

Review Article

A Review on Bite Marks in Forensic Dentistry

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Abstract

Forensic odontology plays an essential part in recognizing the bodies of victims in mass casualties, crime scenes and terrorist attacks. Bite marks are a significant substitute in crime investigation, when routine means of identification cannot be performed owing to distortion of facial structures and fingerprints. Forensic odontologists are associated with the analysis of bite marks and presentation of the evidence in the court. Bite mark identification is based on the exclusivity and singularity of individual dentition. This article reviews the importance of bite marks analysis, methods of identification and recovery of bite mark evidence and its role in forensic investigation.

Keywords: Dentition; Forensic dentistry; Humans; Human bites; Mass casualty incidents

Introduction

Forensic odontology is a branch of dentistry, which in the interest of justice, deals with the proper handling and examination of dental evidence, and also with proper evaluation and presentation of dental findings. The term 'forensic' is derived from the Latin word *forensis*, which means 'pertaining to the forum' and, 'odontology' refers to the study of teeth [1]. The concept of forensic odontology is that, no two mouths are alike and that the teeth leave arecognizable mark. The human dentition is often considered as a hard tissue equivalent to fingerprints [2]. Forensic odontology has played a vital role in the identification of individuals whose bodies have been mutilated due to fire accidents, mass disasters, sexual assaults and so on. The various approaches employed in forensic dentistry include bite marks, saliva, teeth, rugoscopy, tooth prints, cheiloscopy, photographic study, dental casts, molecular methods and radiographs [3]. The preservation of dental evidence is exceptionally significant for individual identification in criminal cases [4].

History

Bite marks were utilized in the past for the identification of a person. In 1692, the trial of Reverend George Burroughs in Salem, Massachusetts testified that a bite mark on one of the witches was left by Reverend Burroughs. Evidence of his biting was given by one of the ladies accused of witchcraft. He was hanged to death [5].

Texas was the first court of appeal to permit bite mark as evidence in 1954. The case involved a bite mark on a piece of cheese left at a crime scene and a firearm expert performed the analysis instead of a dentist [6].

Perhaps the most well-known criminal case to bring about a conviction based on bite mark examination is that of Ted Bundy. He raped and killed numerous ladies, distinctly Lisa Levy and Martha Bowman. Bundy had bitten Levy's buttock, leaving an imprint for forensic researchers to use to their advantage. This mark was at last what sentenced Bundy in 1979 of the homicide of Levy and the other ladies he killed. Bundy had severely crooked lower teeth, the impression of which considered simple distinguishing proof for the bite mark identification [7].

In India, the use of bite marks as forensic evidence has been limited. A notable example is the infamous Delhi Nirbhaya case 2012-2013 where Dr Ashith Acharya, secretary of the Indian Association of Forensic Odontology (IAFO), played an essential part in convicting all the accused. He utilized police photographs of the suspect's dental features and matched it with the bite mark injuries on the victim's body [8].

Definition and Classification

Bite mark is defined as a mark caused by the teeth either alone or in combination with other parts of the mouth [1]. It might be viewed as an identical representation of the arrangement and characteristics of dentition. Bite marks are either left on the victim, on the culprit or on an inanimate object found at the crime location. The classification of Bitemarks is discussed in detail in (Table 1).

Crimes Involved in Bite Marks

In circumstances related with life and death struggles between attackers and victims, the teeth are regularly utilized as a weapon to incur injury on an assailant. This might be the lone accessible protective technique for the victim. On the other hand, it is notable that aggressors in sexual attacks often bite their casualties as a manifestation of supremacy and rage. The various crimes involved in bite marks are violent crimes, child abuse cases, abduction, sporting events, homicide, self-inflicted injuries, etc [10].

Violent Crimes

Bite marks in cases of violent crimes might be experienced where the assailant may bite the person in question or the victim biting the aggressor during protective retorts. In sexual bites, the teeth are utilized to hold during sucking and the resultant central or peripheral suck marks are apparent as petechiae [11].

Child Abuse Cases

Human bite marks in children are relatively common but are either not recognized or not assessed thoroughly when suspected. Older kids reflect bite marks which address either attack or sexual maltreatment [12].

Table 1: Classification of Bitemarks.

Cameron and Sims Classification [9]	1. Agents:	a. Human
		b. Animal
	2. Materials:	a. Skin
		b. body tissue
c. Food stuff		
d. Other materials		
Mc Donald's Classification [9]	1. Tooth pressure marks - caused by incisal edge/ occlusal surface of teeth	
	2. Tongue pressure marks - seen as impression of the palatal surface	
	3. Tooth scrape marks - may be scratches and abrasions that can indicate irregularities in the teeth such as incisal fractures, restorations or attrition	
	4. Complex marks - are a combination of all the above, occasionally complicated by multiple bites	
Websters classification [9]	Type 1 – Food item fractures readily with limited depth of tooth penetration. E.g.: hard chocolate	
	Type 2 –Fracture of fragment of food item with considerable food penetration of teeth. E.g.: apple and firm fruits	
	Type 3 – Complete or near complete penetration of food item with slide marks. E.g.: cheese	

Sporting Events

Here, the bite marks are produced when the victim manages to bite the assailant during sports such as soccer, rugby and boxing [13]. The most iconic and grotesque biting incident in sports history took place on June 28, 1997 when Mike Tyson bit off a slice of Evander Holyfield's ear [14]. A similar incident occurred during the 2013 Rugby Championship, when Argentina's Leonardo Senatore bit South African player Eben Etzebeth on his arm [15]. The most recent example, is that of India's Ravi Dahiya who endured a painful bite on his right biceps from the opponent NurislamSanayev during the Tokyo Olympics semifinal 2021 [16].

Self-Inflicted Bite Marks

If the bite mark is present on a part of the body which is reachable to the victim's mouth, there is a possibility that the bite is self – inflicted. They are commonly seen on the forearms of the children. Intellectually hindered and mentally disturbed individuals may also perpetrate a bite on themselves [17].

At the Scene of Crime

In some cases, the criminals happen to have their teeth marks on the substance left at the scene. Such bite marks may be encountered on skin and soft tissue as well as on inanimate objects such as foodstuffs, fruits, clothes. [18]

Steps in Bite Mark Record (Abfo Guidelines 1986)

American Board of Forensic Odontology (ABFO) has put forth certain guidelines for the collection and analysis of bite marks from the victim and suspects [19]. The steps involved in Bite Mark recording is shown in (Table 2).

Obtaining Evidence from the Victim

Consent: The collection of evidence from the victim must begin only after proper consent has been obtained. The written consent must be signed by the victim in the presence of a witness [19].

Documentation of History: A detailed history of the individual, including history of dental treatments has to be gathered. It should also be determined if the bite mark has been affected by washing,

Table 2: Steps involved in Bitemark recording.

From victim	From suspect
Consent	Consent
History	History
Documentation	Clinical examination
Photography	Photographs
Saliva swab	Impressions
Impression and model	Bite samples
UV illumination	
First aid	

contamination, embalming, decomposition etc [19].

Photography: Photography is the essential method for recording and safeguarding the bite mark and is basically significant in archiving the evidence. Since the skin marks are able to change over the long haul, photos give the most dependable method for saving the data [19]. The photographs must be taken with the camera at an angle of 90° to the injury, preferably at 24 hour intervals on both living and deceased victims as their appearance can vary [20]. A scale crafted by individuals from the American Board of Forensic Odontology (ABFO) has advanced as a norm, assigned as the ABFO scale no.2. It is valuable to procure serial photographs of bite mark injury. In addition to conventional photography, video imaging can also be used [21]. Besides the conventional color and black and white films, ultraviolet photography is recommended at the early encounter and for a couple of days later [22].

Saliva Swab: Swabbing of bite mark injury is essential to recover trace evidence. Stains of saliva or human cells should be collected for DNA analysis. Human beings secrete “ABO” antigens through saliva. Swabs should be taken from bitten area, control area, and oral cavity. On account of rapes and assault, oral swab ought to be taken for semen. The sample materials should be analyzed as soon as possible, or else frozen storage and cold transportation are suggested [13]. The two techniques involved are saline washing technique and double swab technique.

- Saline washing technique - In this method, the bite mark

area is rinsed with normal saline and the subsequent saliva solution is gathered in Petri dish. Following high velocity centrifugation, the supernatant is disposed and the filtrate is observed under a microscope [23].

- **Double swab technique** - First, a cotton swab dampened with distilled water is utilized to rinse the surface that was in contact with the tongue and lips. Circular motion and light pressure is used for 7 to 10 seconds to wash the dried saliva from the surface. A dry swab is then used to collect the residual saliva that is left on the skin by the first swab. The two swabs are altogether air-dried at room temperature for at least 45 minutes. Subsequent to drying, swabs are packed and sent to the laboratory. A control sample is prepared using same technique but without swabbing the saliva [24].

Impression and Model: In order to preserve the three dimensional nature of the bitten area, impressions should be taken to devise stone models. The impression materials used for recording the impression of the bite marks of the site are rubber-base and silicone-base impression compounds [18]. The two methods for taking impressions are:

Method I - The bite area is covered with the impression material. A wire gauze is placed and additional material is injected over it [18].

Method II - Using cold cure a special tray is constructed pertaining to the shape of bite mark and an impression is taken. Master casts ought to be poured with type-IV stone. Duplicate casts should also be fabricated. Either epoxy resin clear material or visible light cure may be used to make rigid model [18].

First Aid

1. **Stop bleeding** – If there's bleeding, raise that area of the body and apply firm pressure to the wound, with sterile gauze or clean cloth until bleeding stops [25].

2. **Clean and protect** –Sterile medical gloves should be worn to reduce risk of contamination. If the wound is mild and there is no blood, clean it with mild soap and rinse for several minutes under running water. Apply antibiotic ointment and cover the wound with sterile gauze [25].

3. **Get Medical Help**- Medical practitioner should be consulted about any human bite that has abraded the skin, as there is a high risk of infection. If the infection is untreated, it may lead to lack of mobility, damage to tendons or nerves, stiffness and numbness in the area. Deeper wounds may require stitches and also tetanus shot or booster. Antibiotic therapy maybe prescribed to prevent bacterial infection [25].

Obtaining Evidence from Suspect

Consent: Before gathering proof from suspected biters, the odontologist must guarantee that suitable court order, search warrant or signed inform consent containing specific information on what and how evidence is to be collected. The written consent must be signed by the victim in the presence of a witness. The odontologist must explain the procedures to the subject prior to performing them. A duplicate of these reports should be held as a piece of the case record. If the specialist takes an impression of suspect's teeth without his consent, it very well may be viewed as an assault on him. Therefore, such a plan of action may lead to legal ramifications for the

person who takes the impressions [26].

History: A thorough history of the individual, including history of dental treatments before and after the bite marks has to be noted. Medical history to document any medication the suspect has been taking at or before the date of bite [27].

Clinical Examination

Extra-Oral Examination: It involves recording of hard and soft tissues. Estimations of maximal opening, any deviations on opening or closing, TMJ status, occlusal disharmonies, muscle tone and balance, and facial asymmetry must be made. The presence of facial scars or proofs of a medical procedure, along with the presence of facial hair have to be noted [28].

Intra-Oral Examination: Salivary swabs should be taken. Missing and fractured teeth should be noted. The tongue is examined to assess size, function, any abnormality such as ankyloglossia, bifid tongue as well as tongue and lip piercings. The periodontal status has to be noted with particular reference to mobility [28].

Photographs

Extra oral photographs includes, a full face and profile views. Intra oral should include frontal views, two lateral views and a close-up photograph of the teeth in normal occlusion, maximal opening and biting edge-to-edge [29]. Care should be taken to remove any undesirable shadows. Digital Single Lens-Reflex (DSLR) cameras are utilized to accomplish these results [30].

Impressions

Utilizing ADA (American Dental Association) specified material, two impressions of each arch are taken and master casts are made with type II stone. The inter occlusal relationship should be recorded. Duplicate casts can be obtained from master cast. One set of casts is used as direct evidence and the other set for comparability. If removable prosthesis are present, impressions are taken with and without the prosthesis in place. Teeth and soft tissue records should not be altered by carving, trimming or making other alterations. Sample bites are made into appropriate material simulating the type of bite under examination [31].

Bite Samples

A sample bite should be recorded in centric occlusion by means of appropriate materials approved by American Dental Association, for example, Aluwax or Copra wax. These samples are photographed immediately and used for future comparison [29].

Bite Analysis

The first stage of bite mark analysis is to confirm if the injury is a bite mark and then provide a statement on its forensic significance. The steps in bite ark analysis are:

Demographics

Includes name of the victim, case number, date of examination, referring agency, person to contact, age, race and, sex of the victim and name of the examiner [30].

Location of Bite Marks

Bite marks may be located on various parts of the body. It can be broadly classified as non-sexual and sexual bite marks. The sites

where non sexual bite marks are often seen are on arms, legs, fingers, hands, chest and ears. Whereas, the sexual bite marks may be seen on breast, neck, thigh, genitalia, axilla, buttock, upper back, arm, cheek, etc. The frequencies of occurrence of bite marks on the various parts of the body are as follows: breast, arm, genitalia, back, thigh, legs, nipple, hand, buttock, abdomen, waist, face, neck and so on [32].

Shape, Size and Arrangement of Teeth

Bite marks maybe crescent, ovoid, round, or irregular in shape. The cross-section of human incisors produces rectangular marks whereas canine yields triangular marks. A vertical and horizontal dimension of the bite mark is noted, preferably in metric system. The prominent dental features like tooth size and arrangement, secondary features like gaps or broken teeth are compared. Both the prominent and secondary dental features have to match for the bite mark to be considered a match. Tooth numbers, missing teeth and placement of tooth marks should be noted [19].

Size of Dental Arch

The size relationship of bite-marks, as defined by the dental arches, could relate to a child or adult bite. It consists of U-shaped arches separated by an open space in between where bruising is usually seen. The average diameter of adult arches from canine to canine is 25-40mm [33].

Suction Marks

Suction marks or hickeys are a collection of punctate haemorrhages. A central ecchymotic area surrounded by radiating linear abrasions resembling a 'sun-burst' found usually after sexually oriented crime. These bruises are due to suction or negative pressure resulting in leakage of blood from capillaries [34].

Type of Injury

The seven types of injuries seen in bite mark are:

- Petechial Haemorrhage – a small bleeding spot
- Contusion - ruptured blood vessels
- Abrasion - undamaging mark on skin
- Avulsion - skin is torn off
- Laceration - near puncture of skin
- Incision - neat punctured or torn skin
- Artefact - bitten off piece of body

These further can be classified into four degrees of impression- clearly defined, obviously defined, quite noticeable and lacerated.

- Clearly defined – marks that are a consequence of application of substantial pressure.
- Obviously defined – due to mild pressure.
- Quite noticeable – due to vigorous pressure
- Lacerated – a deep cut or tear in the skin [5]

Colour of the Wound

The colour should be noted e.g. red, purple etc [30].

Evaluation of the Bite Mark Photographs

This is a significant step during examination. Images should be of

sufficient resolution to permit amplification to life-sized dimension without pixilation [33].

Methods of Analysis

Odontometric Triangle Method

The odontometric triangle method is an objective method in which, three points are marked on the tracing of bite marks and teeth models. Two points on the outermost convexity of the canines and one in the midline between the maxillary central incisors, which are then joined to form a triangle. The three lines and angles are calculated and compared. This is done for both upper and lower teeth model and contrasted with the marks on the specimen. After thorough examination, results are obtained [26].

Comparison Technique

Direct method/ cast on photo method: In this method, direct comparison is made between photographs and models or finger print powder lift model. In this technique, models from the suspect can be directly placed over the life sized photograph of the bite mark for demonstration [27]. In finger print powder lift technique involves, using appropriate powder and brush to dust the bitten skin and utilize finger print tape to transfer the marks on to a sheet of acetate. Investigators should be careful while developing the print to prevent its damage [35].

Indirect method-overlay: Indirect method involves preparation of transparent overlay to record the suspect's biting edges. Transparent overlays are made by free hand tracing the occlusal or incisal surfaces of a dental model on to an acetate sheet which is then placed over the scaled 1:1 photographs and comparison is made. The use of transparent overlays is considered subjective, easily manipulative and irreproducible. Photocopier-generated overlays are considered a better alternative in matching the correct bite mark to the correct set of models without using free hand tracing [35]. The four methods of bite mark overlay production are-

- Computer based
- Radiopaque wax method
- Xerographic
- Hand traced [36]

Other Special Methods

- a. Stereometric graphic analysis
- b. Vectron
- c. Scanning Electron Microscopic analysis
- d. Image perception technology
- e. Experimental Marks [37]

Factors Influencing Severity of Bite Marks

Force- Original Injury Inflicted

Negative pressure created by the biting teeth and tongue, leads to an extra-vascular bleeding which causes bruising in the centre of the bite mark injury. These bruising show colour changes over time as the injury goes through a process of healing in the skin of a living person [36]. There are four degrees of impression which when

examined can help to detect the type of violence –

- a) Significant pressure,
- b) First degree pressure
- c) Violent pressure
- d) Skin violently torn from body [38]

Anatomical Location

Bite marks may vary from one site to another since they are altered by mechanical properties of tissue, for example the breast tissues are inherently softer than those of the back. Body parts with loose skin have lesser fibrous tissue, excess subcutaneous fat and muscular tone leading to easy bruising. The skin holds tension and releases in different ways during movement which affects the impression of the bite mark on the person. More bruising is seen in children due to loosely attached, delicate skin and subcutaneous fat. In elderly individuals, more bruising is because of lesser elasticity and subcutaneous fat while in women it is attributed to more subcutaneous fat and delicate skin [31].

Time of Examination

The time span of the bite mark is governed by the intensity of force and the duration the victim has been bitten. Bruising can appear four hours after a bite and disappear after thirty six hours. Abrasions within the mark retain their morphology and are valuable identification features. Appearance of the bite mark will become more discernable with time as swelling subsides and tissue repair starts [39].

Bite Marks Characteristics

A characteristic is a distinct feature, trait or pattern within the mark. There are two types of characteristics, namely class characteristics and individual characteristics

Class Characteristics

As indicated by the Manual of American Board of Forensic Odontology (ABFO), a class characteristic is a feature or pattern that differentiates a bite mark from other wounds. While assessing the indentations, the initial step is to affirm the presence of class attributes. The dimensions differ in size depending upon what caused the injury: primary or permanent teeth and whether maxillary or mandibular teeth. Furthermore, the overall size of the injury will vary depending on the perpetrator's arch dimension. The class characteristics identify the group from which it originates: human, animal or others. The two types of class characteristics are- 'bite mark characteristics' and 'tooth class characteristics' [40].

According to tooth class characteristics, the anterior teeth are the primary biting teeth. Each sort of tooth in the human dentition has class attributes (tooth class qualities) that separate one tooth type from the others [40].

- Incisors - Rectangular shaped mark
- Canines - Triangular markings with variations
- Premolars - Single or dual triangle, appearing as diamond shaped
- Molars - Rarely leave marks, but when present appear

quadrilateral in shape.

Individual Characteristics

An individual characteristic is a feature that represents a variation from the expected finding in a given group. They are of two types- arch characteristics and dental characteristics.

Arch characteristics: The arch characteristics are a form of individual characteristic that help to differentiate between individuals by discerning one person's arch from another. It is based on the fact that some patterns, traits or features, may be seen in some individuals and absent in others. It is exhibited as rotated teeth, changes in arch size and shape, diastema, displaced or drifted teeth, etc [40].

Dental Characteristics: They are explicit to a singular tooth and makes one tooth not quite the same as the other. The teeth of various people vary from each other regarding their position, shape and size in the dental arch. Dental characteristics such as rotated, damaged or fractured tooth, supernumerary tooth, crowding, attrition, spacing and retained deciduous teeth help in recognizing an individual [41].

Range of Conclusions for Bite Marks

A range of conclusions can be reached when reporting a dental identification. The American Board of Forensic Odontology recommends that these be limited to the following four conclusions:

Excluded

The bite mark and suspect's dentition are inconsistent which indicate that, the suspect's teeth have definitely not caused the mark. The ante mortem and postmortem data are clearly unreliable which excludes the bite mark as having been caused by the suspect [42].

Inconclusive

There is insufficient forensic detail between the bite mark injury and the suspects' dentition to draw any conclusion [42].

Possible Biter

Teeth like the suspect's could resemble the bite mark but so could other dentition. There is consistency between the bite mark and the suspect's dentition however; there are no characteristic matches to be absolutely certain that the suspect's teeth could have made the bite mark. The ante mortem and postmortem records are reliable but it is not possible to establish positive identity because of the quality of the evidence [42].

Probable Biter

Suspect's teeth show some resemblance to the bite mark including some corresponding individual characteristics. There are no incomprehensible differences. The evidence firmly supports the source from the suspect but could perhaps be caused by others [42].

Reasonable Medical Certainty

There is no doubt that the bite mark pattern matches with the suspects teeth. The ante mortem and postmortem data match correctly with no discrepancies [42].

Controversies Regarding Bite Mark Evidence

Since bite marks aren't as accurate as DNA, they must be utilized carefully when presented as evidence in crime scene. Various factors such as collection, recording, comparison, interpretation,

preservation, and reporting of the bite mark can alter the evidence. Bite marks can only be employed for including or excluding the biter from among the suspects, but hardly for a definitive conviction. Therefore, there has consistently been a dispute regarding the legal status of bite mark as evidence [43].

The most prominent exoneration including bite mark proof is the Ray Krone case, where he was unjustly indicted for homicide and condemned to death. The only proof was, an exceptional bite mark found on the victim. Aforensic odontologist affirmed that Krone's teeth coordinated with the bite mark on the victim. Upon additional examination, DNA proof demonstrated Krone's honesty and he was released from jail in 2002 [44].

Roy Brown was absolved after 15 years of being imprisoned for assaulting Sabina Kulakowski, dependent on bite mark proof. Dr. Edward Mofson asserted that Brown's teeth were a match to the bite marks found on Kulakowski's body. Fifteen years after the conviction, DNA testing performed on saliva stains left by the culprit eliminated Brown and coordinated with another suspect, Barry Bench. Eventually, the lead prosecutor recognized Brown's innocence, and he was exculpated [45].

Levon Brooks went through 16 years in jail for the assault and murder of a 3-year-old girl that he didn't commit. Forensic odontologist, Dr. Michael West compared the dentitions of 13 suspects and declared that the marks on the casualty's body matched Brooks' dentitions. Based on this, Brooks was indicted for capital homicide and was imprisoned. Subsequent DNA testing and confession uncovered that Justin Albert Johnson committed the homicide. Johnson had been one of the 12 different suspects whose dental impressions Dr. West had examined and eliminated. Following Johnson's admission, Brooks was liberated on February 15, 2008 [45].

Forensic odontologists have conceded that mistakes have occurred in determining the suspect in the past. However, investigation of the facts and circumstances of the cases, demonstrate that numerous variables were additionally impacting the situation. Comprehending the reasons and striving to elucidate how, why and where the wrongful convictions happened, is essential to be able to take actions to diminish the probability of such failures from occurring again [46].

Recent Advances - Digital Methods

Image Perception Software Procedure

An area of interest is chosen in the image perception software using the photograph of a bite mark. Different levels of grey values are assigned a particular colour which enables the forensic odontologist to select regions with similar grey values. It is feasible to isolate the region of the image which shows the bite mark, by excluding certain areas of pixel intensity. A comprehensive duplicate of the bite mark is produced. The coloured image of the bite mark is then superimposed over the original bite mark photograph using Photoshop [47].

Automated Dental Identification System (ADIS)

This is a computerized program for the postmortem examination of victims based on the oral features of the subjects. It is precise and time efficient compared to the conventional approaches. It delivers computerized examination and analyses digital radiographs and dental images, which are difficult to assess merely by visual

examination and shortlists multiple digitized dental records that are identical to those of the subject [48].

3D Reconstruction of Bite Marks

The benefit of utilizing 3D-CBCT over the conventional technique is the minimal handling of the sample, leading to lesser changes in the original bite mark found at the crime location. Additionally, it is simpler to store and recover the information, better reproduction of the bite marks, minimizes angular distortions and permanence of records [49].

Odontosearch

It provides an objective means of assessing the frequency of occurrence for dental code. The strength of match between a post mortem and ante mortem dental code is based on the clinical experience of the dentist. It compares data base of missing people and criminals. It helps the odontologist to determine the uniqueness of a particular arrangement of fillings a person may have [50].

Conclusion

Bite marks are a valuable and also a controversial aspect in forensic odontology as they can not only prove the suspects as guilty of the crime but also help in vindication of the acquitted. Bite marks if analyzed properly are a reliable, easy and cost effective source of identification. Misrepresentation of the bite mark due to the appearance, position and elasticity of skin is a hindrance in its identification. Recent advances may enable extensive analysis of the bite mark to accurately identify its source and eliminate room for errors.

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