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JOURNAL of FORENSIC ODONTO-STOMATOLOGY
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SECTION BITE MARKS

# Are they dermatological lesions, bottle top burns or bite mark injuries?

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***ABSTRACT***

***Bite marks can be considered as a patterned injury where identification of the causative tool will lead to the identification of the perpetrator. When patterned injuries resembling bite marks are seen on the victim or an assailant of a potential crime, all efforts must be made to carry out an immediate and proper investigation.***

***The classical human bite mark pattern will appear as an oval or circular injury. However there are several dermatological lesions which can be misinterpreted or confused with bite marks. Similarly scars left as a result of contact with hot objects can sometimes bear a resemblance to bite marks. To the untrained eye, identification of bite mark injuries is not an easy task.***

***Since bite marks are common in cases of child abuse and neglect, it is recommended that dental surgeons with forensic background become members of the child abuse and neglect management teams.***

***During investigation of bite marks in alleged cases of child abuse and neglect, it is imperative to compare the injury with dentition of all the persons who have direct access to the child including siblings and playmates. Information revealed through the forensic analysis of bite marks not only helps in the criminal investigation but also in the clinical management of the persons concern***

***KEYWORDS*****:** Forensic odontology, Bite marks, Child abuse and neglect, Siblings and play mates, Dermatological lesions, Bottle top burns

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## *INTRODUCTION*

Bite mark evidence is now accepted within many jurisdictions.[1] If a mark contains sufficient detail and data it can be used to identify the perpetrator and /or exclude suspects thereby becoming a powerful tool in criminal investigations.[2-4] Not all bite marks can be analyzed and presented as evidence in court of law.

Teeth can be used as weapons and as a result, bite marks are usually seen in crimes against persons and such injuries are referred to as attack injuries.[5]They are frequently found on victims of homicide, domestic violence, sexual abuse and child abuse cases.[4,6]Bite marks are also found on children who have been involved in fights with same-age children and also among institutionalized individuals.[7]It is not uncommon to find bite marks on perpetrators of violence which are usually known as defense injuries.[5]

A classical human bite mark will appear with specific markings as a circular or oval shaped injury[8] but they also can mimic burn injuries, bottle top injuries[9] and dermatological lesions[7] and vice-versa.

It is important that healthcare workers are adequately aware of such injuries so that pertinent cases are referred to the relevant specialists in forensic odontology for further investigations and differential diagnosis. This will especially help in early detection and facilitate initiating proper therapy and counseling as well as a search for the perpetrator where indicated.[7]All dentists and dental hygienists should be familiar with the clinical appearance of bite marks because it may be the first sign of child abuse and child neglect.[4, 7]

This case report describes a case where marks on the skin were clinically mistaken initially for dermatological lesions and subsequently as bottle top burn injuries before finally being recognized as bite marks which provided major evidence in investigations and clinical management.

## *CASE HISTORY*

On 18th January 2013 a female child aged 3 years was referred to the Forensic Odontology Unit by a Consultant Judicial Medical Officer in the Institute of Legal Medicine and Toxicology, Colombo, Sri Lanka for forensic odontological examination. At the time of the examination she was in the care of a Consultant Pediatrician at the Lady Ridgeway Children's' Hospital in Colombo, Sri Lanka. This child had been treated by two different medical officers prior to being admitted to the children's hospital for a condition which was suspected to be a dermatological condition. Since the child's response to the medical treatment was not satisfactory she was referred for specialist care in Colombo. When the said child was examined by the Pediatric Dermatologist, he suspected that the child was being subjected to physical trauma i.e. burnt with heated bottle tops. The child was then referred to the Consultant Pediatric Psychiatrist and subsequently to the Consultant Judicial Medical Officer to investigate the cause of the injuries.

The child was in the care of her parents. She was the youngest in a three-children family. Her siblings were an elder sister aged 11 years and an elder brother of 8 years. During the day the elder children attend school while the youngest stayed at home with the mother. The mother was the chief care giver in the family and was a housewife who suffered from diabetes mellitus with poor glycaemic control. According to the social worker's report the child was living in a well-functioning home but there were limitations of space allowing the youngest child easy access to the schoolbooks of the oldest child. Furthermore there were opportunities for the three children to play away from adult supervision. In these circumstances, access to the child was limited to the family members.

There were 42 separate injuries on the child which were in the areas of the face, upper limbs, front and back of the body (Fig. 1). No such injuries were found on the lower part of the torso (below the waist) and on the lower limbs. The injuries were in different healing stages. The injuries were photographed after obtaining an informed proxy consent from the father. Biological swabs were not taken.


**Fig.1:** *Back of the body(left); Front of the body* (right)

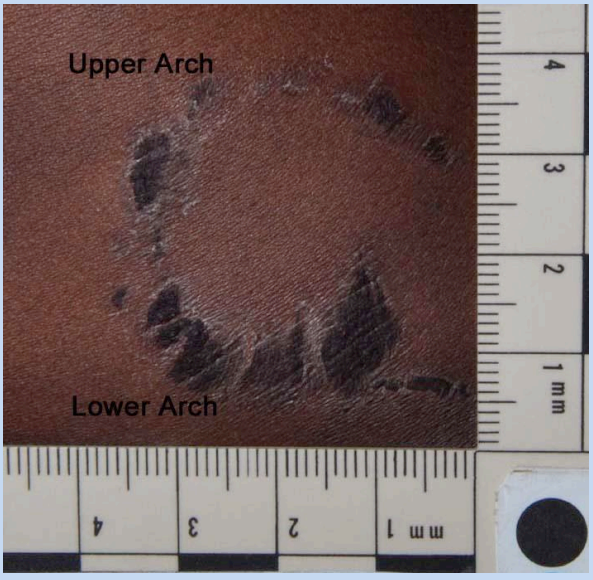


**Fig. 2:** *Injury*

A wax bite of the victim and alginate impressions of the dentition of all the family members were taken after obtaining voluntary informed consent from the parents and proxy consent for the children by the father. Subsequently Plaster of Paris (POP) study models were prepared. Digital overlays of all the dental casts were produced using the technique described by Johansen and Bower.[10] An injury which showed clear features (Fig.2) was selected for analysis and was photographed digitally and edited using the computer software Adobe Photoshop®. The digital overlays of all the family members were then compared with the photograph of the selected injury (Figs.3-4).

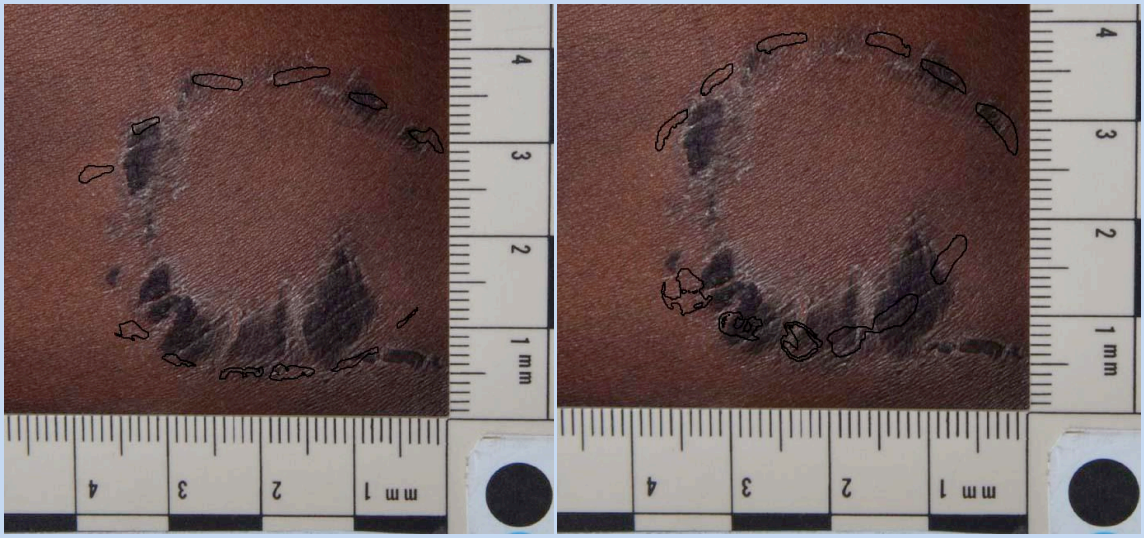

**Fig.3**: *Comparison with the mother's dental casts (left); Comparison with the father's dental casts (right)*

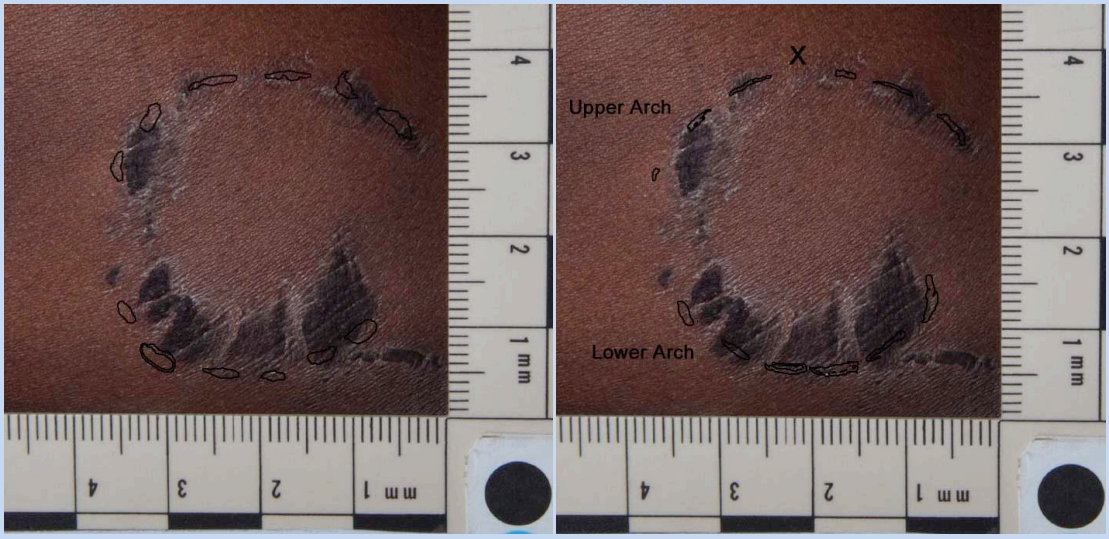


**Fig.4**: *Comparison with the brother's dental casts (left); Comparison with the sister's dental casts (right)*

Since the people who had direct access to the child were known, for bite mark analysis, this case was considered to be a "closed population case". The dental arch of the mother, father and the brother showed gross incompatibility with the shape of the injuries (Fig. 3-4). The arch and dental characteristics found in the sister's dentition could be correlated to the features in the injury to a certain extent.

- Arch width, for both upper and lower casts of the sister, was consistent with the injury.
- The unevenness in the incisal edge of tooth 11 was present as a lightly injured area (marked X in Fig 4) in comparison to the rest of the areas in the injury.
- The lower central incisors have even biting surfaces (Fig. 5) with a very tight contact. This corresponds to the single indentation mark seen on the arch that was identified as the injury caused by the lower teeth.

The uneven incisal edge in the upper central incisors is a feature that is not uncommon in the Srilankan population and the frequency of the occurrence of this feature in the age group concerned is also unknown.

In the final analysis and assessment of the injury, it was concluded that:

- The injuries are a result of an ongoing process of human biting (positive bite marks).
- They are not a result of self-inflicted bites.
- It excludes the father, mother and the brother being the cause of the injuries.
- The pattern analysis of the injury is suggestive that a dentition similar to that of the sister has caused the injuries.
- The sister is the probable biter considering the fact that this is a closed population case scenario

Outcome of the investigations**:** Even though the evidence produced may not have been sufficient to prove a case in a court of law, having considered the extent of the injuries and circumstances around the case it was decided to convey the findings to the Consultant Judicial Medical officer by way of a confidential report and subsequently to the Pediatric Psychiatrist as it could help in medical management of the case.

On the recommendation of the Forensic Pathologist, the family was directed to a family counseling service and the elder sister subsequently confessed. She was then referred to the Pediatric Psychiatrist for necessary management. Under the recommendations of the social service officers the family moved into a better housing facility. After six months of treatment for the injuries by the dermatologist and counseling services to both the family and the elder sister, the child is now observed to be free of any further evidence of recent injuries of similar nature.

## DISCUSSION

Recognition, recovery, analysis and interpretation of bite marks is one of the most challenging tasks that a forensic odontologist has to perform. With the advancements in technology, analysis of bite marks has now become more objective as well as highly technical.[11] Presenting the findings in a court of law and explaining the findings to the legal professionals and jurors can be difficult.[12] For a forensic odontologist to be competent in analysis of bite marks requires not only the knowledge/education but also skill and practice.[13]

Bite mark analysis is carried out in three stages. Firstly the evidence is recovered from the bite mark; secondly the details of the suspects' dentitions are recorded and finally the pattern and individual details of

the mark are compared with the features of the suspects' dentitions. As a general rule the bite mark should be examined first and recorded before examining the suspects' dentitions to avoid any subliminal bias during the interpretation of the mark. [14] This general principal was followed in the described case. The American Board of Forensic Odontology (ABFO)[15]provides an array of terminology that can be used to describe whether or not an injury is a bite mark. These are:

1. *Human bite mark* –Human teeth created the pattern; other possibilities were considered and excluded
2. *Suggestive human bite mark*- The pattern is suggestive of a human bite mark, but there is insufficient evidence to reach a definitive conclusion.
3. *Not a human bite mark* – Human teeth did not create the mark.

Almost all the injuries that were present on this child had similar *class characteristics*. They were round/oval in shape and consisted of two opposing arches. The arches were separated at the base by open space. The indentation marks caused by the individual teeth were clearly visible. For these reasons it was concluded that the injuries were human bite marks.

Commonly used methods for bite mark analysis include metric analysis, pattern analysis and the combination of both.[16] Several researchers have tried to calculate the minimum number of concordant points necessary to establish a positive identification. To establish the identity of the perpetrator in a bite mark case it is necessary to prove beyond any reasonable doubt that another individual could not leave an identical print to that of the mark concern. This can be achieved with a single unique feature or by the effect of large number of features considered together. It has been said that the conclusion of the forensic analysis of a skin bite mark should never exceed the standard of "high degree of certainty" and "absolute certainty" or "100% sure" is not a standard that can be used.[17, 18,]

According to the ABFO guidelines[15]only the injuries recognized as "Bite Marks" which show class characteristics and individual characteristics should be analyzed and compared with the suspects' dentition. They also provide a range of terms to describe the link between the bite mark and the suspect. These are:

1. The biter
2. The probable biter
3. Not excluded as the biter
4. Excluded as the biter
5. Inconclusive

The ABFO does not support a conclusion of "The Biter" in an open population case.[15]The recommended conclusions for an open population case are either "Not excluded, Excluded or Inconclusive".

It is a fact that all bite marks cannot be analyzed to an extent that could be presented as evidence in a court of law, even though bite marks may be the only evidence that connect the suspect to the crime. Even inconclusive evidence gathered from bite mark analysis may help in better medical management of the case as in the case described above. Bite mark evidence is considered as difficult but highly persuasive especially to the jurors.[19]For this same reason, there is a very high onus on the forensic odontologist to do an impartial investigation in bite mark cases.[17, 18]

To increase the objectivity in bite mark analysis and interpretation, and to reach more certainty, extraction of the suspect's DNA (Saliva DNA) from bite mark can be performed.[20]The double swab technique with control swabs is the recommended practice.[21] For positive results the area of the bite should not have been washed prior to swabbing. In the case presented, swabbing was not done as the child had bathed on the morning of the forensic odontological examination

In cases where children have been subjected to bite mark injury, it is important to compare the injury pattern with the dentitions of all the individuals who have access to the child. This includes the parents, care givers as well as siblings and play mates.

**Fig.5:** *The sister's dentition*

## CONCLUSION

Bite mark injuries can be considered as a unique type of patterned/tool- mark injury. Identifying an injury as a bite mark automatically qualifies it to be called as tool-mark injury and creates a requirement to identify the tool. Identifying the tool in this unique incident (biting) inevitably leads to the identification of the perpetrator which is not so with other types of tool-mark injuries. Hence if a mark similar to that of a bite mark is present on a person (victim or a perpetrator) all efforts must be taken to conduct a complete analysis. Especially in cases of abuse and neglect, identification of the injury as a bite mark and providing information that may subsequently lead to the identification of the perpetrator as in the case described above, may serve a great function towards the better medical management of the case.

Bite marks do not always present as circular or oval patterned injuries. The shape of the injury can vary depending on the site of the injury, shape of the causing dentition as well as the position and movement of the victim during the incident. Recognition, analysis and identification of a bite mark injury is challenging and requires special investigation and should never be performed by clinicians with no forensic background. It is important to stress the fact that bite mark evidence to be presented and accepted by a court of law it needs to be of very high quality.

The ultimate goal of managing cases of child abuse and neglect is to prevent subsequent injury to the child and to bring perpetrators to justice. These cases of abuse and neglect are usually managed by pediatric specialists with forensic medicine practitioners. As for many other cases[22], the case presented confirms the importance of forensic odontological involvement in investigations of cases of child abuse and neglect. It further exemplifies the importance of communication and collaboration between pediatric specialists and forensic practitioners, and emphasizes the multidisciplinary approach in investigation and management of cases of child abuse.

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SECTION JURISPRUDENCE AND LITIGATION

# The impact of tooth avulsion on daily life performance using the Brazilian OIDP index in children and young adults.

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***ABSTRACT***
***Introduction: The evaluation of orofacial damage is an emerging branch in the forensic sciences, specifically in forensic odontology and medicine. One of the major limitations during the evaluation of forensic orofacial damages is establishing the consolidation date of acquired lesions. The consolidation date is defined as the moment from which orofacial damages are considered irreversible.***
***Aim: To stress the relevance of knowing the consolidation date in children who underwent orofacial trauma, and to enhance forensic expertise on the evaluation of dentomaxillofacial damages.***
***Material and methods: Ninety-six patients, aged between 11 and 31 years old, treated at the dental clinics of the Federal University of Minas Gerais, Brazil, were selected for forensic orofacial evaluation. All the patients presented at least one traumatically avulsed tooth and a temporary partial denture.***
***Results: The mean age for the traumatic avulsion was 10,3 years old. The mean time for the placement of a prosthesis was 2,9 years after the initial consultation. The mean time for the use of prosthesis was 2,2 years. No significant differences were observed regarding orofacial damage outcomes between patients younger or older than 18 years of age. It was observed that patients using temporary removable partial dentures presented a 3,6-fold greater possibility of developing socially significant sequels if compared with patients using temporary fixed partial dentures.***
***Conclusion: Knowing the consolidation date of orofacial damageenables the prediction of the potential development of social sequels in children and adolescents who isaster victim identification (DVI) is an intensive and demanding task involving specialists from various disciplines. The forensic dentist is one of the key persons who underwent traumatic dental avulsion.***

***KEYWORDS*:** dental avulsion; orofacial damage; traumatic injury; consolidation date

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## INTRODUCTION

Avulsion of permanent teeth corresponds to 0,5-3% of all the dental lesions in this study. This modality represents one the most damaging dental injuries, in which prognosis depends on the decisions and attitudes taken at the time and location of the trauma, and immediately after the dental avulsion.[1,2] Mostly, dental reimplantation is the treatment of choice, but it cannot always be performed immediately. The treatment plan is usually decided by an emergency dental surgeon, who will execute the best approach to achieve optimal prognoses.

Nowadays, violence and vehicle accidents are the main source of facial trauma.[3] Consequently, the stomatognathic system is directly affected. In specific cases, accidents involving orofacial trauma will result in legal repercussions, and forensic expertise will be necessary. In this context, forensic dentists are requested to perform clinical evaluation and to provide forensic reports.

The estimation of the consolidation date during the clinical evaluation of orofacial traumas, such as dental avulsions, enables greater understanding of the trauma process, guiding a further treatment plan and helping to achieve the optimal prognosis. Especially in children and adolescents, dental avulsion implies potential social sequels, both due to the absence of teeth and the use of temporary dentures. Thus, the present study aims to establish the consolidation date in youngsters who underwent dental avulsion.

## MATERIAL AND METHODS

Ninety-six randomly selected male and female patients, aged between 11 and 31 years old, were selected. All the patients were treated for dental avulsion at the dental clinics of the Federal University of Minas Gerais, Brazil. The patients had suffered dental avulsion, losing at least one tooth, and were using temporary removable or fixed dentures. The clinical choice for the type oral rehabilitation was

based on the patients' age and the feasibility of performing fixed dentures. Limitations were directly related to the necessary time for the completion of dentomaxillofacial growth, and to the stability of the fixed denture considering the status of dental abutments and personal hygiene. The social status of the patients was not a factor because dental treatment was provided pro deo by students at the university dental clinic.

The child Oral Impact on Daily Performance (OIDP) index was applied to assess the oral impact on the performance of the children and adolescents during their daily routine. The OIDP index, previously validated[4], is an interview-based test which measures the physical, psychological and sociological performance of patients in relation to the presence of oral injuries, providing information regarding quality of life. The interviewed patients were requested to assess their limitations in relation to the frequency and severity of 1) smiling; 2) eating; 3) emotional stability; 4) speaking; 5) mouth cleaning; 6) social contact 7) sleeping; and 8) studies .[5-6] The OIDP index reveals whether dental trauma is present, whether it affects life quality, and whether it hampers daily activities. [7-8]

## RESULTS

In the present survey, there was a sexual bias in the incidence of dental avulsions, with approximately 67% of dental avulsions occurring in males. The main causes of dental trauma were falls to the ground (31%), bicycle falls (23%), and motor vehicle accidents (12%). All the studied children and adolescents were initially treated by performing late reimplantation, followed by endodontic treatment with calcium hydroxide. Later, in

the absence of additional treatments, teeth were extracted and temporary prostheses placed in the space in the dentition. Among the dental prostheses, the temporary removable partial denture was used in 83% of the cases. The other patients (17%) underwent treatment with temporary fixed partial dentures (Table 1).

**Table 1 – Mean age, expressed in years, of the studied patients at different periods of examination and time lapse for the use of prosthesis.**

| | Mean age | SD |
|---|---|---|
| 1) Age at OIDP application | 15,7 | 3,6 |
| 2) Age at dental trauma | 10,3 | 3,4 |
| 3) Time lapse until initial prosthesis consultation | 2,9 | 1,9 |
| 4) Time using prosthesis | 2,2 | 1,8 |
| 5) Period between the accident and the use of prosthesis | 3,4 | 2,3 |

Table 2 presents information regarding the potential impacts caused by dental trauma in the quality of life of the studied patients, considering two different age groups: patients younger or older than 18 years old. The correlations between the variables addressed in the OIDP test and the age groups were performed by using Chi-square and Fisher's exact test. P-values were considered statistically significant when less than 0,05.

No statistically significant correlations were observed between the variables addressed in the OIDP test and the age groups of patients (younger than, or equal to 18 years and older than 18 years). Statistically significant correlations between the OIDP-addressed variables and the type of prosthesis used, were revealed (Table 3) Specifically, patients using temporary removable prostheses report a larger number of complaints in relation to eating, social contact and global impact, when compared to the patients using fixed prostheses.

Considering the influence of using removable prostheses on OIDP variables, an Odds Ratio statistical analysis was performed to evaluate the level of impact in the patients' quality of life (Table 4). Temporary removable prostheses have a 3,6 fold higher impact than the temporary fixed prostheses.

## DISCUSSION

The evaluation of temporary injuries in children and adolescents is part of the forensic expertise in the living. Especially in forensic dentistry, the evaluation of dental trauma must be interpreted as a public health issue. Moreover, dental avulsion plays an important psychosocial role in young individuals.[9] Based on that, the evaluation of temporary injuries in the forensic sciences should differ between young individuals and adults. [10]

In the present survey, dental avulsion was selected for investigation because it is one of the most commonly observed lesions caused by dental trauma. Specifically, dental avulsion is predominant in young male patients. [12]

Dental avulsion is most common in anterior teeth, the absence of which has a strong impact in social activities and psychological status. The consolidation date in children who underwent dental avulsion consists of the moment from which damages are irreversible, and the only possible treatments are those that aim to attenuate their effects on quality of life [12, 13]. Specifically in children, the consolidation date is sometimes hampered by skeletal development. Thus, the

consolidation date of dental avulsion is best assessed after the complete arrangement and reshaping of the affected alveolar bone.[10, 13] At this stage, no signs of potential reversibility are observed. Yet in adults, forensic expertise concerning the evaluation of dental damage is often related to the post-traumatic working capability [15] and possible legal claims are based on dental injuries caused during work. The present study suggests that in children the consolidation date should be properly established from the moment of dental avulsion and prosthesis placement, because at this stage the lesion would be clinically consolidated. In this context, the skeletal development is not taken into account for the consolidation date, because no statistical significance was observed for the correlation between patients younger than 18 years old in face of the global impact (Table 2). Thus, after the dental avulsion and placement of a prosthesis, individuals younger or older than 18 years old are able to return to daily activities, even under reduced performance.

**Table 2 – Correlations between OIDP variables and age.**

| Variables | Age (years) <18 | Age (years) ≥ 18 | P value |
|---|---|---|---|
| **Smiling** | | | |
| No | 38 | 8 | 0,062 |
| Yes | 26 | 14 | |
| **Eating** | | | |
| No | 47 | 17 | 0,722 |
| Yes | 17 | 5 | |
| **Emotional stability** | | | |
| (No) Altered | 52 | 15 | 0,238 |
| (Yes) Maintained | 12 | 7 | |
| **Speaking** | | | |
| No | 57 | 21 | 0,674 |
| Yes | 7 | 1 | |
| **Mouth cleaning** | | | |
| No | 46 | 11 | 0,061 |
| Yes | 18 | 11 | |
| **Social contact** | | | |
| No | 29 | 7 | 0,268 |
| Yes | 35 | 15 | |
| **Sleeping** | | | |
| No | 60 | 20 | 0,643 |
| Yes | 4 | 2 | |
| **Scholarly work** | | | |
| No | 58 | 20 | 1,000 |
| Yes | 6 | 2 | |
| **Global impact** | | | |
| No | 14 | 3 | 0,541 |
| Yes | 50 | 19 | |

**Table 3 – Correlations between the OIDP variables and the type of dental prosthesis.**

| Activities | Type of prostheses | | P-value |
|---|---|---|---|
| | Temporary fixed | Temporary removable | |
| **Smiling** | | | |
| No | 9 | 37 | 0,578 |
| Yes | 6 | 34 | |
| **Eating** | | | |
| No | 15 | 49 | 0,009* |
| Yes | 0 | 22 | |
| **Emotional stability** | | | |
| No | 13 | 54 | 0,505* |
| Yes | 2 | 17 | |
| **Speaking** | | | |
| No | 14 | 64 | 1,000* |
| Yes | 1 | 7 | |
| **Mouth cleaning** | | | |
| No | 13 | 44 | 0,066 |
| Yes | 2 | 27 | |
| **Social contact** | | | |
| No | 10 | 26 | 0,032 |
| Yes | 5 | 45 | |
| **Sleeping** | | | |
| No | 15 | 65 | 0,585* |
| Yes | 0 | 6 | |
| **Scholarly work** | | | |
| No | 15 | 63 | 0,341* |
| Yes | 0 | 8 | |
| **Global impact** | | | |
| No | 6 | 11 | 0,030 |
| Yes | 9 | 60 | |

**Table 4 – The influence of the type of dental prostheses in the global impact, performed by calculating Odds Ratio values.**

| | Type | *OR* | P-value |
|---|---|---|---|
| **Prostheses** | Fixed | 1,000 | 0,038 |
| | Removable | 3,636 | |

The forensic assesment of dental trauma in the living plays a relevant role in pointing to an optimal treatment, and consequently striving for better prognosis, preventing further sequels and especially indicating whether the damage affects the patient in his global environment. The present study revealed that the global impact, as well as eating and social contact variables, are strongly affected by the type of temporary prosthesis, or specific removable prosthesis. This finding suggests that fixed prostheses are more suitable for rehabilitating patients who underwent dental avulsion. Thereby the impacts on eating, social contact, and global effects could be reduced.

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SECTION IDENTIFICATION

# Estimation of stature in a young adult indian population using the carrea's index

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*The authors declare that they have no conflict of interest.*

***ABSTRACT***

***The stature or height of an individual is useful for assisting in forensic identifications. Teeth can act as a valuable tool for stature estimation when only the skull is available. Carrea's index estimates the stature of a person from the dimensions of lower anterior teeth. The aim of this study was to assess the reliability of the Carrea's index in an Indian population. Data was collected from plaster models of 125 undergraduate students for examination. Each hemiarch was considered separately equaling 250 inferior hemi-arches, which were divided according to the dental alignment into normal, crowded and diastema and the measurements (Arch and Chord) were made with a 'divider caliper'. A statistically significant difference between the types of dental arch was obtained for both males and females with regards to the different dental alignments; where normal dentition (94.03%) obtained the highest success rates for males and crowded dentition (87.87%) for females. Statistically significant differences were also found between the types of arches for both right and left side ($p<0.001$; $p=0.004$). The presence of diastema reduced the success rates when compared in terms of both sex and side of the arch. It was concluded that the Carrea´s index is a reliable method for height estimation in arches with normal and crowded dentitions, useful for both sexes, and for both right and left side of the arch. However, the method was not reliable for hemiarches with a diastema.***

***KEYWORDS*****:** Forensic Odontology, Stature Estimation, Carrea's Index, Dental Arch.

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## INTRODUCTION

Forensic odontology and anthropology provide valuable support with regards to human identification. In cases where soft tissue is destroyed, carbonized or absent for whatever reason, bones and teeth become the only source of information about the identity of the deceased. In human identification, any variation from normality becomes an important tool when trying to establish the identity of the deceased.[1]

Stature is the height of a person in the upright posture[2] and has a definite and proportional biological relationship with each and every part of the human body, i.e. head, face, trunk, extremities.[3] This relationship helps a forensic scientist to calculate stature from dismembered and mutilated body parts during forensic examinations and thus aids in narrowing down the investigation process by providing useful clues to the investigation agencies. The dental arch has many variables which makes it almost impossible for two people to have identical tooth features. Teeth are special in cases of identification of deceased since they can resist the effect of time, are resistant to fire and trauma and can also provide information on species, race, gender, age, height and individual characteristics. Teeth have also added advantage of standard anatomical landmarks which are easy to locate.[4]

Many studies have been conducted on the estimation of stature from various body parts like hands,[5] intact vertebral column,[6] upper and lower limbs,[7] individual long and short bones,[8] foot and footprints[3] etc. Only a few studies have been conducted on the cephalo-facial region with respect to the estimation of stature.[9-12]

From this perspective, Carrea[13] conducted studies to estimate height, based on the fact that there is proportionality between the diameter of the teeth and body height, and used it to estimate height from the dimensions of the anterior mandibular teeth. Carrea's index basically measured two dimensions: the Arch and the Chord. The 'arch' represented by the sum of mesiodistal widths of anterior teeth on one side and the 'chord' represents the direct distance between mesial edge of central incisor and the distal edge of canine on the same side. Using these measurements, the upper and lower range of the height estimates are derived. Similar studies conducted by Silva (1990); Sampaio(1995); Cavalcanti et al (2007), have verified this fact.[14-16] A recent study was also conducted regarding the estimation of stature from teeth dimensions however the buccolingual and mesiodistal dimensions of all teeth (except third molars) were assessed instead of just the mandibular anterior teeth where correlation analysis revealed that 21 of the 56 tooth crown variables had a low albeit statistically significant correlation to stature ($p < 0.05$). They concluded that moderate correlation is probably due to early completion of growth of tooth crowns vis-à-vis other parameters such as long bones that mature later and have a higher stature-correlation.[17] Looking at the scarcity of studies pertaining to the estimation of stature from dental dimensions in the Indian scenario, the present study provides anthropometric relationships of dimensions of certain teeth with stature based on the Carrea's Index and to test the reliability and accuracy in a sample taken from mixed population of North India.

The aim of the present study was to estimate the height range of a person through measurements of his teeth using the Carrea's index and check its accuracy in different types of dental alignment;also, to compare accuracy between both sides of the arch and determine if there are sex-wise differences in success rates.

## MATERIALS AND METHODS

The study protocol was approved by the Institutional Ethical review committee of Sudha Rustagi College of Dental Sciences and Research, Faridabad. A sample size of 250 was found to be sufficient, taking 5% as margin of error at 95% confidence level. The sampling unit was one hemi-arch so 125 subjects were selected to give a sample size of 250 hemi-arches. The study population consisted of students aged 21 to 25 years from a dental college in Faridabad, Haryana. Young people show less physiological wear, less wasting diseases and less periodontal disease which if present, might lead to spacing between teeth thus affecting the accuracy of the method. This population was selected since it comprises of students from all over the state of Haryana and also some neighbouring states, thus a mixed young adult North Indian population.

All subjects willing to participate and who had dimensionally stable teeth i.e. intact crowns without any loss of enamel, were included. The subjects who had any of the mandibular anterior teeth missing or had any structural abnormality were excluded. The subjects who had undergone or were currently undergoing orthodontic treatment were also excluded.

Plaster models of the lower dental arch of each subject were obtained from alginate impressions poured in dental stone. A standardized procedure was followed for mixing of dental stone with water, taking fixed water/powder ratio (W/P ratio) for all the models constructed. A calibrated dispenser was used for dispensing of dental stone and water so that a uniform W/P ratio was maintained.

For examining the plaster models, each hemi-arch was considered separately and was divided into three categories: normal, crowded and spaced. The greatest mesio-distal crown widths of the mandibular anterior permanent teeth and the chord were measured using the modified method for Carrea's index where dividers with fixing device were used. The distance between divider tines was read off on a stainless steel scale and recorded to the nearest millimeter. Although shown to produce systematic errors, use of dividers is an acceptable method.[18] The modified method has presented greater effectiveness in stature estimation when compared with the original Carrea's method.[16]

Carrea's Index:[13] For the Carrea's index, the mesio-distal widths of lower central incisor, lateral incisor and canine (Fig 1) were recorded and summed. This was termed the 'ARCH'. The linear distance between the ends of the arc, represented by the mesial edge of central incisor and the distal edge of canine on the same side, measured on the lingual surface were also measured (Fig B). This was termed the 'CHORD'. The estimated height was calculated using the formula below:

Formula: Maximum Stature = $\frac{\text{arch (in mm)} \times 6 \times 3.1416 \times 100}{2}$

Minimum Stature = $\frac{\text{chord (in mm)} \times 6 \times 3.1416 \times 100}{2}$

The actual stature was measured with an anthropometer, by making the subject stand erect on the horizontal plane, barefooted, in the anatomical position according to the Frankfurt plane, in inspiratory apnoea, aligning the posterior surface of heels, pelvic girdle, scapular girdle, and occipital region to the vertical plane. The stature was measured with the rod of the anthropometer in contact with the vertex.

All examinations and calculations were done by a single dentist. The intra-examiner variability was tested in the measurement of the actual height using the anthropometer and the measurement of the arch and chord of twelve casts using divider calipers.

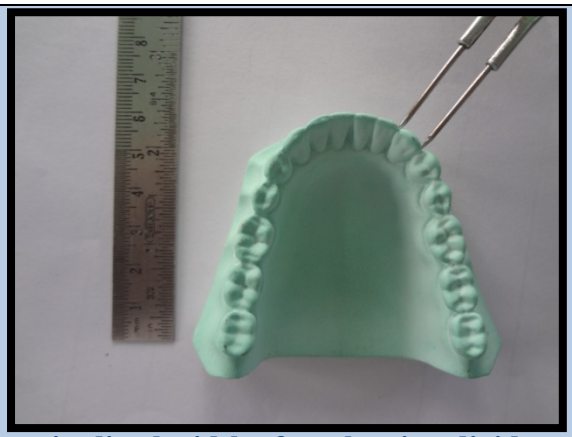

**Fig 1: Measurement of mesio-distal width of tooth using divider calipers.**

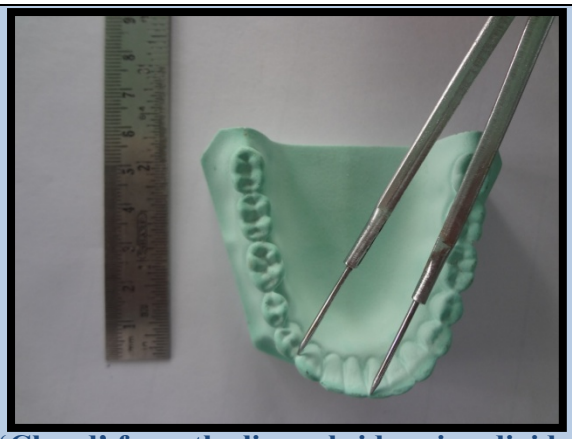

**Fig 2: Measurement of 'Chord' from the lingual side using divider calipers.**

The data was entered into an Excel spreadsheet (MS Office 2007) and then analysed using the SPSS software (version 11.5). Frequencies of correct height estimation were calculated. Proportion of correct estimations were compared according to sex, side of arch and the types of dental alignment using Chi square test.

## RESULTS

Assessment of intra-examiner variability, showed repeatable results for measurements of height, arch and chord with kappa values ranging from 0.76 to 0.82.

A total of 67 males (53.6%) and 58 females (46.4%) were selected. Out of the total of 250 inferior hemi-arches, there were 131 (52.4%) normal arches, 79 (31.6%) crowded and 40 (16%) arches with diastemata (Table 1). The height distribution and mean arch and chord values for both sexes is given in Table 2. Males were taller and had higher mean arch and chord values.

Table 3 shows the overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to sex. A statistically significant association was found in the stature estimation accuracies between the types of arches for both males and females ($p<0.001$ and $p=0.016$ respectively).

Table 4 represents the overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to side. Statistically significant association was found in the differences between the types of arches for both right and left side ($p<0.001$ and $p=0.004$ respectively).

A higher success rate was seen for males (94.03%) as compared to females (87.5%) for normal alignments (Table 1), but there

was no statistical difference between the two (p=0.235). The left side of the hemi-arch showed a higher success rate (93.84%) in comparison to right side (87.87%) but again no statistically significant differences were observed between the two sides (p=0.365).

In case of crowded hemi-arches, a higher rate of success was obtained for males (n=35; 92.1%) and left side of the dental arch (n=38; 92.68%) in comparison to females (87.80%) (Table 3) and right side (86.84%) (Table 4) respectively. However this difference in percentages was not proven to be statistically significant for either sex (p=0.713) nor side of dental arch (p=0.471).

In case of hemi-arches with diastemata, there was a somewhat balanced distribution of success and failure for estimation of height if we compare it with dental arch categories. There was a 58.62% and 54.54% success rate for males and females respectively (Table 3). The left sided hemi-arches showed a higher success rate (68.42%) as compared to the right side (47.61) (Table 4). The differences in case of both sex and side showed no statistical significance (p=1.000 and p=0.216).

**Table 1: Overview of statistics related to sex, kind of dental alignment and side of hemi-arch.**

| ALIGNMENT | NORMAL | | CROWDED | | DIASTEMA | | |
|---|---|---|---|---|---|---|---|
| SEX | | | | | | | TOTAL |
| | Right | Left | Right | Left | Right | Left | |
| MALE | 34 | 33 | 18 | 20 | 15 | 14 | |
| Total | 67 | | 38 | | 29 | | 134 |
| FEMALE | 32 | 32 | 20 | 21 | 6 | 5 | |
| Total | 64 | | 41 | | 11 | | 116 |
| Grand total | 131 | | 79 | | 40 | | 250 |

**Table 2: Descriptive statistics of the actual height, arch (mm) and chord (mm) values in the study population**

| | Males | Females | Total |
|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) |
| Actual Height | 174.52 (5.51) | 160.87 (5.42) | 168.19 (8.74) |
| Arch (mm) | 20.11 (0.97) | 18.74 (0.94) | 19.47 (1.17) |
| Chord (mm) | 17.51 (1.23) | 16.33 (0.87) | 16.96 (1.22) |

**Table 3: Overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to sex.**

| SEX | ARCH TYPE | HITS | MISSES | GROUP TOTAL | P value |
|---|---|---|---|---|---|
| | | n (%) | n (%) | N | |
| MALES | NORMAL | 63(94.03) | 4(5.97) | 67 | |
| | CROWDED | 35(92.10) | 3(7.89) | 38 | |
| | | | | | <0.001 |
| | DIASTEMA | 17(58.62) | 12(41.37) | 29 | |
| TOTAL | | 115 | 19 | 134 | |
| FEMALES | NORMAL | 56(87.5) | 8(12.5) | 64 | |
| | CROWDED | 36(87.80) | 5(12.19) | 41 | |
| | | | | | 0.016 |
| | DIASTEMA | 6(54.54) | 5(45.45) | 11 | |
| TOTAL | | 98 | 18 | 116 | |

**Table 4: Overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to side.**

| SIDE | ARCH TYPE | HITS | MISSES | GROUP TOTAL | P value |
|---|---|---|---|---|---|
| | | n (%) | n (%) | N | |
| RIGHT | NORMAL | 58(87.87) | 8(12.12) | 66 | |
| | CROWDED | 33(86.84) | 5(13.15) | 38 | |
| | | | | | <0.001 |
| | DIASTEMA | 10(47.61) | 11(52.38) | 21 | |
| TOTAL | | 101 | 24 | 125 | |
| LEFT | NORMAL | 61(93.84) | 4(6.15) | 65 | |
| | CROWDED | 38(92.68) | 3(7.31) | 41 | |
| | | | | | 0.004 |
| | DIASTEMA | 13(68.42) | 6(31.57) | 19 | |
| TOTAL | | 112 | 13 | 125 | |

## DISCUSSION

A known biological relationship between bones and body parts exists and this is very useful in determining the estimated height from long bones.[3,8] However, this cannot be said to be true in case of teeth where no defined relation between the lengths of teeth exists in relation to body parts and the development of teeth is not directly related to the development of other body parts. Still, teeth could be used as a reliable source for stature estimation especially in those forensic cases where other body parts are not available for forensic examination.[4] The most traditional method of estimation of human stature by examining the teeth

was proposed by Carrea in 1920 which was based on the relationship of measurements of lower anterior teeth with the actual stature of the person.[13] Unfortunately there is no written description of the origin of this formula since Carrea's studies of 1920 and 1939 were done at a time when papers often lacked important information and methodological patterns were not observed by authors.[13]
The Carrea´s index for normal arches, as originally described has shown significant rates of success among both sexes with no statistically significant difference between them. The same result was seen on left and right hemi-arches, demonstrating that the method can be applied for both sides, without affecting the outcome.

In a study by Cavalcanti *et al*[16] to estimate the stature through Carrea's index, two methods of measuring the arch and chord were used namely the 'conventional' method and the 'modified' method. In case of the conventional method, the arch was measured using a millimeter tape and the chord was measured using a divider caliper whereas in the modified method, both were measured with a divider caliper. Higher success rates were observed in males (100%) as compared to females (93.3%) and equivalent rates were observed for both sides in case of modified method used in the study by Cavalcanti *et al*.[16] The conventional method on the other hand showed lower success rates for both sexes and both sides. These findings are comparable with those found in the present study where the modified method was used. It should be noted that normal and crowed arches were analyzed together in the original studies, without distinguishing between them and arches with diastemata were not mentioned in the original study. This is different from the present study in which the arches were divided into 3 types (normal, crowded and diastema) for separate analysis.

This study has obtained high success rates for crowded dentition for both sexes and both sides which is in contradiction to a study by Croce & Croce Junior [19]who had obtained lower success rates for crowded arches and hence had discouraged the use of Carrea's index for crowded arches.

There was a higher consistency between the stature estimation and the left hemiarch in this study for all the three types of dental arches, even though not statistically significant. This finding was similar to the results by Cavalcanti *et al*[16] which has shown equivalent success rates for both sides by the modified method, and higher correlation to the left hemiarch by the conventional method. When considering the differences between sexes, a higher consistency was observed for males as compared to females, although not significant.

In comparison with a study conducted by Lima *et al* in subjects in the age group of 18 to 30 years,[20] contradictory findings were observed where higher success rates for right side were obtained. This finding could be attributed to factors such as plasticity of teeth, eruption sequences of teeth, dentition differences due to differences caused by favouring one side of the mouth and racial differences where Lima had conducted the study among a young adult South American population as compared to this study where a young adult Indian population was taken. Hence age would not be a factor which could lead to these variations.

As stated by Carrea,[21] any hemiarch can be used to estimate the stature, considering the principle of bilateral symmetry, accepting small variations as normal asymmetries. The statistical insignificance of the variation found in this study is in line with Carrea´s theory.

Silva in his study[14] had measured the chord with a caliper, and the arch with a millimeter tape. A 70% success rate was observed when actual height was compared with the estimated height however no distinguishing between the different types of arches was done. Both hemiarches and sex were examined together, with no distinction.

The hemiarches with diastemata had shown low success rates. This could be due to the increased chord value and the small range of estimated maximum and minimum height values. In these cases, the value from chord that predicts the minimum height, was higher than the value from the arch, which estimates the maximum height. This error in the minimum stature value might have been the reason for low success percentages in arches with diastemata. This is in accordance with the study conducted by Lima etal[20] which has also shown lower success rates (50%) when it comes to arches with diastemata.

There are numerous factors which affect the normal development of the dentition. Any deviation leading to an abnormality in the alignment of the teeth results in either crowding or spacing of the dental arches. Crowding occurs when there is disharmony in the tooth to jaw size relationship or when the teeth are larger than the available space. Supernumerary teeth, missing teeth, impacted teeth, or abnormally shaped teeth are other reasons that may cause crowding. Spacing with diastemata occurs when jaw size is greater than the size of teeth or when teeth are smaller than the available space. Other reasons could be due to congenitally missing teeth or due to any habits such as thumb sucking or tongue thrusting.[22]

Overall, this study showed similar success rates for both males and females in all the 3 types of arches (normal - 94.03% & 87.5% respectively; crowded - 92.1% & 87.8% respectively; diastema - 58.62% & 54.54% respectively).

In case of side of the arch, similar success rates was seen for both sides in case of normal and crowded dentition with the left side showing slightly higher success rates in comparison to the right side (normal – 87.87% & 93.84% respectively; crowded – 86.84% & 92.68% respectively). Significant differences in the success rates for both the sex and the side of the arch were found. This might be attributed to the low success rates associated with diastema and is probably not between the normal and crowded dental alignments.

It has been well reported in literature that the stature in adults declines significantly as the age advances.[23-25] Height of the person increases progressively and it becomes maximum at the age between 21 and 25 years. After this, for every 25 years, stature is shortened by 2.5cm.[26] Studies have confirmed this well established fact relating to the substantial decrease in stature once the mature age is attained.[27,28] The stature loss may be associated with the thinning of intervertebral discs and loss of vertebral body height,[25] stooping posture, decreased tone in muscles, and osteoporosis.[29] As the sample age in the study ranged from 21 to 25 years, the criteria for loss of stature was not valid and the results of this study can be generalized over a young Indian population. In some other studies, the age ranges varied between 18 to 30 years[20] and between 18 and 44 years.[30] Further studies could be planned to see the effect of increasing age on the accuracy of this method.

## CONCLUSION

Carrea´s index can be used for stature estimation for both males and females as well as in right and left hemi arches in arches with normal and crowded dental positioning. For the hemiarches presenting

diastemata, the method was found to be less accurate..

The present study concludes that, like other parts of human body, dimensions of the teeth can also be used for estimation of stature in forensic applications when remains of other body parts are not found. It is seen that Carrea's formula shows good reliability and applicability of estimates for a sample taken from a mixed population of North India.

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