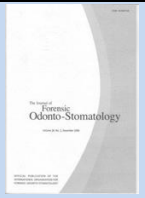


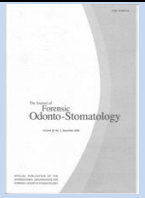

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SECTION BITE MARKS

A SIMPLE, SAFE, RELIABLE AND REPRODUCIBLE MECHANISM FOR PRODUCING EXPERIMENTAL BITEMARKS

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ABSTRACT

With improving technology it should be possible to develop an objective, reliable and valid method that can be undertaken by most forensic Odontologists without recourse to expensive or bulky equipment. One of the main factors that affect the physical appearance of bitemark is the amount of force applied during biting. There is little evidence relating the appearance of a bite mark to the amount of force applied and how that force relates to the biters maximal biteforce. This paper describes simple apparatus that can be used to inflict experimental bites on living subjects reproducibly and with minimal risk.

The aims of this study are to report on the development of a mechanical apparatus that produces experimental bitemarks on living human subjects with a known force in a safe, reliable and reproducible manner and to relate the force applied during production of the experimental bitemark to the maximum bite force of the biter. Maximum bite force of one of the authors was determined as 324N. Experimental bitemarks were inflicted on living subjects with known weights. Weights of up to 10kg were well tolerated by the subjects. The relation between forces used to inflict bites and the maximum bite force of the author is reported, with 10kg being approximately one third of the maximum bite force. The apparatus was well tolerated and the results were reliable and reproducible. The results from this study could help in determining the severity of bitemarks. This apparatus could help researchers in developing objective based bitemark analysis techniques.

KEYWORDS**:** *forensic dentistry, bitemark, biteforce, living subjects*

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INTRODUCTION

Bitemark (or tooth mark) evidence is relied on by legal systems throughout the world in a wide range of cases.[1] Historically, bitemarks have been examined in a subjective manner. With the increased scrutiny of courts to ensure reliable evidence it is important to develop an objective, reliable and valid method of analysing bitemarks. With improving technology it should be possible to develop such a method that can be undertaken by most forensic odontologists without recourse to expensive or bulky equipment.

Bitemark studies have used experimental bites on a variety of substrates: wax,[3] Styrofoam,[4] porcine skin models,[5-7] plastic and embalmed cadaver models.[8-11] Few studies have produced experimental bites on living human subjects.[12]

There are a number of techniques for producing experimental bites. Some studies have used a clamping mechanism connected to a force transducer to produce the bite[8,9] while others have used a vice grip linked to a load cell for monitoring the force applied.[13] The disadvantage of using a clamping technique on living subjects is that force may not be applied evenly over time and it may take some time to release the force if the subjects' pain threshold is exceeded. A load cell has the potential to malfunction which could result in increased weight being applied for longer durations causing injuries to the subjects.

One of the main factors that affect the physical appearance of bitemark is the amount of force applied during biting.[6] Using a gnathodynamometer, Sheper related the changes observed in the bite forces generated during normal and anger states of human volunteers to the resultant bitemarks on wax.[14] However, there is little evidence relating the force applied to produce a bitemark to the level of effort of the biter. Many studies within the discipline of oral physiology have measured the maximum biteforce of individuals.[15-17] This paper describes a simple apparatus that can be used to inflict experimental bites on living subjects reproducibly and with minimal risk.

The aims of this study are to report on the development of a mechanical apparatus that produces experimental bitemarks on living human subjects with a known force in a safe, reliable and reproducible manner and to relate the weight applied during production of the experimental bitemark to maximum bite force of the biter.

MATERIALS AND METHODS

The first step in the study was to construct a mechanical apparatus for production of experimental bitemarks (Fig 1).

The mechanical apparatus was a metal frame that supported a vertical rod and a loading platform. Upper and lower alginate impressions of one of the authors were taken along with a facebow recording and an occlusal record. Casts were produced in die stone (Shera premium, Sherawerkstoff-technologie®, Lemforde, Germany) and articulated on a semi-adjustable articulator (DenarMK II®, Prestige dental, Bradford, England).The articulated casts were placed within the frame under the rod allowing a load to be applied to the cast. A locating jig that ensured consistent and full transfer of the load to the articulator was constructed from self-cure acrylic (Unodent®, Witham, England). - The frame was large enough to allow entry of an arm into apparatus. Weights of 5kg, 7.5kg and 10 kg were used for production of test bites on the forearm of subjects. Positioning the subjects' forearm during the production of bitemarks in the device was done without causing any discomfort to the subject and bitemarks were easily produced.

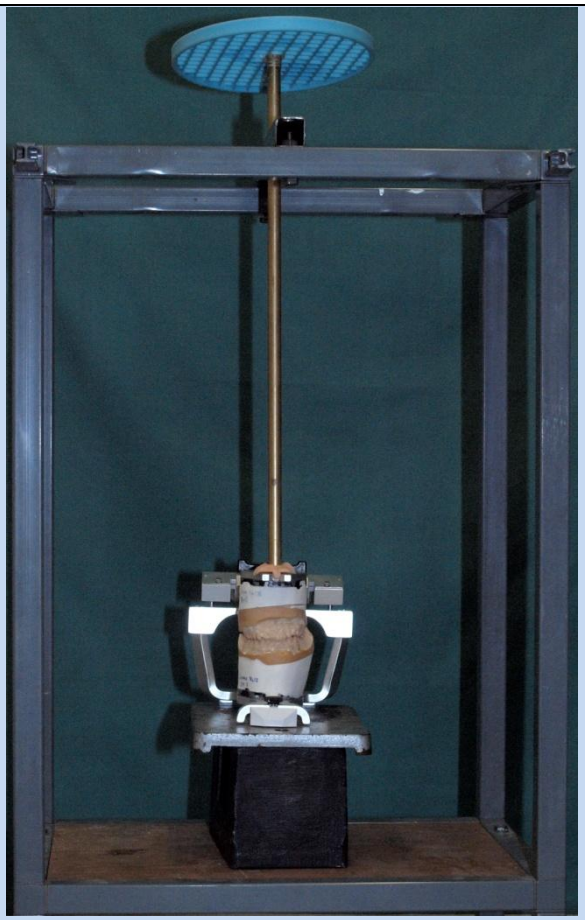

Fig.1: Biting apparatus with articulator in place

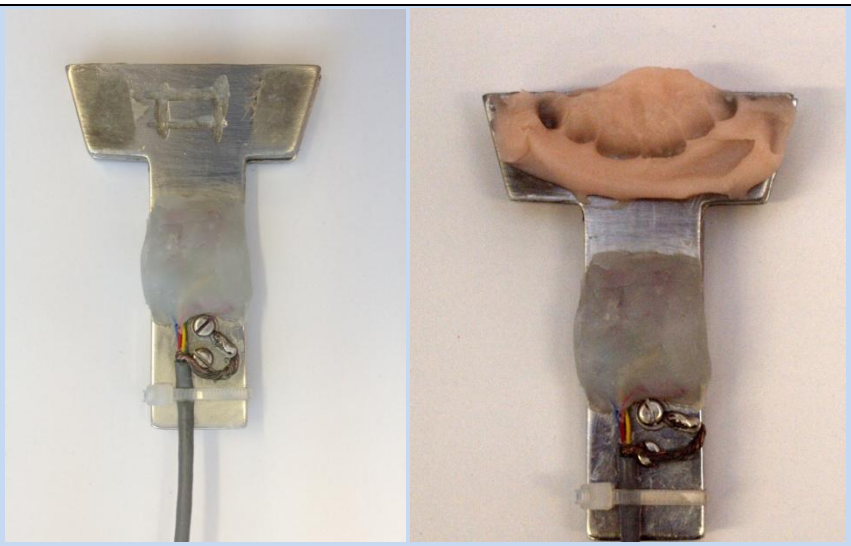

Fig.2: Left: Metal force transducer. Right: Metal force transducer with occlusal index to ensure constant positioning during experiments.

The second and major part of study, testing the apparatus, involved measuring the maximum bite force of the biter and using casts of his teeth to inflict bites on the subjects. This allowed the weight applied on the apparatus to be related to the maximum bite force. Following ethics approval two male subjects aged 25 and 45 volunteered for the study: subject 1 and 2 respectively.

The maximum biteforce of the anterior teeth was measured using a metal force transducer (Fig 2). Metal force transducers have been used in many bite force studies.[18-21] The force transducer used in this study was described previously by Lyons *et al.* (1996).[20] It consisted of two metal beams with two strain gauges attached to each side of one of the beams; the four strain gauges were connected in a Wheatstone bridge circuit. The overall thickness of the transducer was 8 mm.The change in resistance of the strain gauges that follows loading of the transducer i.e. bending the strain gauges will result in change in electric potential or voltage. This change in voltage can then be calibrated with known weights and presented on a graph or on a digital display unit. A Neurolog voltage amplification device(NL 107, Digitimer®, Welwyn Garden City, UK) was used to record and amplify the voltage changes of the force transducer. These changes were imported on to the computer screen as a voltage graph using the 1401 data acquisition interface and analysed using Signal Software (Cambridge Electronic Design®, Cambridge, UK). This technique was described by Tortopidis *et al.*[16]

The force transducer was calibrated prior to each session using a bespoke jig. Weights of 0.5 kg, 1.5 kg, 5kg, 10kg, 12.5 kg, 10kg, 5kg,1.5 kg, and 0.5 kg were sequentially applied to the transducer to produce a calibration curve. The response of the transducer was found to be linear over the above range of weights. Figure 4 shows the calibration voltage graph of the transducer.

To obtain the maximum biteforce the subject was seated in a dental chair with a head support. To make the metal biting surface more comfortable and to ensure a consistent position for biting an acrylic (Unodent®, Witham, England) occlusal index was fitted onto the transducer (Fig 2). At the start of each session the subject was asked to undertake trial clenches with the transducer. To measure the bite force the subject clenched on the transducer with maximum effort and then relaxed.The highest value of three measurements was considered as the maximum bite force for that session. The process was repeated four times with at least 7 days between each session. The highest value of the four sessions was considered to be the maximum anterior bite force of the subject. On every occasion the subject bit the transducer only with the anterior teeth.

Experimental bites were inflicted on subjects' forearms by applying weight to the apparatus for 15seconds. This was initially done with minimal weights to observe how the apparatus functioned, to optimise its handling and to ensure the comfort of the subjects.

To relate the weight applied during production of experimental bitemarks to maximum bite force of the biter in a meaningful way it was necessary to produce visible bitemarks. The minimum weight required to produce a visible bitemark was 2.5kg. This was sequentially increased to 5kg, 7.5kg and 10kg. The process was repeated three times with each weight and with a gap of at least 1 day between each bite. The marks were photographed.

RESULTS

During production of the bitemarks 5kg and 7.5kg were well tolerated by the subjects. There was some discomfort when 10kg was used but the pain was below the threshold level of the subjects. Figure 3 displays the 10kg bitemarks 1minutes, 20minutes and 40minutes after infliction of the bite on each subject.

No mark was identifiable as a bitemark 40 minutes after infliction. However, indistinct marks lasted for four to five hours with 5kg and 7.5kg, while those produced by 10kg were visible the next day. No cuts or abrasions were produced. Visually similar bitemarks were produced in a consistent and reliable manner.

Table 1 shows the maximum bite force values of the subject recorded at each of the four sessions. 323.7 N was the highest value recorded and was considered as the maximum anterior bite force of the subject. This corresponded to a voltage change of 4.2V (Fig 4).

Therefore, weights of 5kg, 7.5kg and 10kg used to produce the bitemarks represented 16%, 24% and 32% of the maximum bite force respectively

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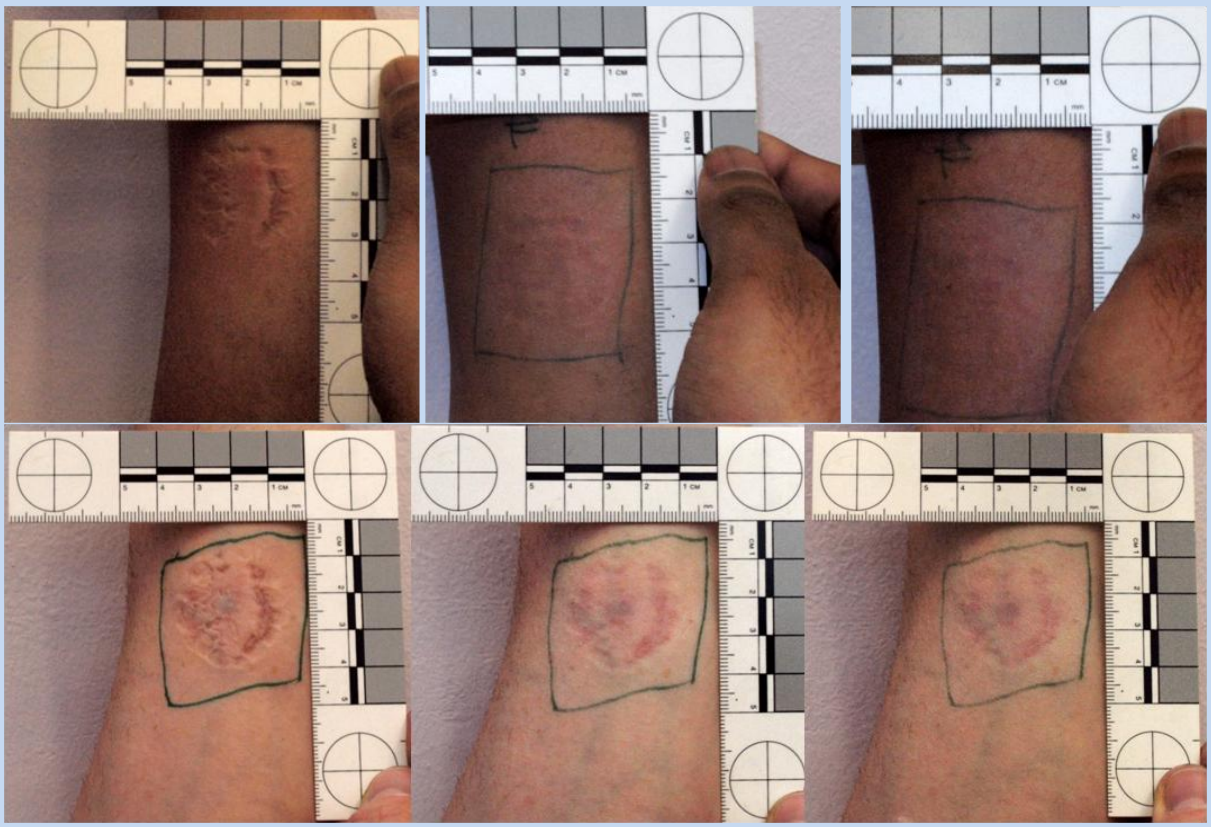

Fig.3: 10kg bitemarks 1minutes, 20 minutes and 40 minutes after infliction of the bite on each subject. Upper series: Subject1; Lower series: Subject 2.

DISCUSSION

This biting apparatus was simple, easily built, convenient to use and reliable for inflicting bitemarks on living human subjects. The weights used were known and were not used beyond the level of subjects' comfort. It was noticeable that the marks of lower teeth were clearer and more obvious than the upper teeth marks. This is likely to be a result of the fact that

when mounted on the articulator the lower cast was fixed and upper cast was movable. In future, to make replicate bitemarks the articulator could be placed upside down in the apparatus. As the apparatus relies on manual application of the loads there is no risk of equipment malfunction. It is also easy to alter the weight applied at different sessions.

Relating the force used to produce a bitemark to the maximum bite force of the biter is a difficult task. The authors chose to do this in an indirect way by measuring the maximum bite force of the subject and then produced experimental bitemarks with known weights. These weights were then related to the maximum bite force. The maximum anterior bite force value increased at each visit.This could be a result of self-motivation, increased confidence and reduced fear of injury to teeth on every occasion on the part of the biter.[15]In fact, in the final session, the biter made the beams of the transducer contact each other and saturated the apparatus. From the published literature the maximum anterior bite force can range between 120 and 350 N (Helkimo *et al.* 1977; Tortopidis *et al.* 1998).[22,23] The maximum anterior bite force recorded in this paper is within the previously reported range of maximum anterior bite force values for adults.

The relationship of force used to inflict the bite to the maximum bite force of the biter is a very important factor which helps in assessing the intentions of the biter and the severity of the mark produced to the court. In this experiment the authors produced experimental bitemarks on living subjects with known weights of 5kg, 7.5kg and 10kg with the help of a mechanical apparatus specifically constructed for this purpose. These experiments were repeated three times to ensure repeatability of results. The resultant bitemarks on the subjects gave us an idea of how bitemarks may appear different on different subjects. For example 40 minutes after infliction of a 10kg bite subject 1 showed no significant tooth marks which could identify it as a bitemark (Fig 3) whereas subject 2 showed a semi-circular arch form that is consistent with a bitemark (Fig 3) and with redness around the indentations. This study also reports on the minimum weight/force used to produce a visible bitemark (2.5kg/24.5N).

Despite controversy around the credibility of bitemark evidence, it is indisputable that bitemark evidence has already been established as an important tool in the administration of justice.[24] Considering the serious consequences of erroneous results in bitemark analysis there is a need for scientific research to underpin its principles and practice.[2,25]

Researchers have often used simulated bitemarks to study the basic principles of bitemark analysis. Artificial bites have been produced in materials like wax, Styrofoam, food stuffs and pig skin both living and dead.[3-7]None of these materials have the qualities of human skin. Some studies have been carried out on human cadavers to investigate the biomechanical properties of skin and bitemark distortion.[8-11,13] Very few studies have used living human subjects for the simulation experiments.[12] Ethical concerns concerning biting of living volunteers might have been a hindering factor.

To reduce the ethical concerns associated with using living subjects this paper has reported the construction of a mechanical but fully human-controlled apparatus to inflict experimental bites of known force. It can be constructed easily from readily available materials to help produce bitemarks in future studies by other research groups. It may even have practical applications in case work by

allowing test bite marks to be produced using conditions that replicate, as closely as possible, the initial circumstances. Having a standard method for inflicting bites will help to progress bitemark analysis so that future techniques are objective, valid and reproducible and accepted by other researchers, odontologists and members of judiciary system.

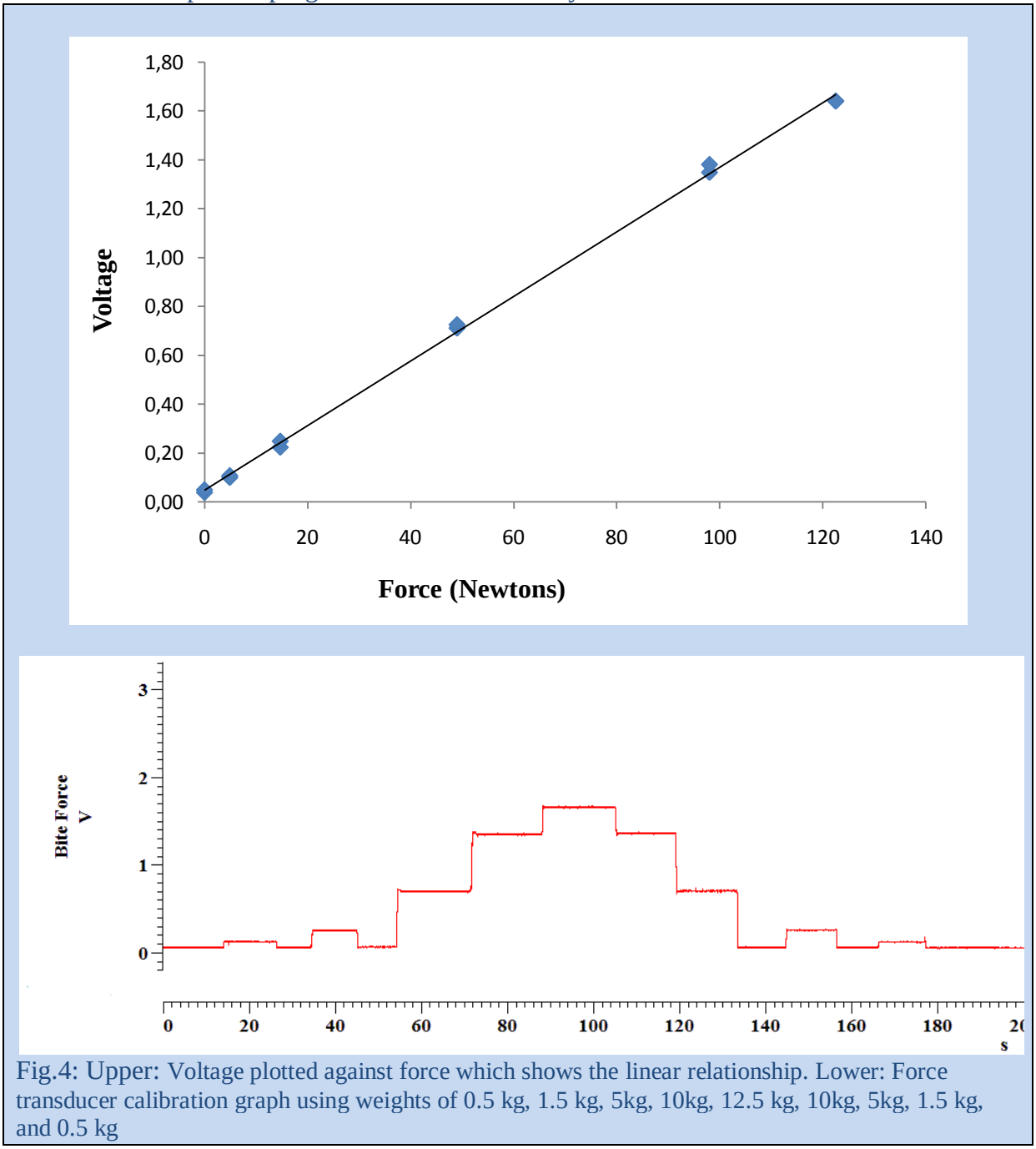

Fig.4: Upper: Voltage plotted against force which shows the linear relationship. Lower: Force transducer calibration graph using weights of 0.5 kg, 1.5 kg, 5kg, 10kg, 12.5 kg, 10kg, 5kg, 1.5 kg, and 0.5 kg

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