	90	90	73	73	83	70
3 Materials (90)	92	95	96	96	85	84	88	88	85	84	88	85	82	83	81	73

TABLE 5.4: Percentage of correctly identified teeth in respect of arch position and rotation.

	Tooth Displacement in Model — No Record in Bite	No Tooth Displacement in Model — Displacement Recorded in Bite	Tooth Displacement in Model — Wrong Displacement Recorded in Bite	Total
CHEESE Uppers	1	1	0	2
Lowers	4	2	3	9
CHOCOLATE Uppers	5	1	1	7
Lowers	13	7	2	22
APPLES Uppers	4	0	1	5
Lowers	7	2	3	12

TABLE 5.5: Arch position features wrongly coded

	Rotation in Model No Rotation in Bite	No Rotation in Model Rotation in Bite	Rotation in Model Wrong Rotation in Bite	Total
CHEESE Uppers	9	3	2	14
Lowers	6	7	1	14
CHOCOLATE Uppers	14	5	1	20
Lowers	20	6	2	28
APPLES Uppers	8	6	3	17
Lowers	16	7	2	25

TABLE 5.6: Tooth rotations features wrongly coded

	MESIAL EDGE								DISTAL EDGE							
Tooth	$\underline{2/}$	$\underline{1/}$	$\underline{/1}$	$\underline{/2}$	$\overline{2/}$	$\overline{1/}$	$\overline{/1}$	$\overline{/2}$	$\underline{2/}$	$\underline{1/}$	$\underline{/1}$	$\underline{/2}$	$\overline{2/}$	$\overline{1/}$	$\overline{/1}$	$\overline{/2}$
Cheese (30)	86	96	90	90	93	90	83	80	56	80	96	83	66	93	73	73
Chocolate (30)	80	73	70	66	70	43	66	43	36	66	76	50	60	66	70	76
Apples (30)	76	70	73	80	70	80	70	70	56	80	73	63	56	63	66	50
3 Materials (90)	81	80	77	78	77	71	73	71	50	75	82	65	61	74	72	66

TABLE 5.7: Percentage of correctly identified tooth prominences

	PROMINENCE IN BITE				NO PROMINENCE IN BITE	
	Not apparent in model		Wrong prominence recorded		Apparent prominence in model	
Anterior						
Cheese	2		10		11	
		(7)		(14)		(24)
	5		4		13	
Apples	7		12		19	
		(16)		(23)		(41)
	9		11		22	
Chocolate	7		7		21	
		(19)		(18)		(43)
	12		11		22	
Posterior						
Cheese	5		6		5	
		(13)		(11)		(14)
	8		5		9	
Apples	3		9		15	
		(11)		(20)		(36)
	8		11		21	
Chocolate	13		13		24	
		(22)		(26)		(36)
	9		13		12	

TABLE 5.8: Prominence features wrongly coded

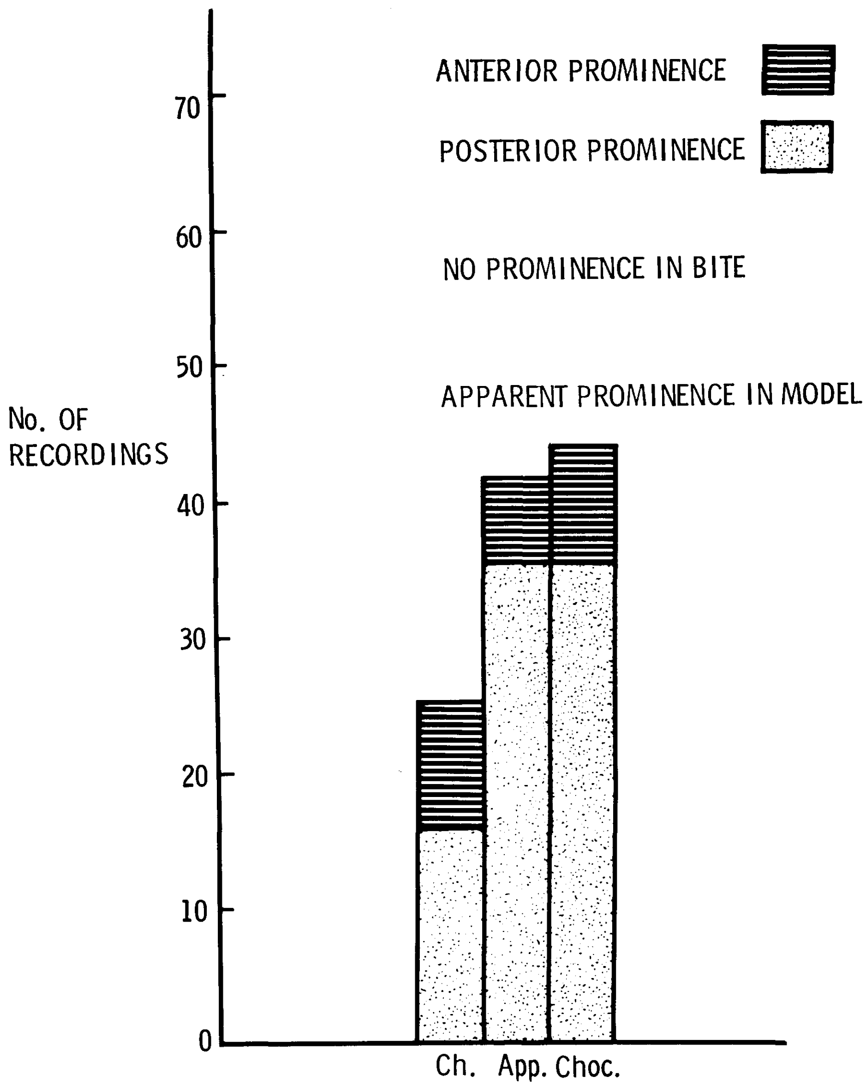


TABLE 5.9: Tooth prominences apparently present on the models but not recorded in the bite marks.

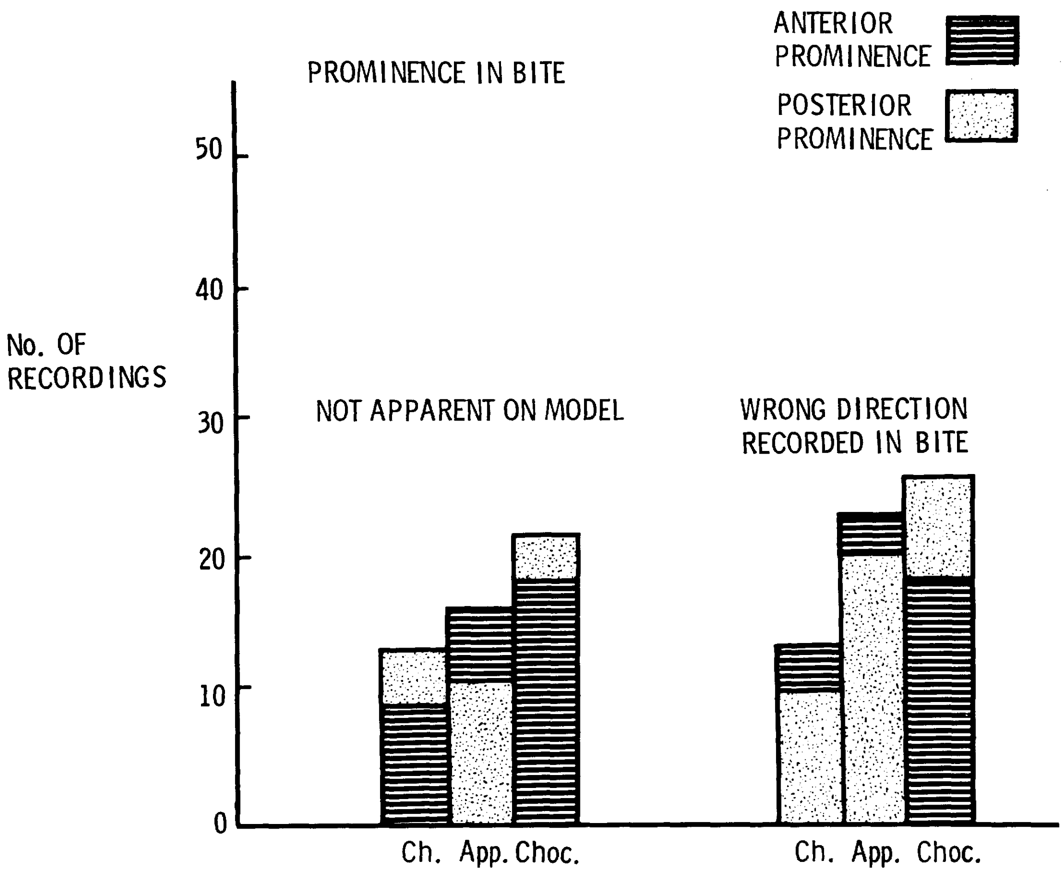


TABLE 5.10: Tooth prominences recorded in the bite marks not apparent on the models, and prominences recorded in the wrong direction.

TOOTH	Mesial Overlap								Distal Overlap							
	$\underline{2/}$	$\underline{1/}$	$\underline{/1}$	$\underline{/2}$	$\overline{2/}$	$\overline{1/}$	$\overline{/1}$	$\overline{/2}$	$\underline{2/}$	$\underline{1/}$	$\underline{/1}$	$\underline{/2}$	$\overline{2/}$	$\overline{1/}$	$\overline{/1}$	$\overline{/2}$
Cheese	1	2	2	2	2	1	1	-	-	1	1	-	-	-	2	-
Choc.	-	1	1	-	-	-	2	-	-	1	1	-	-	-	-	1
Apples	-	1	1	-	-	1	2	-	-	1	-	-	1	-	1	-
Models	1	1	1	2	1	3	1	-	-	-	-	-	-	2	2	-

	Models	Cheese	Chocolate	Apples
Upper	5	9	4	3
Lower	9	6	3	5
Total	14	15	7	8

TABLE 5.11: Tooth overlaps in 30 bites.

Over scoring occurred in cheese bites, particularly the upper marks. About 40% of overlaps were missed in chocolate and apple bites.

TOOTH	$\underline{2/}$	$\underline{1/}$	$\underline{/1}$	$\underline{/2}$	$\overline{2/}$	$\overline{1/}$	$\overline{/1}$	$\overline{/2}$
Cheese	5	2	-	-	6	5	2	6
Chocolate	3	-	1	-	2	3	-	3
Apples	-	-	3	-	3	3	1	4

	Cheese	Chocolate	Apples
Upper	7	4	3
Lower	19	8	11
Total	26	12	14

TABLE 5.12: Tooth wedges in 30 bites. Over recording occurred in cheese bites and under-recording in chocolate and apples.

Bite No.	Model A	Model B	Cheese A	Cheese B	Apples A	Apples B	Chocolate A	Chocolate B
1	46	41	46	40	48	42	46	40
2	48	36	48	36	49	37	48	36
3	52	39	52	39	52	40	52	39
4	51	41	52	42	51	42	51	41
5	48	39	48	39	49	40	48	40
6	55	41	54	41	55	41	56	42
7	48	35	49	37	50	36	48	34
8	51	38	50	38	51	38	50	39
9	51	44	51	45	50	45	51	44
10	45	39	45	40	45	42	45	38
11	48	38	50	38	48	38	48	39
12	54	40	54	41	53	42	56	40
13	51	39	52	38	51	39	50	40
14	44	33	44	33	45	33	46	33
15	48	35	49	36	49	37	48	35

TABLE 5.13: Intercanine distances measured from 15 bites in 3 materials. The measurements (mm) have been increased to $1\frac{1}{2}$ times life size (A) upper (B) lower.

Material	No. of bitten surfaces	Correct Measurement	Incorrect measurements	
			Increased	Decreased
Cheese	30	50	73	27
Apples	30	40	88	12
Chocolate	30	55	61	39

TABLE 5.14 Percentage of correct intercanine measurements from 15 sets of models and bites, and the breakdown of the incorrect results.

	Tooth width	Cheese	Apples	Choc.	Tooth width	Cheese	Apples	Choc.
1	10	11	12	10	5	5	6	5
2	9	11	9	9	6	5	7	6
3	10	11	11	10	6	6	6	7
4	8	10	8	9	6	7	6	6
5	8	8	8	8	5	6	5	4
6	10	10	10	10	5	6	6	5
7	9	9	9	8	6	5	6	6
8	9	9	10	9	5	7	6	5
9	10	9	11	9	6	6	7	6
10	8	9	8	8	6	7	7	6
11	8	8	7	7	5	4	5	6
12	8	10	10	8	5	5	5	5
13	8	8	9	9	6	5	5	6
14	9	11	8	8	5	7	6	5
15	10	11	10	10	6	6	7	6
	Upper central incisors				Lower central incisors			

TABLE 5.15 Measurements of individual tooth widths (mm) in 15 bites.

FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

6 CLASSIFICATION OF FOOD BITE MARKS AND THE PROBLEMS OF INTERPRETATION

6.1 INTRODUCTION

Early in these studies it was noted that the volunteer biters approached the act of making a bite to order in different ways, which varied according to the foodstuff being used, and quite different end results were obtained. It was not clear whether or not experimental bites would produce the same types of bites as those made prior to normal mastication.

Other workers have described bites in foodstuffs and the terminology employed by them varies considerably. Kerr (1977) considers a bitten apple to be a three dimensional bite. Nickolls (1963) describes a case of a bitten apple in which there was an extremely well defined tentative bite. Lower down on the same apple there was a complete bite showing "as usual" little detail. The same author also states that a hesitant bite will result in a confused smudged type of mark. The manner in which the bite is made is important according to Layton (1966) who is of the opinion that a sliding bite will tend to produce the characteristic details more accurately than will a shearing bite or a piercing bite.

It is interesting to note that text books have little to say about the mechanisms of biting foods. Much is written about chewing movements but these observations relate to dentures rather than to natural teeth. Accordingly it became necessary to observe biting mechanisms in a number of individuals, and these bites coupled with the detailed studies of the experimental bites has allowed a classification of food bites to be formulated.

6.2 FOOD BITE MARK CLASSIFICATION

6.2.1 Material and Methods

Members of the staff of the Department of Oral Medicine and Pathology, Glasgow Dental School, the author's own dental staff and random patients with no dental knowledge, were asked to make bites on samples of cheese, chocolate and apples. The specimens bitten were of the size and shape used in the previous experiments and the biters were told that the reason for the experiment was to study the saliva traces left on the foodstuffs, thus no attempts were made to produce deliberate bite marks.

6.2.2 Results

Classification of Bite Marks on Foodstuffs

Examination of the mechanism of biting and many bites in different materials has shown that three main types of bites are found. The value of a classification lies in the fact that each type gives an indication of the tooth features which are likely to be recorded. Examples of each type is shown, as are models of the teeth which made the bites (Fig. 6.1).

Type 1 Bites are those in material such as chocolate, which fractures readily, with a limited depth of tooth penetration. Bites of this type will record the most prominent incisal edges of the upper and lower anterior teeth, up to a depth of 1 to 2 mm. There is unlikely to be much evidence of tooth scrape marks in the body of the bite which usually displays a fractured surface (Fig. 6.2).

In Fig. 6.2 it can be seen that there is a record of some detail of the labial aspect of the incisal edges but other areas such as the distal edge of /2 in the bite, record no features because the chocolate has fractured. A false impression of gaps between the teeth may also be given.

Type 2 Bites consist of those where a good grip of the material is obtained by the teeth, and then the bitten piece is removed by fracturing it from the main material, by movement of the head or the hand holding the bitten object. This is typical of the bite seen in firm fruit such as apples or pears but may also be seen in a large piece of cheese (Fig. 6.3). This type of bite shows a record of the labial surface of the upper and lower incisor teeth and tooth scrape marks penetrating the bitten material. Both the labial surface marks and the tooth scrape marks tend to record those elements of the teeth which are most prominent anteriorly and not necessarily the incisal edges. Similarly the width of the tooth scrape marks, will be of the horizontal width between the most mesial and most distal parts of the tooth crown recorded. For a tooth lying at an angle, this may give a large gouged out mark greatly in excess of the actual tooth width.

In type 2 bites as the lower anterior teeth travel upwards through the bitten apple into the body of it, there is an eventual 'stopping point' at which a second outline of the incisal edges of the lower anterior teeth may be found. This stopping point often divides the bite into two parts in a ratio of 1:2 from the upper outline downwards, and in some cases this can be of value in orientating the bite on apples if the marks are indistinct. The bite in Fig. 6.3 does not show the rotation of $\underline{/1}$ and no mark of $\underline{3/}$ is present.

Type 3 Bites are those in which the teeth bite right through, or almost through the bitten material, and is typical of the bite found in cheese. Such bite marks show the same features as type 2 bites, with the added advantage that the body of the bite exhibits extensive tooth scrape marks and may give an indication of the relative positions of the upper and lower incisor teeth in centric occlusion. The depth of tooth penetration varies according to the size of the material and records the labial surfaces of the anterior teeth (Fig. 6.4).

The apparent width of individual teeth may be increased because the mark shows the greatest mesio-distal width of the tooth and not the incisal edge length.

6.3 PROBLEMS OF INTERPRETATION

During the experimental bites difficulty was experienced on some occasions in the analysis when it was not possible to say which tooth had made a particular mark. This was found in bites in each material studied but particularly so in the marks made by evenly arranged lower teeth in apples. Mistakes occurred also in the interpretation of arch position and tooth rotation, and some quite bizarre marks were found at the canine position in a number of the bites (Fig. 6.5).

6.3.1 Wrong Recording of Features

A re-examination of the score sheets and the photographed bite marks revealed errors in identifying individual teeth within some marks. This caused a failure in the use of the key system during the process of matching bites and models. If for instance in the case of arch position $\overline{1|}$ was wrongly scored as $\overline{2|}$, the key which should have read

R					L
	0	2	1	1	

was recorded as

R					L
	6	0	2	1	

thus although only one error was made by this mis-interpretation, only one matching feature appeared to have been found and the case was relegated to the non-identified group. The re-appraisal of the score sheets showed this to have happened on 8 occasions. This difficulty was found mostly in apple bites especially if the edge was torn or if the canine marks could not be identified.

6.3.2 Arch Position and Rotation

Wrongly scored features of arch position in the analysis of the bite marks occurred most often in chocolate bites, where no displacement had been evident in the models. Of recorded errors in bite marks made by the lower teeth, eleven errors involved central incisors, which had been interpreted as being outwith the arch. Re-examination of the models and the photographed bite marks indicated that the production of the feature in the marks was false rather than a mis-interpretation during the analysis of the models. Only a limited amount of tooth penetration takes place before the material fractures and there appeared to be a tendency at this time for a dragging movement of the teeth through the material to occur thus sometimes creating the false impression that a tooth was displaced.

The crumbling of the edges of bites caused confusion when interpreting rotations of the teeth, and this was especially so in the case of small lower anterior teeth exhibiting minimal variations in position.

In apple bites the teeth bite into and grip the apple and a part is then torn out. Some features of the labial surfaces of the teeth are recorded but even a distinctive rotation may not be evident in the bite (Fig. 6.3).

6.3.3 Canine Teeth

It has been noted that all six anterior were recorded in only 65 per cent of food bite marks and of the non-recorded teeth, the majority were canines. Although in many instances a mark of some sort indicated the possible presence of a tooth unit where the canine tooth should have been, the marks were not sufficiently distinct to be positively identified as having been made by a canine. This occurred with all three foodstuffs.

The relatively soft consistency in the case of cheese bites prevented positive identification of some canine marks, which were often much larger than would be expected and appeared more as a gouge mark than as a bite mark. The material was found frequently to split through the mark thus distorting both the shape and indication of any characteristics present (Fig. 6.6). As the arch position of the other teeth was analysed in terms of the canine position, difficulty was occasionally experienced in assessing the relationship of the central and lateral incisors to the arch.

This difficulty was also found in chocolate bites. The size of the samples was such that they were usually positioned against the incisor teeth as the bite was made, and a record of the central and lateral incisors was obtained. As the bite proceeded the material sometimes fractured or chipped through the canine region. The chocolate bite shown in Fig. 6.7 has broken through the canine position and there is no record of the lateral incisor.

The bite mark on the skin of apples was sometimes torn at the site of the canines rendering the mark of little value (Fig. 6.8). It was also found that the skin pattern showing the outline marks could vary according to the size of the fruit, medium sized apples gave one shape of mark but bites on small apples sometimes resulted in an altogether different mark (Figs. 6.9 and 6.10), and this appeared to be due to the mechanism of biting. With large apples most biters inserted the incisor teeth through the surface, followed by the canines as the mouth was opened more widely. The specimen was pushed further into the mouth, resulting in a bite which had been made in two parts. Smaller fruit was mostly bitten in one biting action, and the canines were frequently not recorded.

The relationship between the canines and the adjacent lateral incisors caused occasional difficulty in interpretation. Where the lateral incisors were small teeth, a step existed between them and the canines, and this type of dentition caused a bite mark, in which the canine mark was considerably wider than the natural tooth. In addition the canine mark could be dragged or distorted. This was found mainly in cheese bites (Fig. 6.11) but occasionally chocolate bites also exhibited this distortion.

6.4 DISCUSSION

The random biting of food samples has allowed a classification of food bites to be formulated. The bites which were examined have provided a basis for describing bite marks in foodstuffs found at the scene of a crime. Using the classification it should be possible to obtain reliable information about the dental details of the biter, and some ideas can be formulated as to the further investigations which may be necessary, particularly in relation to the numbers of teeth which should be studied in models of the felon's teeth.

Personal experience in individual criminal cases has sometimes revealed difficulty in orientating bites on apples, but the recognition of a classification may help to solve this problem. The same teeth making bites in similar or in different materials have not been found to exhibit all the characteristics of the dentition in each case. Thus the idea of asking a suspect to make a simulated bite in a similar or in a different material is not a reliable technique. In particular this would seem to be the case with apple bites. The use of chocolate for repeat bites would also appear to be of dubious value as the breaking point of the chocolate can not be determined and this is the greatest influence in the number of accurately reproduced characteristics of the dentition.

The experience of the operator in interpreting the details in the bite mark is obviously important. In particular his willingness to exclude marks which are present where a tooth mark ought to be is vital; if such a mark is so distorted that it is not recognisable as a tooth mark then it must be excluded from the analysis.

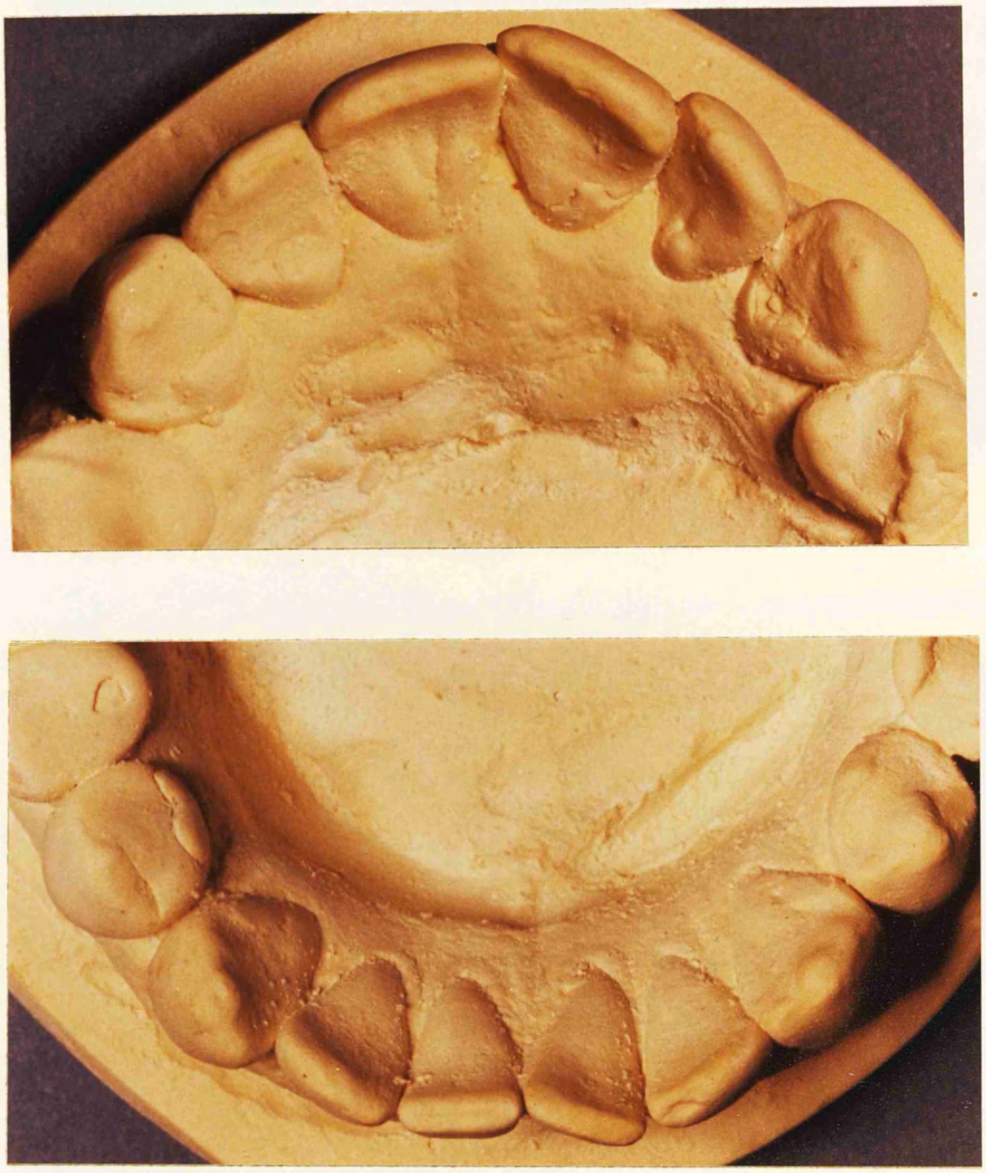


Fig. 6.1 Classification of food bite marks. Upper and lower models of the individual who made the bites.

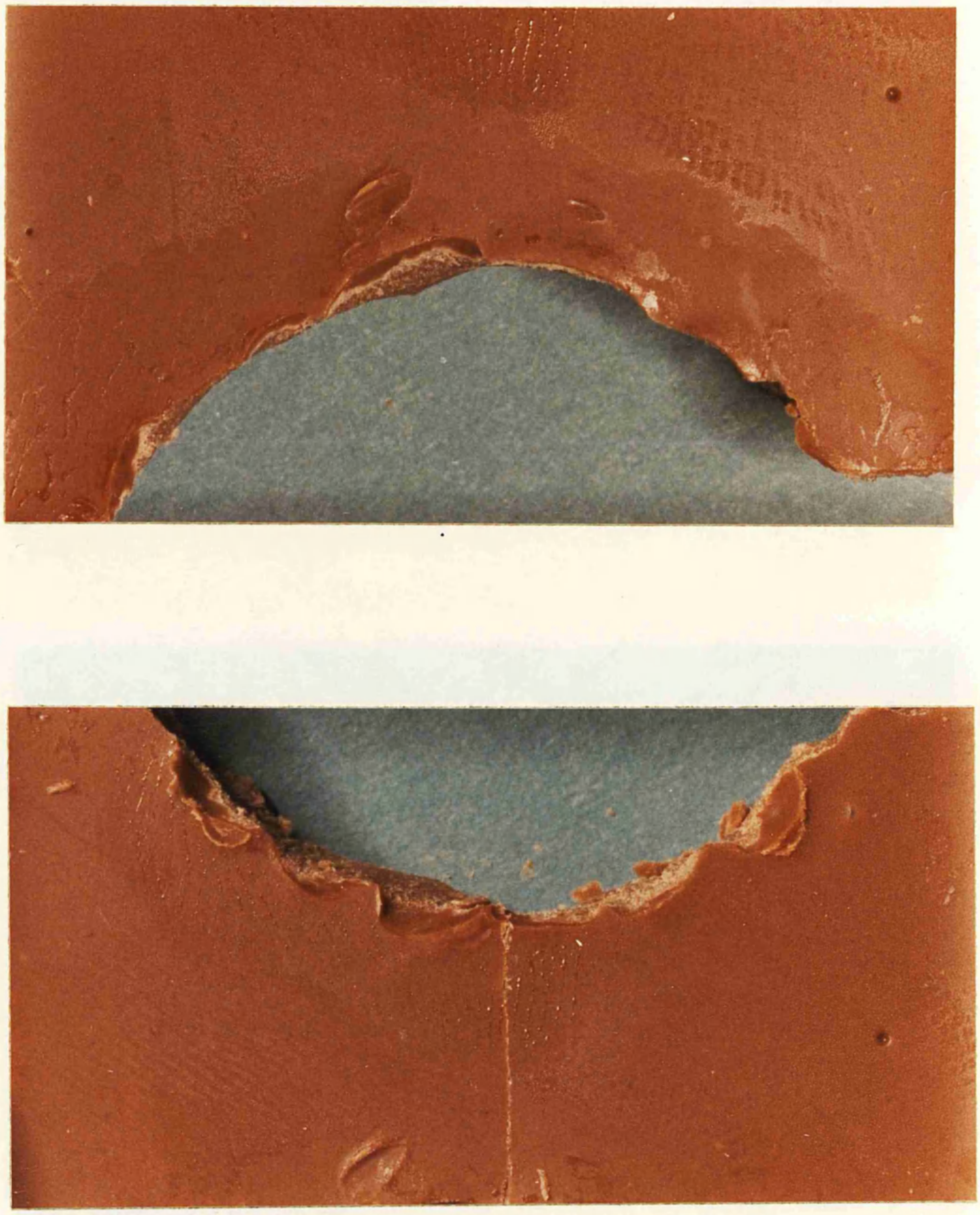


Fig. 6.2 Type one food bite marks. The most prominent parts of the anterior teeth are shown up to a depth of about 2 mm.

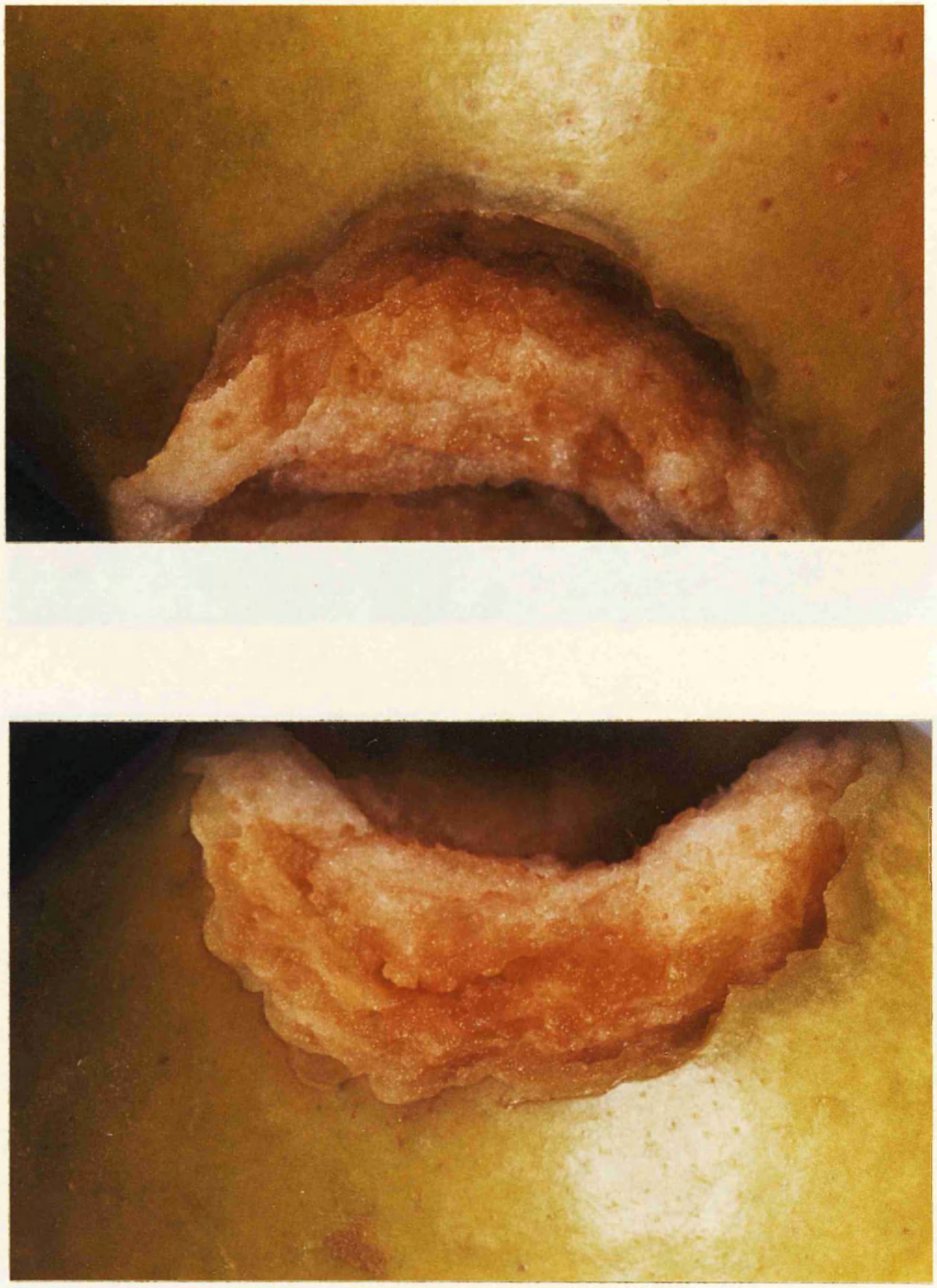


Fig. 6.3 Type two food bite marks. The incisal edges are not always evident, but a record of the most prominent part of the labial surfaces of the anterior teeth is usually recorded.

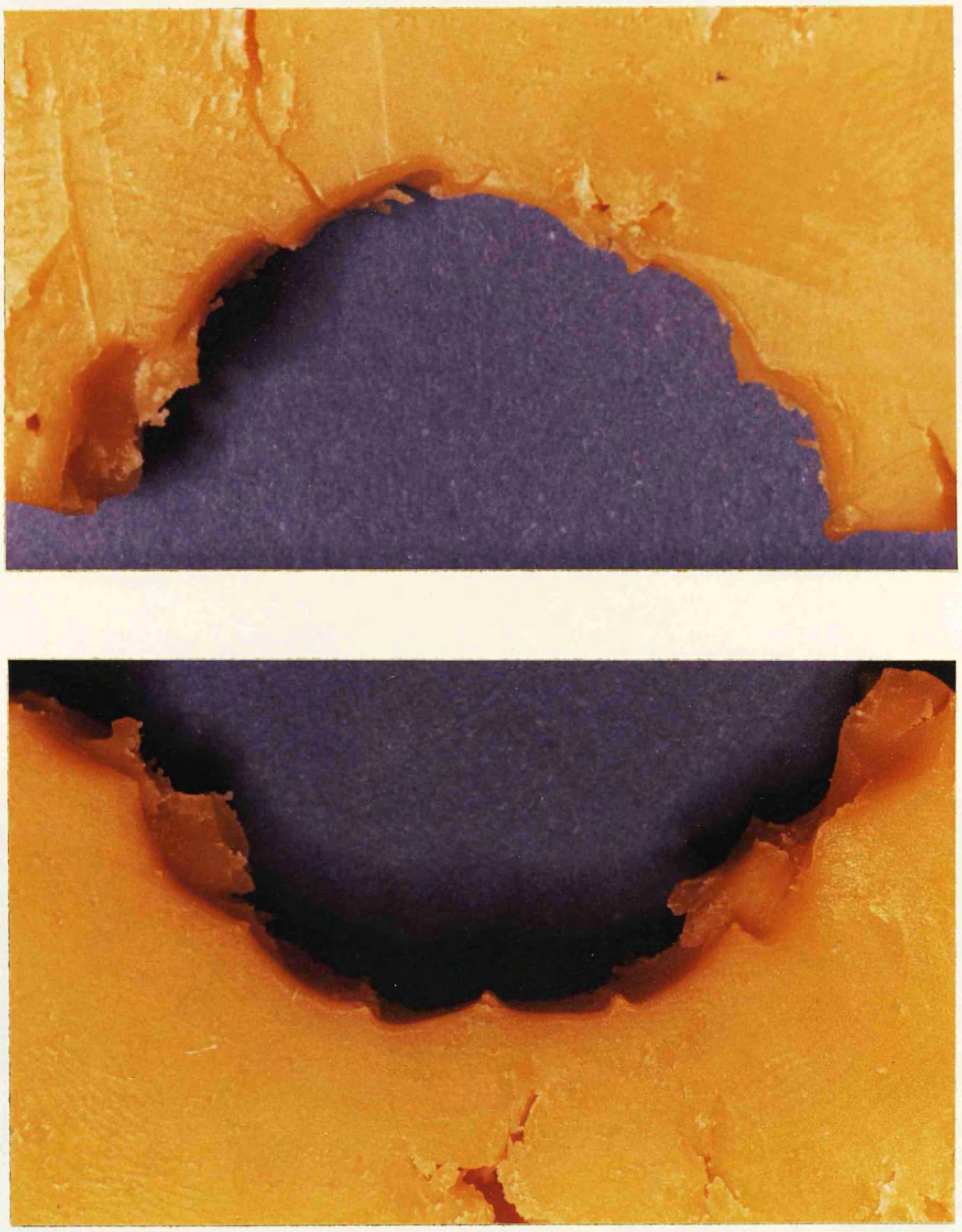


Fig. 6.4 Type three food bite marks. The depth of penetration varies and records the labial surfaces of the anterior teeth.

Fig. 6.5 A distorted canine mark (A). The $\underline{/2}$ (B) appears to be rotated but was in correct arch position on the model.

Fig. 6.6 The canine mark is distorted and torn.

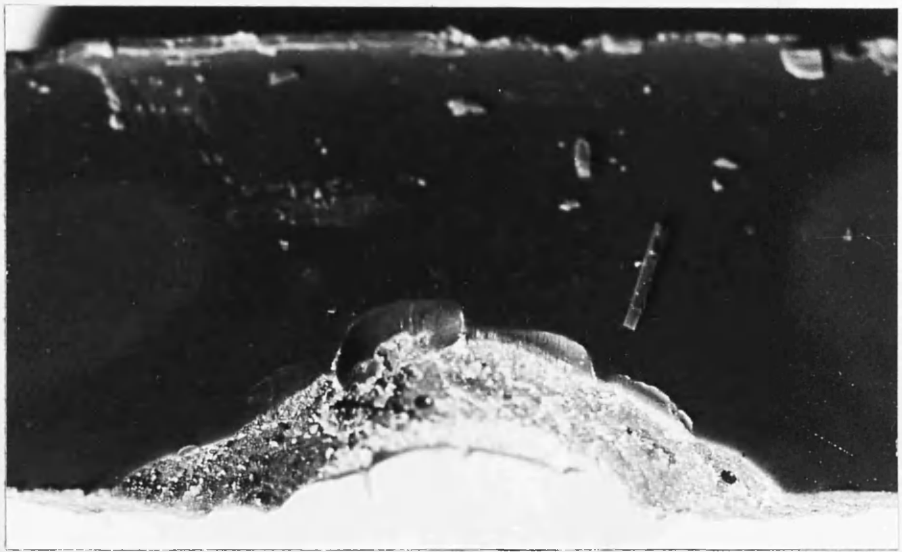


Fig. 6.7 The material has broken through the canine area and the lateral incisor is not recorded.

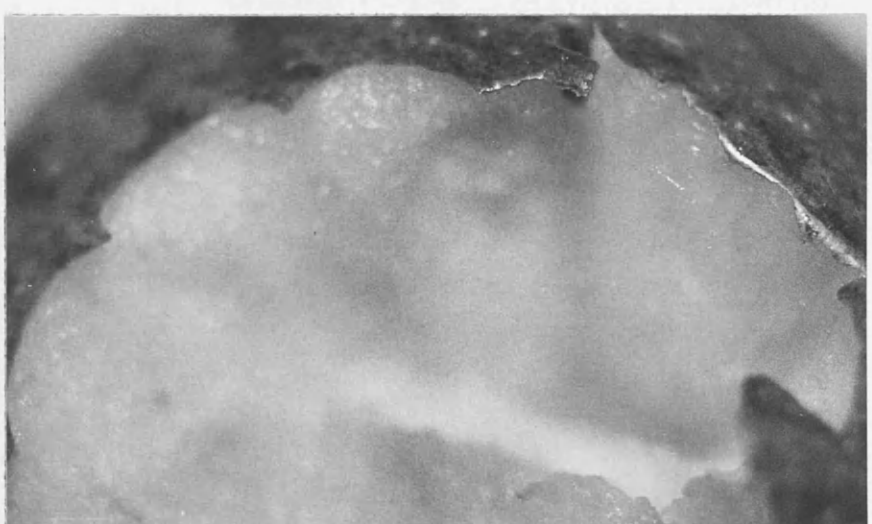


Fig. 6.8 There is no evidence of individual tooth marks on the right side of the bite and the skin is torn.

Fig. 6.9 A bite mark on a large apple.

Fig. 6.10 A quite different mark made by the same biter as above on a small apple.

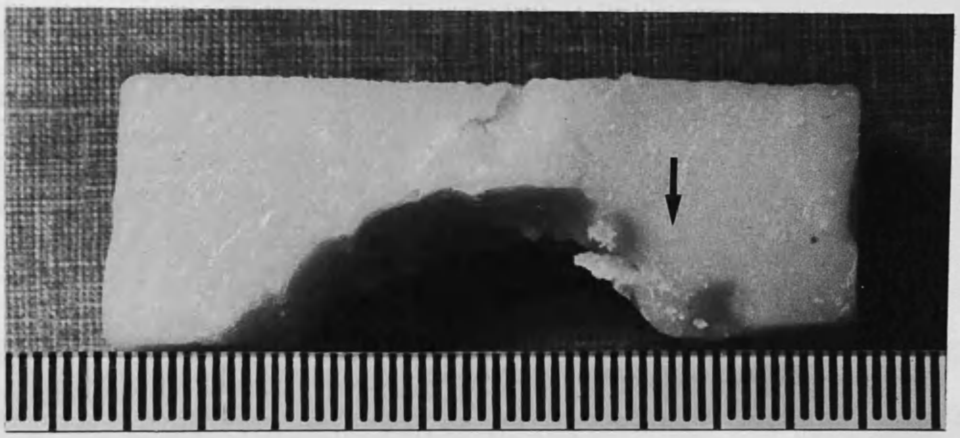


Fig. 6.11 This canine mark is wider than the natural tooth because the lateral incisor is short and was not included in the bite.

FORENSIC ODONTOLOGY

EXPERIMENTAL BITE MARKS IN FOODSTUFFS

7 THE COMPLETE INVESTIGATION

7.1 INTRODUCTION

Despite an increasing awareness by the courts of the value of forensic odontological investigations, there exists still, a degree of scepticism about the accuracy of bite mark evidence. The evidence of the forensic dentist, stating in court that he believes a bite mark had been made by a particular dentition is likely to be subjected to a searching cross examination. It is essential therefore that all possible evidence is utilised in the presentation of a report, or is reported by other experts.

Foodstuffs or other inanimate objects are held in the hand during the biting process and finger prints may be left on the bitten material; also saliva traces may be deposited on the foodstuff. It has been stated that attempts should be made at a very early stage in criminal investigations to collect saliva from possible bite marks (Clift and Lamont, 1974). Experimenting with bite marks in food Schaidt (1954) claims successful determination of blood group substances from saliva traces in 4 out of a possible six cases, and reported that with cheese bites the blood group could be diagnosed in 'almost every case'. The same author states that generally speaking it can be said that in some two thirds of those cases where blood groups A, B, or AB are present, identification of these groups should be possible.

It seemed desireable therefore that attempts should be made to investigate the possibility of using finger prints and saliva traces to corroborate other evidence in cases of bitten foodstuffs and a number of experiments were devised.

7.2 FINGER PRINTS

The chance of two individuals having exactly the same finger prints is at least one in 64,000 millions (Galton, 1892) and the skin pattern is constant through out life (Herschell, 1916).

The overlying epidermis of the skin is folded in ridges and furrows along the surfaces of which are found the ducts of sweat glands. The act of criminal activity may excite the individual and the normal sweat excretion from the glands can be considerably increased. As the sweat contains fat and if the skin is applied to a smooth surface an impression of the skin pattern may be made on the object. Many techniques are available for the demonstrating of finger prints but for the purposes of this study only one was used.

7.2.1 Material and Methods

Bites were made on samples of cheese, chocolate and apples which were of the size and shape used in the previous experiments. The materials were examined visually for the presence of finger prints.

Where finger prints were noted as being present the materials were very lightly dusted with aluminium finger print powder (supplied by the Strathclyde Police Force) using a soft camel hair brush for the purpose. Finger print lifting tape is manufactured in 2" wide rolls similar to commercial sticky tapes (Fig. 7.1) and a length of this was cut for each specimen, taking care not to contaminate or touch that part of the tape which would be applied to the finger printed area. The tape was laid gently over the required area, smoothed down, and thereafter peeled off. This tape now contained the prints and it was then laid on cellulose acetate sheets measuring 6" and 4" with the finger print surface in contact with the sheets, thus allowing safe handling. The cellulose sheets were treated as photographic negatives, and from them photographic prints were obtained in the normal fashion (Fig. 7.2).

7.2.2 Results

Finger prints were obtained from a number of cheese and chocolate specimens, but bitten apples, were found to be particularly resistant and this appeared to be due to the water proof property of the apple skin. In addition difficulty was experienced in applying the lifting tape to the apples. After twelve hours at room temperature the oily film which exudes from cheese made it impossible to lift the prints and when this had dried out after three or four days, all evidence of finger prints had usually disappeared or was distorted. Chocolate specimens retained the marks and in one case finger prints were obtained two days after it was made. As before, apples dried out and exhibited such a degree of distortion that they were useless after 24 hours.

When lifting the finger prints it was found that the bite mark could in effect be lifted as well and Fig. 7.3 shows a section of bitten cheese and the lifted bite mark photographed as described. This mark was found to be dimensionally accurate and physically exact such that a model of the biter's teeth could be placed over the bitten surfaces. This was demonstrated in both cheese and chocolate bites.

7.3 SALIVA TRACES AND BLOOD GROUPING

The detection and subsequent ABO grouping of saliva traces may provide evidence of the possible association of an individual and a bitten foodstuff. In many forensic investigations highly sensitive techniques are used to indicate the presence of saliva, but in the case of bite marks in food it is logical to assume the presence of saliva traces on the bitten object.

As the bitten foodstuff is held in the hand the possibility of contamination from sweat exists but the most up to date techniques are very sensitive and should be well controlled to avoid possible false positive results from other body fluids.

The main blood group substances are present in water soluble form in body fluids such as the saliva of secretors who make up about 80 per cent of the population. The concentration of blood group substances in saliva is very much higher than it is in blood itself and it is possible therefore to group very small traces. The tests used are absorption-elution and absorption inhibition which are carried out in parallel to avoid or overcome bacterial or other interference, and using these methods A and B blood group substances in some non-secretors can sometimes be detected also (Nickolls and Pereira, 1962). The forensic odontologist is not concerned with the laboratory techniques as such, and this work should ideally be carried out by a forensic laboratory, although it is within the scope of any hospital haematological laboratory, providing the methods are known.

The investigating dentist, however, may be concerned in the collection of the saliva trace and of samples of the suspects saliva, and there follows suggested techniques for this collection.

7.3.1 The Suspect's Saliva

The suspect should be asked to dribble into a clean sterile test tube producing if possible at least 2 ml of saliva, and this may take some time. Ideally the saliva should then be boiled in a water bath for ten minutes as soon as possible after the sample has been obtained. This inactivates enzymes and precipitates proteins which can then be spun off and the saliva is no longer glutinous. While it is desireable that this process be carried out as early as possible, a delay of up to 24 hours does not seem to cause any deterioration. The saliva should be collected in the presence of a witness, (preferably police personnel). The test tube should be labelled to show the time when it was collected and a production label must be signed and attached thereto.

7.3.2 The Saliva Traces

Various schools of though exist as to the best method of collecting saliva traces from flesh bites on deceased persons, which may be limited by the fact that the forensic dentist is unlikely to have access to a body until it has reached the mortuary and the risk of contamination is high in such circumstances. Flesh bites on living subjects present less problems providing the subject is not allowed to wash the bitten area before collection is attempted. The method used in flesh bites can readily be adapted for bites on foodstuffs.

Probably the simplest technique for the use of the forensic dentist is that described by Clift and Lamont (1974) who advocate the use of 1 cm^2 pieces of 'Rizla' type cigarette paper held in forceps and never touched by hand. The squares of paper are dampened in fresh tap water or distilled water and used to swab the bitten area. Both sides of the paper should be used and the forceps moved such that the collected material is evenly distributed over both sides and the whole area of the paper. Following the swabbings the squares of paper are placed on clear glass and allowed to air dry as soon as possible after collection.

The same procedure should be used to take control swabs from the non bitten area of the bitten food. A further swab simply dampened in water as a control of the paper and the water is also necessary. The control swabs should be cut in different shapes from the squares used to collect the saliva in order to avoid any possibility of confusion in either the laboratory or in Court.

The dried swabs are packed in labelled pre-folded non-absorbent writing paper, placed in labelled envelopes and sent to the laboratory as quickly as possible.

In the absence of cigarette paper, lengths of white cotton thread can be used for the collection of the traces. The thread should be preferably taken from cloth which has been washed many times and old laboratory coats have been shown to be ideal for the purpose.

A possible difficulty in these techniques could be the lack of saliva trace left on the bitten foodstuffs. As has already been pointed out what one is dealing with is the remainder of a foodstuff from which a piece has been bitten out and removed. This would be particularly so in cases of bitten apples when almost the whole area which has been in saliva contact has been taken away.

7.3.3 Specific Saliva Antisera

Research is presently being carried out in the Glasgow Dental School which may be of considerable value in the identification of individuals from saliva stains, and already it has been shown that α amylase has a variant which is detectable by isoelectric focussing. There are other polymorphic proteins in whole saliva which could be of value in forensic investigations, but most important a saliva specific antiserum has been developed for the identification of saliva traces (Eckersall, 1979 personal communication).

7.4 SUPERIMPOSITION PHOTOGRAPHY

Techniques using superimposition have been used for many reasons and perhaps the most well known is that of the Ruxton case described by Glaister and Brash (1937). Modifications of these methods have been used in bite mark Court productions prepared by the forensic odontologists at the Glasgow Dental School for some ten years.

As flesh bites are seldom found on exactly flat surfaces and as there may be a distortion factor of + 10 to - 5% of the tissue, (Susuki, Suzuki and Hadano, 1970) certain limitations are imposed on superimposition techniques. However where such methods are employed it is usually possible to demonstrate the relationship between the characteristic features of a bite mark and the same features in the dentition which made the bite. It has been shown that the characteristics of a dentition are reproduced in food bite marks and a small experiment was devised to test the suitability of applying superimposed overlays to the photographed marks.

7.4.1 Material and Methods

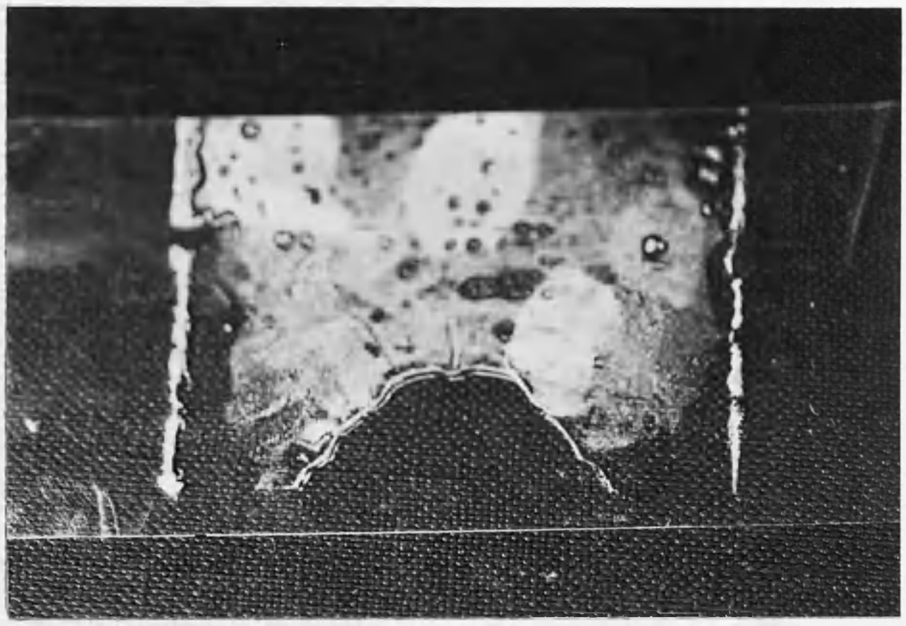
Black and white photographs with a mm. scale incorporated were taken exactly life size of bite marks on cheese, chocolate and apples to show the outline of the bites and views of the incisal edges of the plaster casts of the biters teeth were also taken, in such a way that the lighting high lit the incisal edges of the teeth. The photographs were printed in the normal fashion, on a one to one basis.

A second set of prints of the models were produced as positives on transparent Kodagraph ortho negative film with the images reversed, and these photographs were printed extremely thinly such that when they were laid upon the bite mark prints the details of the mark could be seen through the overlay.

7.4.2 Results

Successful overlaying of bites was demonstrated in cheese bites (Fig. 7.4) and in chocolate, but apples presented difficulty. When the detail in the bites was indistinct it was still possible to show the relationship between the components of the bite and the teeth, as can be seen in the lower bite mark (Fig. 7.5). Instances occurred when the overlay could not be shown to match the bite marks, and this was due to distortion of the tooth marks, and in the case of chocolate when the material had fractured.

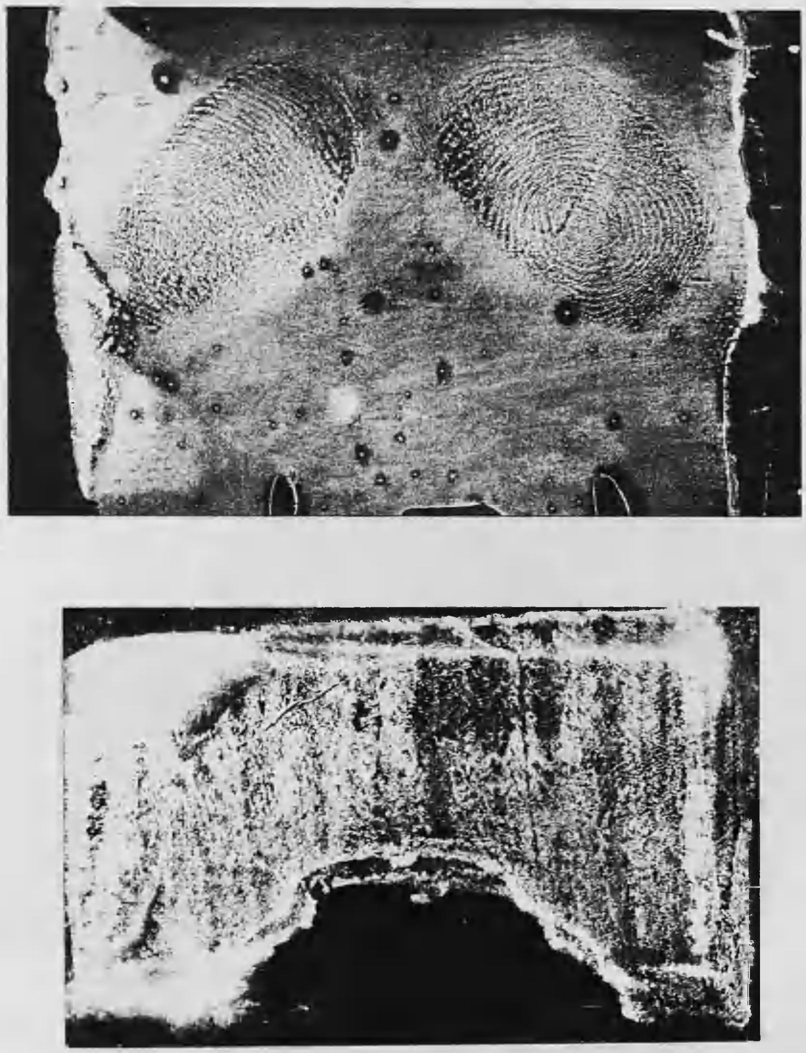
Fig. 7.1 The finger print lifting kit.



A

B

Fig. 7.2 Tape in position prior to lifting the finger prints (A). Photographed finger prints and the bite lifted from chocolate (B).



A

Fig. 7.3 Finger prints obtained from chocolate (A), and a bite mark lifted from cheese.

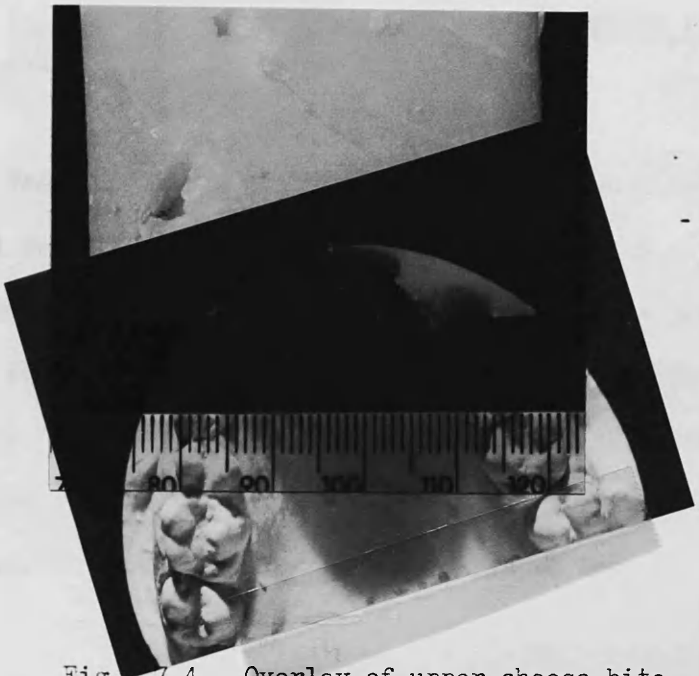


Fig. 7.4 Overlay of upper cheese bite. The lingually placed lateral incisor is obvious.

Fig. 7.5 Overlay of lower bite mark in cheese. The details of the bite are not very clear but the overlay allows apparent successful matching.

7.5 THE PREPARATION AND PRESENTATION OF A REPORT FOR COURT PURPOSES

The forensic dental investigator is in most cases an expert in some practical dental field, be he no more than expert as a general practitioner in his own practice, yet at any time he may be asked to provide a report or evidence for criminal proceedings in an area previously denied him in his daily work. The investigation should follow particular lines and these should be followed out in the ultimate report which goes (in Scotland) to the Procurator Fiscal for production in a Court of Law.

The author is of the opinion that the format to be described fulfils the criteria necessary to satisfy the Court of the accuracy of a dental investigation while allowing both prosecution and defence the opportunity to lead or question the evidence in a manner which can be understood by all the parties concerned. The method of preparing a report should follow the lines of a scientific paper and this technique is to be preferred to the novelist or journalistic approach.

In the mock incident described, the photographs which would be part of the Court production are included at the end of the chapter. Corroborative evidence from a second expert would be required, and all persons involved in photography, model casting, saliva testing or finger printing would be cited to speak to their part in the investigation.

7.6 THE COURT PRODUCTION

The Procurator Fiscal,
Court Buildings,
Inverclyde.

CASE OF JOHN PHILIPS

INTRODUCTION

On Thursday 16th December 1978 at 9.30 a.m. I received a telephone call from Detective Inspector William Little, C.I.D. Inverclyde Police who requested my assistance in the investigation of a case of serious assault. Inspector Little explained the circumstances of the case to me, which were that a night watchman at a building site had been assaulted the previous evening around 11.30 p.m. A portion of cheese which had allegedly been bitten was found at the locus of the crime. A suspect denied having been in the area. I arranged to attend the police station at 10.30 a.m.

At the police station I was shown a portion of cheese from which a piece was missing. A number of marks were present in the cheese which suggested it had been bitten.

I instructed police photographer Mr. David Johnstone on the taking of detailed black and white and coloured photographs of the cheese.

Using Rizla type cigarette papers held in forceps I swabbed the area of the bite for saliva traces using fresh tap water and took control swabs.

The swabs were air dried on clean glass slides and individually wrapped and labelled. The slides were given to Detective Constable Rennie for delivery to the Forensic Medicine Department at Inverclyde University.

DETAILED DESCRIPTION OF THE BITTEN CHEESE

The specimen of cheese which measures some 35 x 70 x 10 mm is of the 'processed' type and may have been purchased individually wrapped in this shape from a 'carry out' food shop. An oval piece is missing from one corner and the marks on the residue are of the shape and size seen in food bites.

The upper part of the mark consists of an arc and shows evidence of several individual components, and the size and shape of these allow this to be positively identified as having been made by human upper front teeth.

Detailed study indicates that the upper part of the mark shows the features of five individual adjacent teeth, these being 2 1 | 1 2 3. Furthermore there is an indication of several distinctive features in the shape and alignment of the teeth which have caused this mark. /1 and /2 show mild mesio labial rotation and there is evidence of a large gap between these two teeth and of a gap between 1/ and /1. The tooth in the position of 2/ is marginally displaced from the arch, in a labial direction (towards the lips).

The lower part of the mark is also in the shape of an arc and shows four features which can positively be identified as tooth marks and these are $\overline{2\ 1\,|\,1\ 2}$. The alignment of $\overline{1\,|\,1}$ is very distinctive as both teeth are rotated in the mesio lingual direction (towards the tongue) causing a V shaped mark to be formed. $\overline{2|}$ is rotated mildly in the mesio labial direction.

DENTAL INVESTIGATION OF JOHN PHILIPS

Philips was brought to Inverclyde Dental Hospital at 3.50 p.m. on Monday 20th December 1978 in the company of Detective Sergeant Baird and Detective Constable Rennie.

In accordance with a warrant of the Sheriff of North Inverclyde at Glasgow and dated 20th December 1978, I examined Philips and obtained dental impressions. The impressions were given by me, directly to Mr. John Carter, Tutor in Dental Mechanics in the Orthodontic Department of Inverclyde Dental Hospital. Mr. Carter cast models of Philips' teeth in dental stone and gave them to me on Wednesday 22nd December.

The following are the findings of the dental examination of Philips.

Teeth Present at Time of Investigation

Upper right | Upper left

8	7		5	4	3	2	1	1	2	3	4	5		7
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7

Lower right | Lower left

Teeth Missing

Upper right | Upper left

6	6	8 (unerupted)
		8 (unerupted)

Lower right | Lower left

Restorations (All amalgam)

Upper right — Upper left

	o	bo	lo	mo	do	o	mo		lo
	8	7	7	5	4	4	5		7
8	8	7		6		4		6	7
b	o	mod		mod		do		mod	o

Lower right — Lower left

Abreviations

o	occlusal	mo	mesial occlusal
lo	lingual occlusal	do	distal occlusal
mod	mesial occlusal distal	bo	buccal occlusal

Special Characteristics

Lower teeth

1/ shows mild mesio lingual rotation. 2/ shows mild mesio labial rotation. /1 is mildly rotated in the mesio lingual direction and /2 is mildly rotated disto lingually. A gap of 2 mm is present between the distal aspect of /3 and the mesial aspect of /4.

Upper teeth

/1 and /2 are mildly rotated in the mesio labial direction. A gap of 2 mm between the /1 and /2, coupled with the rotation of /2 which is about 30^{o} is a very distinctive feature. 2/ is very slightly displaced labially from the arch and there are gaps of 2 mm between 1/ and /1 and between 2/ and 3/. A 1 mm gap is present between /2 and /3 and a 3 mm gap is present between /3 and /4.

COMPARISON OF THE BITE MARK ON THE CHEESE AND THE TEETH OF JOHN PHILIPS

The bite mark on the cheese shows clearly distinguishable marks of five upper front teeth and four lower front teeth. Philips has natural teeth to account for each of these teeth marks.

The teeth marks in the bite show evidence of distinctive individual tooth characteristics. All of these characteristics are evident in Philips' teeth.

Comparison of transparent prints of the upper and lower models of Philips' teeth shows accurate superimposition of $\underline{2\ 1 \,|\, 1\ 2\ 3}$ and $\overline{2\ 1 \,|\, 1\ 2}$ and the marks in the bite identified as having been caused by these teeth.

CONCLUSIONS

1. The mark in the cheese found at the locus is a human bite mark.
2. Within this mark the features of five upper teeth and four lower teeth can be distinguished and each of these teeth can be seen to have possessed individual distinctive characteristics.
3. John Philips possesses the teeth observed in the bite mark and there is correspondence of the distinctive features of all nine teeth.
4. Superimposition shows that Philips' teeth correspond closely in size shape and positions, with the bite in the cheese.

5. It is my opinion that the bite in the cheese was caused by the teeth of John Philips.

Attested on soul and conscience

Gordon Webster, B.D.S.(Glasg).

CASE OF JOHN PHILIPS

DENTAL INVESTIGATIONS

Figure Legends

A Bitten cheese upper view (natural size).

B Bitten cheese lower view (natural size).

C Model of Philips' upper teeth (natural size).

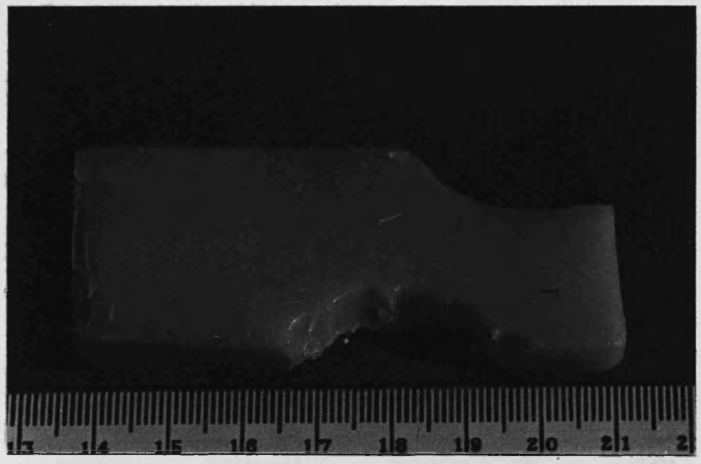
D Model of Philips' lower teeth (natural size).

E Reversed view of model of Philips' upper teeth (natural size).

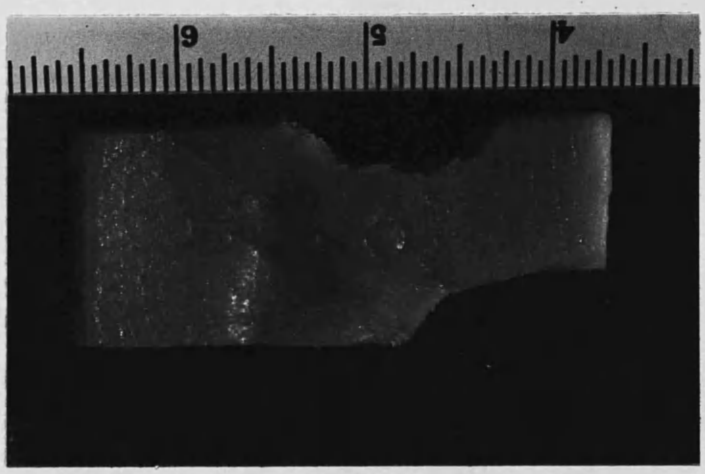
F Reversed view of model of Philips' lower teeth (natural size).

G Bitten cheese with superimposed reverse view of model of Philips' upper teeth.

H Bitten cheese with superimposed reverse view of model of Philips' lower teeth.



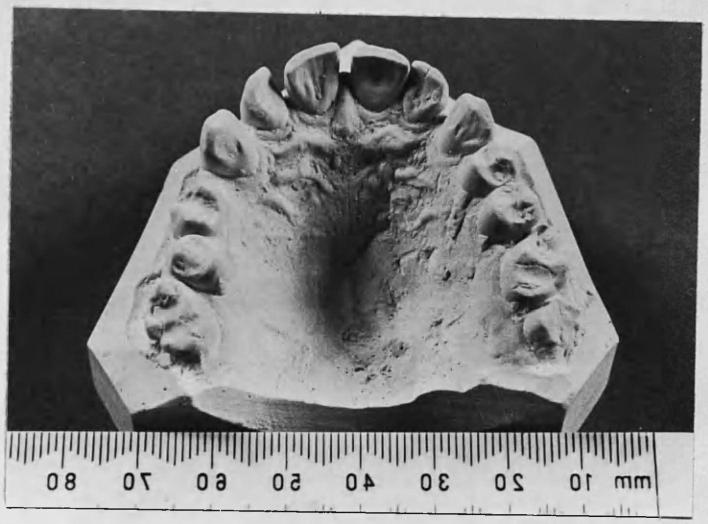
A



B

C

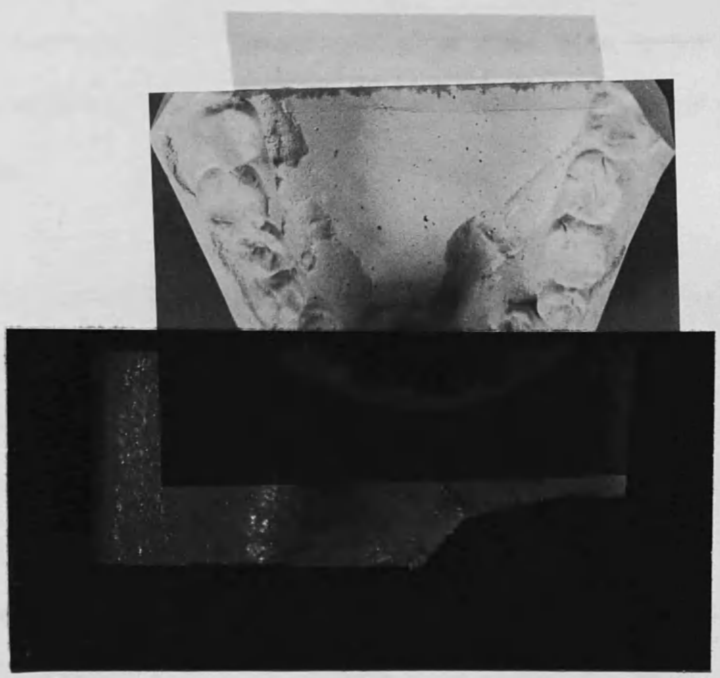
D



E

F

G



H

7.7 DISCUSSION AND CONCLUSIONS

The object of this Thesis has been to gain credance for the concept that a degree of credibility is possible in the assessment and analysis of the dental characteristics which are found in bite marks in foodstuffs, and their accurate comparison with the characteristics in the dentitions of those who made the bites. In a subject which has lacked scientific backing for many of the conclusions which have been reached, it is desirable that the methods of investigation will stand scrutiny by other experts.

In the past assumptions and even errors have been accepted and perpetuated. For example the marks made by the teeth in food bites have been treated as though the marks were the outlines of incisal edges, and plaster casts have been shown 'to fit'. The present studies have shown this assumption not to be true, and that the ultimate bite mark is dependent on the depth of penetration of the teeth and on the material itself. Arising from these observations a classification of food bite marks has been devised and this could be used in Court to satisfy the causation of individual marks within a bite.

It is now known that each tooth in the dentition making a bite does not necessarily cause a mark within the bite. Such factors as short or displaced teeth may not be represented in a bite. It is clear that in general, reliance should only be placed on the upper and lower central and lateral incisors in the analysis of food bite marks. Even when six upper and lower anterior teeth are present in the mouth, the canine marks may be distorted or absent.

It has been proved from the analyses that the data on the features of arch position and tooth rotation is very reliable and that such features are faithfully reproduced and can be accurately identified in the majority of cases, despite a small number of false positive findings. The use of other characteristics such as the wedge shapes caused by teeth which lie outwith the arch can be used to compliment other findings.

The value of making replicas of bitten foods is debatable but the use of Silcoset to obtain labial views of the teeth is highly successful and satisfactory and affords the investigator the opportunity to check his analysis in situations where overlapping, displaced, or rotated teeth appear to be present in the dentition. In addition this labial view of the teeth can be compared to models of the suspect's teeth if these become available.

Other supporting techniques have been shown to be of value and in the absence of a photographer the technique of lifting the bite mark using finger print powder and tape could be utilised by the police. It may be worthwhile to examine other methods and materials which could be used to lift bite marks.

The experiments on food preservation have indicated that the three foodstuffs studied can be usefully analysed up to 24 hours when the exhibits have been stored in a refrigerator, but beyond this period bitten apples in particular can not be accurately analysed by the methods which the author employed in this study.

The study of bite marks in food should not be considered as an extension of flesh bite mark examination, but as a separate entity. The mechanism of biting food is quite different from that of agression and the end result is also different. It has been explained that the food bite mark is the residue after a piece of the material has been removed. However, the common factor between the two types is the analytical method which has been applied in this Thesis. The use of the features of tooth presence, arch position and tooth rotation also allows the application of the statistical evaluations of MacDonald, MacFarlane and Sutherland (1973) to either type of bite. Thus despite discussion to and fro in Court about the fitting of plaster casts into bites, the changes in shape or weight of the specimens, or the accuracy of simulated bites, at the end of the day only the correct analysis of the features is of proven scientific value.

It is the author's hope that the findings and results of this work will add credibility to this branch of forensic science and that one more step towards the recognition of bite marks as an accurate method of identification has been achieved.

SUMMARY

Bite marks in flesh and in inanimate objects such as foodstuffs have been reported in the criminal field for many years. The methods used in the investigations have been largely individual, and little detailed research has been carried out to establish the accuracy or otherwise of the techniques employed.

Tooth characteristics have been studied by MacDonald, MacFarlane and Sutherland (1973) and the statistics obtained have been used to establish the probability of a given dentition having made a particular bite. The difficulties of obtaining and studying large numbers of bites in human subjects are obvious and because the police report many instances of bitten foodstuffs found at scenes of crime, it was decided to study bite marks in food.

The aim of the work described in this Thesis was to advance knowledge of the accuracy of the reproduction of tooth characteristics, and their identification within food bite marks. To achieve this, methods of preserving and recording bitten specimens were studied. The bites were analysed to find which types of tooth marks are recorded and how these relate to biting mechanisms, such that a classification of bite marks in food was devised. The features of teeth which were recorded in the marks were assessed to discover how accurately the characteristic features of a dentition could be identified in the bites, and the numbers of false positive results which were obtained were also analysed.

It was desirable to use the materials most likely to be bitten by criminals, and cheese, chocolate and apples were repeatedly bitten by two

individuals, as a preliminary experiment. This study indicated that although six upper and six lower anterior teeth may be present in a dentition it was not always possible to identify this number of tooth marks within the bites; thus reliance should only be placed on positive characteristics which are identifiable in the bitten material. Lower tooth characteristics were more frequently recorded than upper tooth features, but even distinctive features known to be present from model analysis, were not always discernible in the bite marks.

No false positive recording of features occurred in this very subjective study but it was decided that these could have been missed because experience gained in analysing and recording a very limited number of features, was probably applied to interpret doubtful points.

Attempts to measure intercanine distances and individual tooth widths within the bites indicated that such measurements were unreliable.

To examine the validity of these preliminary results, which had been obtained from a fairly crude analysis, much larger definitive experiments were designed to concentrate mainly on the recognition of distinctive features. The bites were made by 30 students. The bite marks and the student models were analysed separately and an additional 20 sets of models were included in the model series from students who had not supplied bites.

The study of tooth status data has allowed the conclusion that teeth present in the mouth do not always give marks in bites; thus the absence of an expected mark is not an incompatible inconsistency.

The analysis of the features of arch position and tooth rotation of the incisor teeth confirmed the earlier findings that these features are recorded and identified most accurately. The few false positive results which were obtained has suggested that apparent lack of complete correspondence should not necessarily constitute an incompatible inconsistency.

It is necessary that all available information about the suspect in a crime should be studied and it has been shown that superimposition photography, saliva testing and lifting fingerprints from bitten foods can be used to complement the analysis of tooth characteristics in food bite investigations.

Much of the method of analysis and comparison which has been described could be applied to bite marks in flesh. It is suggested that these methods could form a basis for a series of animal studies in which bites made on anaesthetised animals prior to sacrifice, be analysed and quantitated.

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