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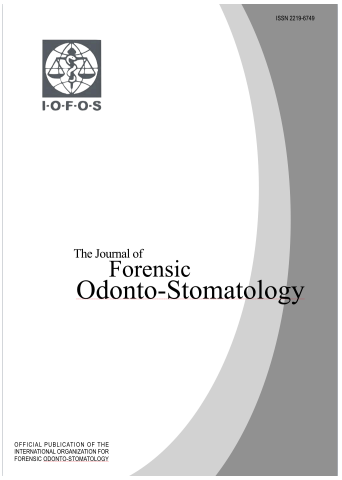

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Sex determination using mandibular ramus flexure in South Indian population - A retrospective study

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KEYWORDS

Sex estimation,
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ABSTRACT

Sex determination or sex estimation from a single or fragment of bone is always difficult in the absence of other bones from the same individual. The current study was an attempt to estimate the sex of an individual from the posterior ramus of mandible or the mandibular ramus flexure. A retrospective study was conducted using orthopantomographs (OPGs) of 200 males and 200 females between the age group of 20 – 70 years. Each radiographic image was examined for the presence of a flexure or notching on the posterior border of the ramus in relation to occlusal plane as the method followed by Loth & Henneberg 1996.The study resulted in samples that were correctly classified as females 59.5% and males 57.5 %. The overall correct sex estimation was achieved in 58.5% of the cases. The predictive accuracy or assessment was higher for females compared to males. Consequently, the posterior ramus of mandible or mandibular ramus flexure can be considered as supplementary rather than a definitive means of sex determination. Hence, it is preferable to include as many parameters as possible to attain optimal accuracy.

INTRODUCTION

Sex estimation is an essential element of anthropological and forensic research. The mandible can be a strong, dense bone of the craniofacial skeleton. Among human bones, the pelvis is the most reliable bone for sex determination. In the absence of a complete pelvis, the mandible is often used as an important means of identification. After the pelvis, the mandible is the most sexually heterogeneous bone. As shown in previous studies, various metric and non-metric parameters are used to assess mandibular sexual dimorphism.[1]

If an examiner has access to a whole skeleton, sex determination is not difficult. Both the pelvis [2, 3] and the cranium [4-6] yield extremely precise data. However, even for an expert, analysing sexual dimorphism in an incomplete or fragmented skeleton can be challenging. In addition to the pelvis and cranium, the mandible is regarded as a useful feature for determining the sex of an unknown skull. Since the beginning of the twentieth century, the utilisation of mandibular measurements began to be investigated [7-13].

Non-metric or visual indicators of the mandible are evaluated quickly and easily by comparing them with index parameters. Metric parameters cannot be used for mandibular fragmentation due to trauma. The dense bone of the lower jaw

helps to maintain its shape for a long time. The shape of the mandible can change depending on chewing habits and lifestyle. Therefore, different ethnic groups may have differences in the shape of the lower jaw. Panoramic radiography and lateral cephalography are methods commonly used in routine dental practice to evaluate important structures of the mandible and maxilla. These radiographs are suitable for checking the integrity of tooth tissue and are frequently used as tools for ramus flexure analysis to determine sex.[1]

The examination of morphologic features led to discovery of distinct angulations of the posterior border of mandibular ramus at the level of occlusal surface of the molars in adults which was termed as flexure that refers to "the quality or state of being flexed." Mandibular ramus flexure, discovered by Loth and Henneberg in 1996, has drawn worldwide attention due to its exceptionally high accuracy in sex estimation. According to Loth and Henneberg the distinct flexure is present in the posterior border of ramus at the level of occlusal surface of the molars in adult males and is not seen in females, if present, it was either above or below the occlusal surface. With this background, the current study is undertaken to evaluate the validity and predictive accuracy of mandibular posterior ramus flexure in sex estimation. [14]

MATERIALS AND METHODS

The present study titled "Age Estimation and Sex Estimation using Ramus Flexure - A Retrospective Study" was conducted in the Department of Forensic Odontology, JSS Dental College and Hospital, Sri Jagadguru Sri Shivarathreeshwara Academy of Higher Education and Research (JSSAHER), Mysuru, Karnataka.

This study was undertaken with the aim of establishing certain mandibular parameters as criteria, thereby setting a population specific standard for age and sex estimation. Digital orthopantomograms (OPGs) archived in the Department of Oral Medicine and Radiology, JSS Dental College and Hospital, Mysuru were used for this study. The study sample consisted of 400 OPGs (200 male and 200 female subjects) that were divided into five groups on the basis of chronological age by decades (40 in each group for male and female subjects), in the age range of 20-70 years. Mandibular parameters namely ramus flexure were studied and assessed whether they aid in estimating age and determining sex.

Digital orthopantomograms (OPGs) were obtained from PLANMECA PROMAX SCARA 3 Digital OPG Machine, (70 kVp, 8 mA for 09 seconds), manufactured by PLANMECA OY, Helsinki, Finland, with a 1:1 ratio. The digital orthopantomograms (OPGs) were imported into Planmeca Romexis Viewer Software 2.9.2.R., and the measurements were recorded. Microsoft Office Excel (2016) sheet was used to compile the data. The statistical analysis was carried out using SPSS Software Package version 20. Panoramic radiographs with all structures clearly visible were selected.

Methodology:

Ethical clearance was obtained from JSS Dental College & Hospital's Institutional Ethical Committee (JSS/DCH/IEC/2017-18/02) prior to conducting the study. The digital orthopantomograms (OPGs) were selected based on the inclusion and exclusion criteria. The selected radiographs were imported to Planmeca Romexis Viewer 2.9.2.R software, where the mandibular parameters were digitally traced. The literature states that a very high degree of symmetry exists between the left and the right sides, therefore all measurements were made on the left side of the radiograph for uniformity. [15, 16]

Ramus Flexure: Ramus flexure is a distinct angulation present at the posterior border of the mandibular ramus. In adult males, ramus flexure is present at the level of the occlusal surface of the molars (Fig 4). In female subjects the posterior border of the ramus can be straight, or, if flexure is observed, it is found to occur at a higher point near the neck of the condyle or below the level of the teeth in cases with gonial prominence or eversion (Fig 1, Fig 2, Fig 3). This method of observation has been obtained from Susan R. Loth and Maciej Henneberg, 1996. [17] After image calibration (to obtain 1:1 magnification) the identification of the ramus flexure on an OPG, two reference lines were traced. One as a tangent to the posterior border of the mandibular ramus (RL) and the other along the cusp tips of the molars to mark the occlusal plane. This methodology has been obtained from Badran D. H. et al., 2015. [18]

Figure 1. Ramus flexure near the neck of the condyle (yellow arrow) seen in females

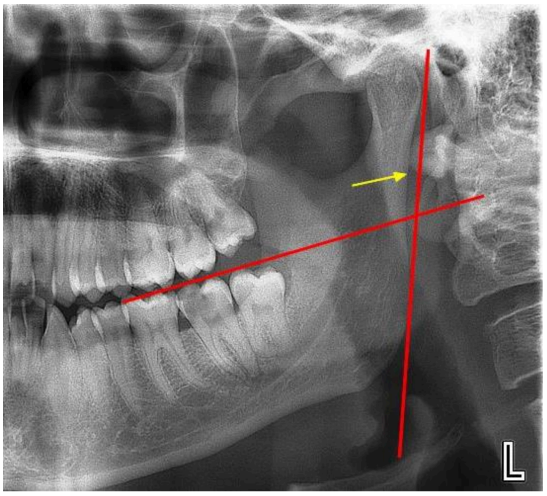


Figure 2. Ramus flexure below the occlusal plane (yellow arrow) seen in females

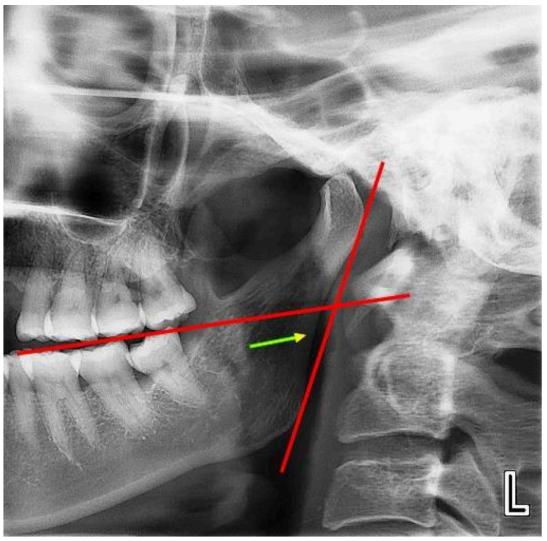


Figure 3. Ramus flexure absent (in yellow) seen in females

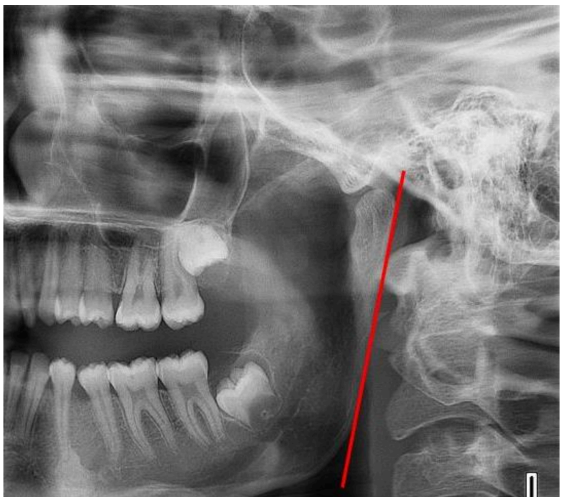
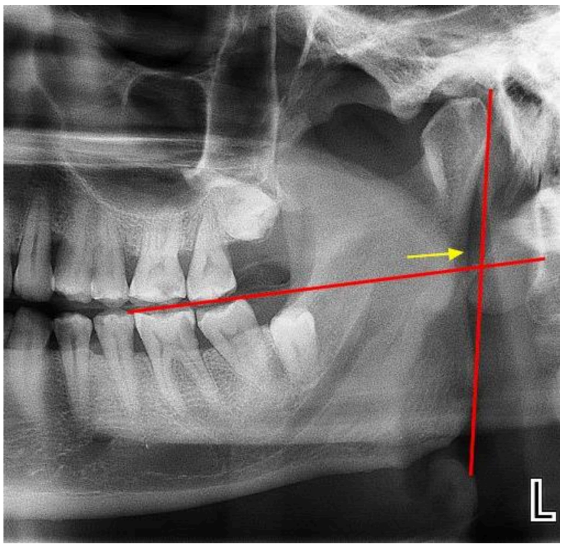


Figure 4. Ramus flexure absent (in yellow) seen in females



RESULTS

This study was undertaken to estimate age and determine sex using the mandibular ramus flexure or notch by digitally tracing measurements in Planmeca Romexis Viewer software. Ramus flexure was separately analysed for sex estimation and hence is not used in the description statistics. The measured values were entered in Microsoft excel sheet. The data was subjected to statistical analysis using SPSS Software Package 20.0. As compared and analysed with the previous national and international studies, we restricted ourselves to Descriptive statistics - mean and standard deviation were calculated. The data was subjected to independent '*t*' test and the 'P' value determined to establish the significance of the parameters in males and females.

Pre-calibration of Examiner

Data collection and exporting to the software were done by a maxillofacial radiologist who did not participate in measurement taking. All the measurements were recorded by a radiologist and a forensic odontologist and also an oral radiologist of similar experience in the field of Oral and Maxillofacial Radiology and forensic odontology. The two observers were blinded to the sex and age of the individual where no evidence of sex or age was visible in the included panoramic images. The two observers were also blinded to the measurements taken by each of

them. The mean values taken by the two observers were calculated and subjected to statistical analysis.
In order to ensure the uniformity with which the analysis was undertaken, the investigator was presented with a random set of OPGs. The agreement analysis of inter-observers had values greater than 0.89, and the intra-observer agreement analysis had values ranging from 0.85 to 0.99. Most Kappa values were interpreted to represent from substantial agreement to almost perfect agreement. The study had high values in the inter- and intra-observer analysis, showing good accuracy in the measurements made for the same person or for more than one observer.
For sex estimation using ramus flexure (Table 1, the samples that were correctly classified as females was 59.5% (119) and as males was 57.5 % (115) of the cases. The overall correct sex estimation was 58.5% of all the cases.

Table 1. Sample size distribution

Study Groups	Age group	Male	Female
Group 1	20-30 years	40	40
Group 2	31-40 years	40	40
Group 3	41-50 years	40	40
Group 4	51-60 years	40	40
Group 5	61-70 years	40	40
	Total	200	200

DISCUSSION

A distinct angulation of the posterior border of the mandibular ramus is termed ramus flexure. This distinct angulation present at the level of the occlusal surface of the molars is seen in adult males. In most females, the posterior border of the ramus is straight (also seen in juvenile mandibles) or, if flexure is observed, it was found to occur at a higher point near the neck of the condyle or below the level of the teeth in cases with gonial prominence or eversion.

It is also important not to confuse a strongly but gradually arched or curved upper ramus and condylar neck, with the distinct angulation of true ramus flexure. [5] In the present study, the classification table correctly classified females in 59.5% and males in 57.5% of the cases. The overall accuracy of correctly classifying ramus flexure was 58.5%. Comparison of percentage of accuracies for sex estimation using ramus flexure is shown in Table 2.

Table 2. Prediction analysis of sex estimation using ramus flexure

Classification Table					
	Observed		Predicted		
			Sex		Total
			Female	Male	
Step 1	Sex	Female	119(59.5%)	81 (40.5%)	200
		Male	85 (42.5%)	115 (57.5%)	200
	Overall Percentage %		58.5%		400

A panoramic radiograph (also known as an orthopantomograph) is widely available and routinely used in clinical practice to evaluate important bilateral mandibular structures. Some investigations showed that the most accurate panoramic measurements were obtained from horizontally

oriented linear items. [19] Moreover, other tests demonstrated that the accuracy and reproducibility of the vertical measurements were adequate when a software-based calibrated measurement instrument was utilised. [20] Comparing ante-mortem and post-mortem radiographs is one of the pillars of forensic anthropology for positively identifying human remains. Hence, ante-mortem orthopantomograms may be extremely useful in identifying human remains. [21] Possessing an abundance of panoramic radiographs affords a significant opportunity to examine sexual dimorphism and age estimation in a given group. This was the reasoning behind employing panoramic images for mandibular ramus evaluation in the current study

Previous studies have been conducted on OPGs as well as mandibular bone, so both methods can be used as reference for sex determination respectively depending on the type of samples available. If the skull is available, panoramic radiographs of the skull can be taken for analysis. Observations of previous researches conducted on various populations with different sample type used as presented in Table 3 can be observed for variations.

Table 3. Observations of previous researches conducted on various populations

Studies	Sample Type Used	Population	Males	Females	Overall
Present Study , 2021	OPG	India	57.5 %	59.5%	58.5%
Nivia M, 2021 [1]	Lateral Cephalogram	India	59%	87%	-
Asma Maniyar, 2021 [14]	OPG	India	44%	84%	-
Altaf 2019 [28]	OPG	India	80%	95%	-
Leena James 2019 [29]	OPG	India	63.5%	64.6%	-
Amin 2018 [18]	OPG	Jordan	78.9%	85.1%	82.2%
Thais Torralbo 2017 [30]	Mandible	Brazil	53.34%	46.66%	-
Damera A 2016 [31]	OPG	India	82.5%	85%	83.8%
Samatha 2016 [32]	OPG	India	53%	60%	-
Bibhuti 2016 [33]	Mandible	India	68.57%	43.33%	61%
Badran, D. H 2015 [18]	OPG	Jordan	95.2%	77.8%	-
Shivaprakash 2014 [34]	Mandible	India	80%	71%	76%
Indira, AP 2012 [35]	OPG	India	76%	76%	76%
Oettle A C 2005 [36]	Mandible	South Africa	69.6%	67.8%	-
Y. Balci 2004 [37]	Mandible	Turkey	95.5%	60.0%	90.9%
Loth & Henneberg 1996 [17]	Mandible	Africa	99.1%	98.8%	99.0%
Susan Jones Haun 2000 [38]	Mandible	South Africa	96.3%	62.5%	80.4%
Krogman 1940 [39]	Mandible	Iran	82.4%	55.0%	72.2%

The study by Susan R. Loth and Maciej Henneberg (1996, 200 mandibles, 116 males and 84 females, South African population) revealed a 94.2% overall accuracy which they say is on a par with the pelvis and superior to the 90% accuracy rate from a complete skull. [17] In a study conducted by Badran D. H. et al., 2015 [18], 419 Orthopantomographic (OPG) images in a

Jordanian population, an overall diagnostic accuracy of 70.9% was observed. The ramus flexure was more accurately diagnostic for females (94.6%), than for males (47.6%). [18] In Saini et al.'s 2011 [22] study, (112 mandibles, North Indian population) ramus flexure was assessed and the results showed an overall accuracy of up to 82%. [22] In the present study 78.5% (157) female subjects and 58.5% (116) male subjects were correctly classified. While most studies show a moderate level of accuracy with sexing using ramus flexure, the present study reveals a low level of accuracy in sex determination. This could be due to the presence or absence of ramus flexure, on only the left ramus of the mandible in the present study. In Loth and Henneberg's study (1996), the ramus flexure was assessed on both the right and left ramus of the mandibles. [17] Another explanation could be due to the fact that the samples in the present study consisted of several cases of partially dentate and a few edentulous OPGs. Tooth loss is also known to alter jaw morphology (Brace and Mahler, 1971; Daegling, 1993). The study suggests that the loss of even one molar may result in African females remodelling to either the male ramus shape or an intermediate configuration. [17] Mandibular tooth loss of many posterior teeth inevitably led to incorrect occlusal plane delineation and gender misdiagnosis in the study by Badran et al.[18] The loss of posterior teeth in the upper or lower jaw does not only lead to displacement, misalignment and rotation of adjacent and opposing teeth in occlusion, but it also alters the pattern of the masticatory muscle action and their effect on the eating habit and distribution of the occlusal load which, in turn, induces irregular bone resorption and may interfere with remodelling and reshaping of bone[18]. Also, substantial post-maturity growth is known to occur in the ramus (Walker and Kowalski, 1975) and elsewhere between the ages of 18 and 27 (e.g., Lubicka, 1944; Hulanicka and Kotlarz, 1983; Roche, 1989). Mandibular morphology is influenced by both masticatory muscle configuration (e.g., CwirkoGodycki, 1928; Strzalko, 1970; Malinowski, 1971; Weijs and Hillen, 1986) and changes in skull shape (e.g., Cheverud and Midkiff 1992; yEdynak and Iacan, 1993). Thus, the formation of flexion may be the result of a change in the size, strength, or angle of the masticatory muscles, especially the masseter and medial pterygoid muscles, which attach just below the level of ramus flexure. Several studies have challenged the validity and predictive accuracy of ramus flexure.(Koski et al., 1996; Oettlé et al., 2005; Hu et al., 2006).

The researchers disagreed with the prediction of ramus flexure sensitivity for both sexes. Some researchers believe that this method has a higher predictive accuracy for men than women (Donnelly et al., Kemkes Grottenthaler et al., 2002; Balci et al.; Oettlé et al.; Shivaprakash & Vijaykumar), while others have suggested that this method is more diagnostically sensitive in women (Suazo et al; Tamer, 2012) as quoted by Oksayan R 2014. [23] The evaluated sex prediction method was more diagnostic for females in the study conducted by Badran D.H et al 2015. [18] These results are similar to those obtained by the present study as well as other studies. [22, 24]

Several studies have found that this method has a higher predictive accuracy for men than for women. [24] Females reach puberty earlier than males, and this may explain why the assessed sex predictor of sexual dimorphism is more diagnostic for females. Changes in the shape of the mandible affected by the force of the muscles, especially the elevator muscles determined during patterning of the mandibular ramus, are maximal in young adults (Koski). During active growth, the mandible, including ramus flexure, is responsive to hormonal influences and is governed, in both sexes, by the forces exerted by the masticatory muscles as cited by Badran 2015 .[18] It was stated that "the high level of dimorphism in the ramus may arise in response to sex-specific hormones in susceptible skeletal sites". [17] The influence of muscles in moulding the mandibular ramus is expected to come to a complete halt at the cessation of growth at the temporomandibular joint around the age of young adulthood. The poor performance of ramus flexure in the present study can be attributed to the subjective assumption of the exact location of flexure of the posterior margin of mandibular ramus. [18]

The sexual variations in the mandible may bear genetic, hormonal or environmental influences. Since the mandible is the last skull bone to cease growth it is sensitive to adolescent growth spurt. Due to the effect of oestrogen, epiphyseal maturation and skeletal mineralization, mandibular growth becomes stable in females at the age of around 14, while it continuous to grow for 2 more years in males making the flexure more curvature. Weaker muscle forces during

mastication may also contribute to small-sized mandibles in females. Morphological features become confounded by inter-observer differences and difficulties in standardization. Very high degree of intra- and inter-observer errors have been noted by Donnelly et al [25] and Grottenthaler et al. [26]

Thus, they considered association between ramus flexure and sex to be weak, which is in accordance with the present study. In a study conducted by Hill CA in 2000 [27], 79.1 % accuracy was obtained. However, on repeating the observations only 64.7% of the cases were accurately classified. Thus, their study states that difficulty in consistent identification of flexure, low overall accuracy, and high intra-observer error indicate that mandibular ramus flexure is an unreliable feature for sex estimation. [27] With an overall accuracy of 58.5 %, the present study recommends using ramus flexure for sex estimation with other means of identification and not as a sole parameter.

CONCLUSIONS

With an overall prediction accuracy of 58.5 %, ramus flexure can be considered as one of the parameters in sex estimation. Thus, use of ramus flexure as a sole parameter for sex estimation should be avoided. It can be used along with other morphological indicators to determine the sex for identification of an individual.

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Knowledge, awareness and attitude of dental professionals regarding child maltreatment

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KEYWORDS

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ABSTRACT

Background: Dental professionals could play a significant role in identifying, documenting and reporting child maltreatment to appropriate authorities as children are exposed to various maltreatments that can present in the head and neck region.

Aim: The aim of this paper is to assess the level of knowledge, awareness and attitude among dental professionals regarding child maltreatment and to identify the barriers that prevent reporting suspected maltreatment.

Methodology: The present cross–sectional questionnaire–based study was conducted on dental professionals practising in India by emailing a self-structured questionnaire to assess knowledge, awareness and attitude regarding child maltreatment.

Results: 422 dental professionals participated in the survey of which 270 were females. A significant difference was observed in mean knowledge (p=.015), awareness (p=.014) score of the participants with regard to place of work and mean knowledge score (p=.024) of the participants with regard to educational qualification. 300 participants reported that lack of adequate knowledge and awareness about the role of dental professionals regarding child maltreatment is one of the major barriers that prevent reporting child maltreatment.

Conclusion: Findings of the study showed that 43.8% of participants had good knowledge and 44.8% were fairly aware regarding child maltreatment. 86.7% of participants showed a very good attitude towards learning more about the role of dental professionals in the management of child maltreatment.

INTRODUCTION

Child maltreatment is a global, social and public health problem that could affect a victim's life without proper treatment.[1,2] Despite being home to 20% of the world's paediatric population and in comparison to many other countries, there is little understanding of trends, extent and magnitude of child maltreatment in India.[3,4] The growing intricacies of life and changes in socio-economic background escalates the exposure of children to several newer forms of abuse.[4] A survey on child abuse by the Ministry of Women and Child Development, Government of India in 2007 publicised that 69% children faced physical, 53.2% sexual and 50% emotional abuse respectively.[5] The literature reported that signs of various types of maltreatment were evident in oral

cavity and 50 – 77% of the abuse cases involved the head and neck region.[6,7] This indicates that dental professionals could play an important role in identifying, documenting and reporting child maltreatment to appropriate authorities.[7] Therefore, it is necessary for dental professionals to have adequate knowledge of child abuse and neglect to address the problem promptly. However, little has been documented in the dental literature regarding the role of dental professionals in recognising and reporting child maltreatment, especially in India. Thus, the aim of this study was to assess the level of knowledge, awareness and attitude among dental professionals regarding child maltreatment and to ascertain the barriers that prevent reporting maltreatment.

METHODOLOGY

The present cross–sectional questionnaire–based survey was conducted on graduate and post-graduate dental professionals practising in India. Ethical approval was obtained from the institutional ethical committee (PGIDS/IEC/2019/42). Sample size was calculated at 95% confidence level and 5% margin of error with web-based research advisors sample size calculator, which came out to be 384. The self-structured questionnaire to assess the knowledge, awareness and attitude of dental professionals with respect to child maltreatment was sent by e-mail. Response by the participants to the questionnaire was considered as their willingness to participate in the study. The link for the survey was live for a period of 9 months from December 2019-August 2020. During this period, 422 participants responded to the survey. A 30-question-based survey was divided into two parts. The first part included questions with respect to demographics of the responding practitioner while the second part comprised questions to assess the knowledge, awareness, attitude and barriers in reporting child maltreatment by the dentists (Figure 1). A correct answer was awarded one point and a wrong answer zero. For questions which included not sure as third option, average marks were awarded when the respondent answered not sure. Based on the participants' scores, knowledge, awareness and attitude were graded into poor (0-25%), fair (26-50%), good (51-75%) and very good (76-100%).

Data obtained was subjected to statistical analysis. The responses obtained for the questionnaire were tabulated and percentage frequency distribution for responses to each question was computed. Parametric data was expressed as mean and standard deviation (SD). One way ANOVA and Post Hoc Bonferroni test were used for analysis. The criterion for significance was $p < .05$.

RESULTS

In the present study, 422 participants responded to the survey. Table 1 shows the participants' demographic details. Among females, mean knowledge, awareness and attitude score±SD was 9.73±2.33, 6.81±2.11and 1.82±.45 respectively. Mean knowledge, awareness and attitude score± SD among males was 9.51±2.45, 6.81±2.37 and 1.89±.31 respectively. No significant difference was observed in knowledge (p=.372), awareness (p=.982) and attitude (p=.080) score between males and females.

With regard to place of work, a significant difference was observed in mean knowledge (p=.015) and awareness (p=.014) score, however no difference was observed in mean attitude score (p=.330) of participants (Table 2). Post-Hoc test for multiple comparison revealed a significant difference between mean knowledge (p=.009) and awareness score (p=.006) of dental professionals working in teaching institutions and private clinics.

With respect to educational qualification, a significant difference was observed in mean knowledge score (p=.024) of participants whereas no significant difference was observed in mean awareness (p=.122) and attitude (p=.549) score (Table 3). Post-Hoc test for multiple comparison revealed a significant difference between mean knowledge score (p=.035) of participants with BDS as educational qualification and participants with MDS/PhD as educational qualification.

No significant difference was observed in mean knowledge (p=.903), awareness (p=.990) and attitude (p=.669) score of participants with respect to work experience (Table 4).

Majority of participants in our study had good knowledge (185), fair awareness (189) and very good attitude (366) towards child maltreatment. (Table 5)

Majority of our study participants were of the opinion that lack of adequate knowledge and awareness about the role of dental professionals (300) is a major barrier in reporting child maltreatment followed by lack of adequate knowledge in identifying (227), lack of knowledge of reporting procedures (220), fear of negative impact on dental practice (116), fear of litigation (106), presence of parents/family members (67) and others (2). The other factor reported by participants was fear of attending court.

Figure 1. Self- Structured questionnaire used in the survey

Part 1—Questions Related to Demographics of the Responding Practitioner	
1.	**Educational Qualification** (you can tick more than one option) a)BDS b)MDS C)PhD d)Fellowship in forensic odontology
2.	**Gender** a) Male b) Female
3.	**Associated with** a)Private Clinics b)Teaching Institution c)Both Clinics and Institution d) Government Hospitals
4.	**Working Experience** a) < 5years b) 5-10 years c) 11-15 years d) > 15 years
Part 2-- Questions to Assess the Knowledge, Awareness, Attitude and Barriers in Reporting Child Maltreatment	
1.	**Are you aware about the role of dentist in identifying the child abuse and neglect** a) Yes b) No c) Not Sure
2.	**Are you aware of the difference between child abuse and child neglect** a)Yes b) No c) Not Sure
3.	**Maltreatment syndrome includes** a) Child abuse b) Child neglect c) Both d) None
4.	**The types of child abuse include (**you can tick more than one option) **a)** Physical abuse b) Emotional abuse c) Sexual abuse d) Munchausen's syndrome by proxy e) All
5.	**Do you know about the general signs/clues of child abuse and neglect** a)Yes b) No c) Not Sure
6.	**If ans to question no.5 is yes, please mention them ----------**
7.	**Do you know about the physical signs/clues of child abuse and neglect identified in oral cavity** a)Yes b) No c) Not Sure
8.	**If ans to question no. 7 is yes, please mention them----------**
9.	**Are you able to differentiate between accidental injuries and injuries because of child abuse** a)Yes b) No c) Not Sure
10.	**According to you, what is the expected /observed behavior of child in dental clinic who had experienced abuse/neglect** (you can tick more than one option) a)Co-operative b)Sullen, Stoic or Withdrawn c) Uncomfortable/skittish with physical contact d) Manipulative e)Not Sure
11.	**Do you know about the role of bite marks in the identification of child abuse** a)Yes b) No c) Not Sure
12.	**Do you know about difference between human and animal bite** a)Yes b) No c) Not Sure
13.	**Do you know about the educational programme, Prevent Abuse and Neglect through Dental Awareness (PANDA) coalition** a)Yes b) No c) Not Sure
14.	**Have you handled any child abuse related case before** a)Yes b) No
15.	**Have you handled any child neglect related case before** a)Yes b) No
16.	**Do you know about the various acts prevalent in India related to prevention of child abuse** a) Yes b) No c) Not Sure
17.	**Do you know where to report the child abuse** (you can tick more than one option) a) Police b) Child welfare societies c) Parents d) Not Sure
18.	**Do you know about the telephonic helpline number (CHILDLINE 1098) to report the child abuse** a)Yes b) No
19.	**Do you know about the protocol regarding documentation and reporting of child abuse and neglect** a)Yes b)No c)Not Sure
20.	**Do you know across the world few countries have made it mandatory for the dentist to report child abuse** a)Yes b) No c) Not Sure
21.	**Are dental professionals in India legally obligated to report child abuse and neglect** a)Yes b) No c) Not Sure
22.	**Do you know in India it is mandatory for medical professionals to report child sexual abuse under POCSO act** a)Yes b) No c) Not Sure
23.	**According to you, what is the main barrier in reporting of child abuse by dental professionals** (you can tick more than one option) a) Lack of adequate knowledge to identify b) Lack of adequate knowledge and awareness about the role of dental professionals c) Fears of a negative impact on dental practice d) Fear of litigation e) Lack of knowledge of reporting procedures f) Presence of parents/family members g) other (please mention)-----
24.	**Did you receive any formal training on child abuse and neglect** a)Yes b) No
	If answer to question 24 is yes, where----------
25.	**Are you willing to attend a training programme on child abuse and neglect** a)Yes b) No
26.	**Do you feel training in diagnosing and reporting child abuse and neglect should be conducted during the bachelors curriculum** a)Yes b) No

Table 1. Demographic details of the participants

Variables		**Frequency n (%)**
Gender	Male	152 (36%)
	Female	270 (64%)
	Total	422 (100%)
Educational Qualification	BDS	116 (27.5%)
	MDS	289 (68.5%)
	PhD	9 (2.1%)
	BDS with fellowship in forensic odontology	2 (0.5%)
	MDS with fellowship in forensic odontology	6 (1.4%)
	Total	422 (100%)
Place of work	Teaching Institutions	105 (24.9%)
	Private Clinics	83 (19.7%)
	Both Private Clinics and Institutions	104 (24.6%)
	Government Hospitals	95 (22.5%)
	Both Teaching Institutions and Government Hospitals	35 (8.3%)
	Total	422 (100%)
Working Experience	< 5years	129 (30.6%)
	5-10 years	136 (32.2%)
	11-15 years	79 (18.7%)
	> 15 years	78 (18.5%)
	Total	422 (100%)

n=Number of Subjects

Table 2. Association of knowledge, awareness, attitude score with place of work

Place of Work		N	Mean ± SD	Range		F-value	p-value
				Minimum	Maximum		
Knowledge Score	Teaching Institutions	105	10.043 ± 2.482	4.0	16.0	3.131	.015 **(S)**
	Private Clinics	83	8.892 ± 2.136	4.0	14.0		
	Both Private Clinics and Institutions	104	9.620 ± 2.354	5.0	14.0		
	Government Hospitals	95	9.858 ± 2.382	5.0	15.0		
	Both Teaching Institutions and Government Hospitals	35	9.800 ± 2.279	6.0	14.5		
	Total	422	9.650 ± 2.370	4.0	16.0		
Awareness Score	Teaching Institutions	105	7.197 ± 2.059	1.8	12.0	3.185	.014 **(S)**
	Private Clinics	83	6.092 ± 1.935	2.0	12.5		
	Both Private Clinics and Institutions	104	6.830 ± 2.321	1.8	12.5		
	Government Hospitals	95	6.942 ± 2.275	2.8	12.5		
	Both Teaching Institutions and Government Hospitals	35	6.926 ± 2.417	2.8	12.0		
	Total	422	6.809 ± 2.206	1.8	12.5		
Attitude Score	Teaching Institutions	105	1.91 ± .314	0	2	1.156	.330
	Private Clinics	83	1.86 ± .387	0	2		
	Both Private Clinics and Institutions	104	1.81 ± .504	0	2		
	Government Hospitals	95	1.81 ± .420	0	2		
	Both Teaching Institutions and Government Hospitals	35	1.86 ± .355	1	2		
	Total	422	1.85 ± .409	0	2		

n- Number of subjects; SD- Standard Deviation; S-Significant
ANOVA

Table 3. Association of knowledge, awareness, attitude score with educational qualification

Educational Qualification		N	Mean± SD	Range		F-value	p-value
				Minimum	Maximum		
Knowledge Score	BDS	116	9.164 ± 2.280	4.0	14.5	3.745	.024 **(S)**
	MDS/PhD	298	9.817 ± 2.394	4.0	16.0		
	BDS/MDS with fellowship in forensic odontology	8	10.500 ± 1.813	8.5	14.0		
	Total	422	9.650 ± 2.370	4.0	16.0		

Awareness Score	BDS	116	6.521 ± 2.0849	2.0	12.0	2.112	.122
	MDS/PhD	298	6.894 ± 2.2561	1.8	12.5		
	BDS/MDS with fellowship in forensic odontology	8	7.850 ± 1.547	5.5	10.0		
	Total	422	6.809 ± 2.206	1.8	12.5		
Attitude Score	BDS	116	1.84 ± .372	1	2	.601	.549
	MDS/PhD	298	1.85 ± .427	0	2		
	BDS/MDS with fellowship in forensic odontology	8	2.00 ± .000	2	2		
	Total	422	1.85 ± .409	0	2		

n- Number of subjects; SD- Standard Deviation; S-Significant
ANOVA

Table 4. Association of knowledge, awareness, attitude score with work experience

Work Experience		**N**	**Mean ± SD**	**Range**		**F-Value**	**p-value**
				Minimum	**Maximum**		
Knowledge Score	<5years	129	9.601 ± 2.307	5.0	14.5	.190	.903
	5-10 years	136	9.761 ± 2.298	4.0	15.5		
	11-15 years	79	9.665 ± 2.648	5.0	16.0		
	>15 years	78	9.526 ± 2.335	5.5	14.5		
	Total	422	9.650 ± 2.370	4.0	16.0		
Awareness Score	<5years	129	6.762 ± 2.190	1.8	12.5	.038	.990
	5-10 years	136	6.821 ± 2.127	1.8	12.5		
	11-15 years	79	6.810 ± 2.208	2.8	12.5		
	>15 years	78	6.865 ± 2.400	1.8	12.5		
	Total	422	6.809 ± 2.206	1.8	12.5		
Attitude Score	<5years	129	1.82 ± .458	0	2	.519	.669
	5-10 years	136	1.84 ± .425	0	2		
	11-15 years	79	1.89 ± .320	1	2		
	>15 years	78	1.87 ± .373	0	2		
	Total	422	1.85 ± .409	0	2		

n- Number of subjects; SD- Standard Deviation
ANOVA

Table 5. Categorization of knowledge, awareness and attitude based on scores obtained by participants

	Poor n (%)	Fair n (%)	Good n (%)	Very Good n (%)
Knowledge	2 (0.5%)	178 (42.2%)	185 (43.8%)	57 (13.5%)
Awareness	21 (5.0%)	189 (44.8%)	184 (43.6%)	28 (6.6%)
Attitude	8 (1.9%)	48 (11.4%)	0 (0.0%)	366 (86.7%)

n=number of subjects

DISCUSSION

Child maltreatment is defined as the abuse and neglect that happens to children below 18 years of age and it includes "all forms of physical and/or emotional ill-treatment, sexual abuse, neglect or negligent treatment or commercial or other exploitation, resulting in actual or potential harm to the child's health, survival, development or dignity in the context of a relationship of responsibility, trust or power".[3,8] Maltreatment syndrome collectively includes both child abuse and neglect and is considered to happen when a child is treated in a manner that is unacceptable for a particular culture at a given time.[9] In the present study, 328 (77.7%) participants knew that both child abuse and neglect are components of maltreatment syndrome whereas 51 (12.1%) and 21 (5.0%) participants considered only child neglect and child abuse respectively as a component of maltreatment syndrome. 13 (3.1%) participants opted none as an answer whereas 9 (2.1%) refrained from answering the question reflecting that they were not sure about the components of maltreatment syndrome. Our study findings were in association with those of Archana et al.[10] where 80.6% participants were aware of child maltreatment (abuse and neglect).

Child abuse is defined as any non-accidental injury, failure to meet basic requirements or abuse levied upon a child by the caretaker that is beyond the acceptable norms of childcare in a particular culture, although neglect refers to the failure by the caregiver to provide necessary, age-appropriate care being financially able to do so or failure to guard the child from situations or actions that compromise the physical or mental health of the child, when able to do so.[9,11] 327 participants in our study reported that they knew about the difference between child abuse and neglect (Table 6). The types of child abuse reported in the literature are physical, emotional, sexual abuse and Munchausen syndrome by proxy and these forms of child abuse generally occur in combination.[9] 307 out of 422 participants were aware of these whereas 89 considered physical, emotional and sexual abuse as the only types of child abuse. (Figure.2) Soumya Mohanan et al. in her survey stated that 80% participants had knowledge about types of child abuse (physical, emotional and sexual) and neglect.[12]

Dental professionals could play an important role in identifying, documenting, reporting and referring with regard to child abuse and neglect.[13] 323 (76.5%) participants were aware of the role of dental professionals in identification of child abuse and neglect (Table 6). In a study by Malpani et al. 32.81% and 63% of the participants strongly agreed and agreed respectively that dental professionals had an important role in identifying and reporting child abuse.[11]

Our survey showed that 185 (43.8%) participants were not sure whereas 181 (42.9%) knew about the general signs of child abuse and neglect (Table 6) which were slightly higher than Soumya Mohanan et al.'s study where 34.3% participants had knowledge of the signs of child abuse and neglect.[12] However, Sharma et al.[14] in their study reported that 80.3% BDS and 82.6% MDS participants were confident that they could recognise indicators of domestic violence and child abuse in their patients. The majority of participants in our study reported physical indicators (bruises, bite marks) and behavioural indicators (shy, depressed and fearful child) as general signs of child abuse and neglect.

Accidental injuries to the cranio-facial region and oral cavity should be differentiated from abusive injuries, by confirming whether the history, timing, pattern and mechanism of the injury is in association with the injury type and child's developmental abilities or not.[15] 211 (50%) participants in the present study affirmed that they could distinguish between accidental injuries and injuries because of child abuse (Table 6), however, 89.7% of general dental practitioners in study by Kaur et al.[7] affirmed that they were capable of distinguishing accidental injuries from

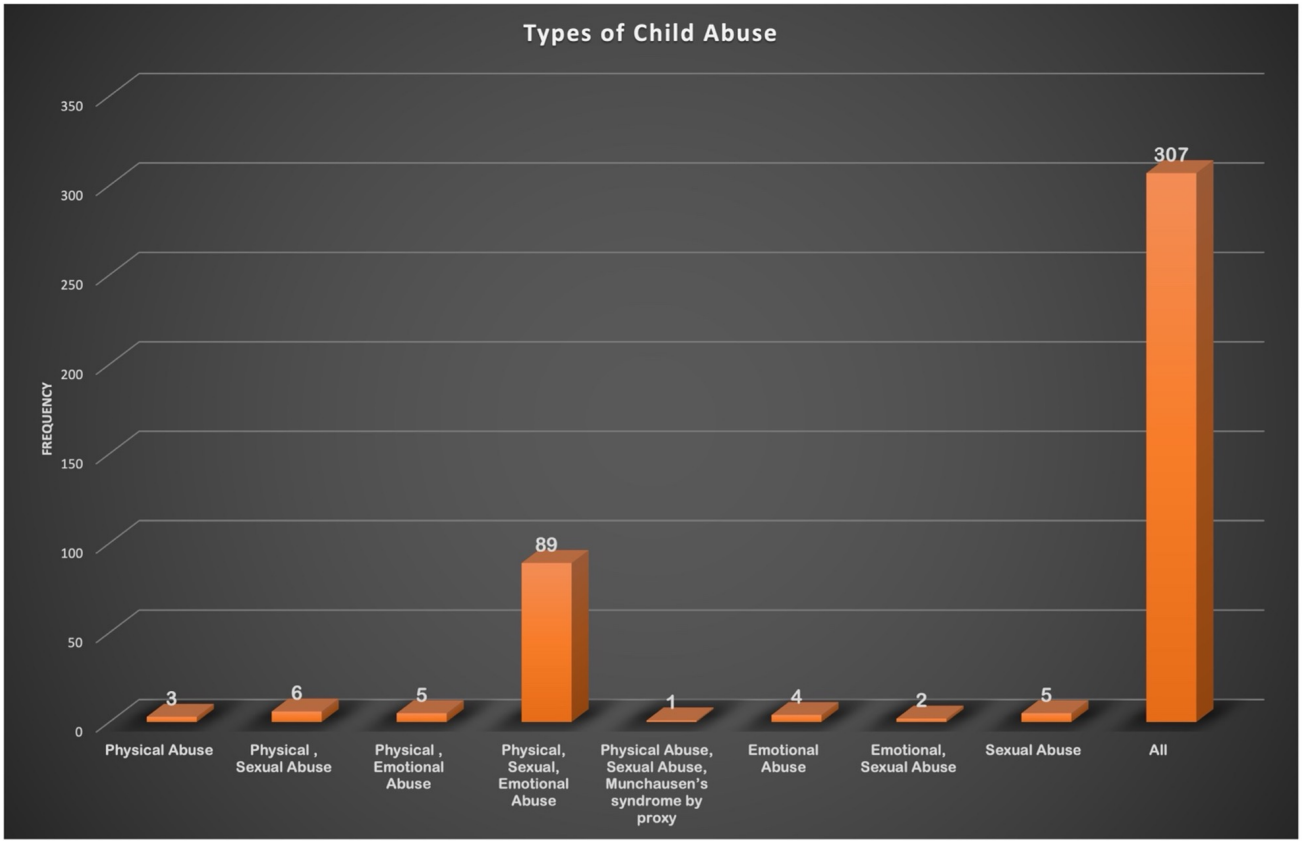
physical abuse. This difference could be explained on the basis that 55% participants in their study were associated with an academic institute and our study showed a significant difference between the knowledge and awareness score of participants working in teaching institutions and private clinics. In addition, the literature reported that guild associated dental professionals have access to a higher number of patients and are suitably prepared to deal with such a situation.[7] Kaur et al.[7] reported that dental professionals with more years of experience have greater ability to differentiate between accidental and abuse-related injuries whereas our study did not observe any significant difference with regard to work experience.

Table 6. Frequency of responses to questions

S.No	Questions	Yes	No	Not Sure
1	Aware about the role of dentist in identifying the child abuse and neglect	323 (76.5%)	37 (8.8%)	62 (14.7%)
2	Aware of the difference between child abuse and child neglect	327 (77.5%)	37 (8.8%)	58 (13.7%)
3	Know about the general signs/clues of child abuse and neglect	181 (42.9%)	56 (13.3%)	185 (43.8%)
4	Know about the physical signs/clues of child abuse and neglect identified in oral cavity	173 (41.0%)	83 (19.7%)	166 (39.3%)
5	Able to differentiate between accidental injuries and injuries because of child abuse	211 (50.0%)	68 (16.1%)	143 (33.9%)
6	Know about the role of bite marks in the identification of child abuse	320 (75.8%)	32 (7.6%)	70 (16.6%)
7	Know about difference between human and animal bite	300 (71.1%)	47 (11.1%)	75 (17.8%)
8	Know about the protocol regarding documentation and reporting of child abuse and neglect	50 (11.8%)	257 (60.9%)	115 (27.3%)
9	Know about the educational programme, Prevent Abuse and Neglect through Dental Awareness (PANDA) coalition	90 (21.3%)	248 (58.8%)	84 (19.9%)
10	Know about the various acts prevalent in India related to prevention of child abuse	86 (20.4%)	199 (47.1%)	137 (32.5%)
11	Know across the world few countries have made it mandatory for the dentist to report child abuse	129 (30.6%)	190 (45.0%)	103 (24.4%)
12	Are Dental professionals in India legally obligated to report child abuse and neglect	121 (28.7%)	52 (12.3%)	249 (59.0%)
13	Do you know in India it is mandatory for medical professionals to report child sexual abuse under POCSO Act	189 (44.8%)	101 (23.9%)	132 (31.3%)
14	Know about the telephonic helpline number (CHILDLINE 1098) to report the child abuse	186 (44.1%)	236 (55.9%)	-
15	Handled any child abuse related case before	42 (10.0%)	380 (90.0%)	-
16	Handled any child neglect related case before	73 (17.3%)	349 (82.7%)	-
17	Did you receive any formal training on child abuse and neglect	18 (4.3%)	404 (95.7%)	-
18	Are you willing to attend a training programme on child abuse and neglect	376 (89.1%)	46 (10.9%)	-
19	Do you feel training in diagnosing and reporting child abuse and neglect should be conducted during the bachelor's curriculum	404 (95.7%)	18 (4.3%)	-

For question no. 14-19, Not Sure was not an option in questionnaire

Figure 2. Graph depicting responses to question on types of child abuse



173 (41.0%) participants acknowledged that they knew about the signs of child abuse and neglect observed in the oral cavity whereas 166 (39.3%) were not sure about the same (Table 6). A staggering 83% were familiar with physical signs of child abuse and neglect in a study by Archana et al.[10]

Bite marks are usually seen in association with violent fights, child abuse and sex crimes.[16] Examination of bite marks as evidence is based on the fact that dentition of the biter (animal or humans) is unique and results in a distinct and unique pattern.[17] Dental professionals must be observant enough to perceive most abuse-related bite marks as 43% of them are noticed in the head and neck region and 65% of bite marks related with abuse can be observed while the child is wearing clothes.[4] 320 (75.8%) study participants reported that they knew about the role of bite marks in child abuse and 300 (71.1%) stated that they could differentiate between animal and human bites. Sharma et al. reported that 76% BDS and 84% MDS participants had knowledge about bite mark patterns.[14]

The literature reports that children who had experienced abuse/neglect might act in different ways in dental clinics, so dental professionals should be aware of these presentations. Our study participants were of the opinion that the most expected behaviour from a child who had experienced abuse was that child might feel uncomfortable/skittish with physical contact (306) followed by sullen, stoical and withdrawn (197), manipulative (22) and co-operative (20) whereas 41 were unsure about the expected behaviour. The majority of participants of a study conducted by Kaur et al.[7] reported that child may be uncooperative (45.5%) followed by co-operative (24.8%), stoical (23.8%) and aggressive (5.3%).

In case of suspicion of child abuse, dental professionals should follow an accurate protocol for documenting and reporting. Child and parents should be interviewed separately in the presence of a witness to ascertain whether the manifestation of injury relates to its history and cause or not and if the explanation given by both are in association or not. Further, all relevant information should be documented with photographs, radiographs and impressions when required.[9,16] 257 (60.9%) participants did not know about the accurate protocol to be followed

to report child abuse and neglect. (Table 6) Bandi et al. reported that 48.7% of study participants knew the exact mechanisms to report child physical abuse.[2]

Child abuse can be reported to the local Child Welfare Committee, the police, child helpline or local NGOs.[18-19] The literature revealed that ideally, a case of child abuse should first be reported to the childcare authorities, as in many cases parents are directly involved.[20] According to participants in our study the main avenue to report a case of child abuse was child welfare societies (272) followed by police (196) and parents (123) whereas 85 were not sure about it. Malpani et al.[11] in their study reported that, 47.5% participants thought that it should be reported to police followed by Childline (21.7%), social agencies (17.3%) and Ministry of Health (4.3%). 41% of participants in the study by Sahni et al.[20] affirmed that they would report to parents and all of them supported reporting the case to the police and only 18% were in favour of reporting the case to childcare authorities. 236 (55.9%) participants in our study were not aware of 24-hour free child helpline phone service (1098) (Table 6) which was in contrast to the findings of Archana et al.[10] where 59.2% were aware of this helpline number.

The majority of the participants in our study did not handle any case of child abuse (380) and neglect (349) (Table 6) which was in association with Malpani et al.[11] where 7.2% participants affirmed that they suspected a case of physical abuse in the past. Kaur et al.[7] reported that 60% participants had witnessed at least one case of child abuse during their practise.

A dental professional should be familiar with the laws associated with child abuse of respective countries. 199 (47.1%) participants of our study did not know about the various acts prevalent in India related to prevention of child abuse (Table 6). In a study by Deshpande et al. 51.2% dental and 39.3% medical residents were not aware of the Indian laws related to child abuse.21 However, 68.2% of the dental professionals in another study were aware of laws to prevent child abuse.[7] Numerous developed countries have well-developed child protection systems which mainly focus on identification, investigation, mandatory reporting and often take strong action.22 190 participants of the present study did not know that few countries have made it mandatory for dental professionals to report child abuse. 249 participants were not sure whether dental professionals in India are legally obligated to report child abuse or not (Table 6). However, Malpani et al.[11] and Kaur et al.[7] reported that 90.3% and 94% of participants in their studies believed that it is dentist's legal responsibility to report child abuse and neglect. POCSO Act (2012) has made it compulsory for doctors, parents and school personnel to report child sexual abuse to the law enforcement authorities.18,23 189 (44.8%) study participants affirmed they knew that medical professionals are mandated to report child sexual abuse under POCSO Act (Table 6) which was in contrast to the results by Archana et al.[10] where 77.4% participants reported that failure to report a case of child abuse forms an offence under POCSO Act.

An educational programme PANDA (prevent abuse and neglect through dental awareness) Coalition introduced in 1992 in Missouri requires dental professionals to complete a two-hour programme in identifying and reporting child abuse as a requirement of relincesure.[9] 248 (58.8%) participants in our study were unaware of the PANDA Coalition (Table 6).

A study by Human Rights Watch in India reported that no doctor has been given any training regarding child abuse examination, interviewing, handling, rehabilitation and the medical and psychological needs of the child.[22,24] The majority of the dental professionals (404) in the present study reported that they did not receive any formal training in child abuse and neglect (Table 6). Participants who had knowledge, received training during their master's course (MDS or fellowships) or through conferences/CDE which became evident by a significant difference in the knowledge score of participants with regard to educational qualification. In contrast to our findings, Kaur et al. [7] reported that 54.1% of participants in their study did not receive any training in child abuse during the academic curriculum. In 2002, all dental schools in the United States and Canada included the education of child abuse in their curricula.[25] 404 (95.7%) participants in the present study thought that training in diagnosing and reporting child abuse and neglect should be conducted during the bachelor's curriculum (Table 6) which was in association to the study by Marengo et al.[26] where 93.7 % of participants reported that identification and mechanism of

reporting child physical abuse should be part of vocational training course.

89.10% of the dental professionals in the present study were willing to attend the training programme on child abuse and neglect which was in corroboration with the study by Bandi et al. where 84.8% of participants wanted more training in identification and the mechanism to report child physical abuse.[2]

The major barrier according to the participants of the present study in reporting child abuse and neglect was lack of adequate knowledge and awareness about the role of dental professionals. Kaur et al.[7] also reported that lack of knowledge was a major barrier whereas according to Soumya Mohanan et al.[12] lack of knowledge in referral procedure was the main factor which prevented the dental professionals reporting child abuse.

The strength of the current study is that it was conducted on dental professionals practising in India and participants from all the sectors (private clinics/government hospitals/academic institutions) participated whereas other studies were conducted either on dental professionals practising in academic institutions only or in particular cities only. Furthermore, as the study is a questionnaire-based study, so bias in filling the responses could occur if the identity of participants is known to the researcher. To avoid bias, we conducted an anonymous survey in which even researchers were unaware about the identity of participants. Our study scored the responses and compared the mean score which to the best of our knowledge has not been performed in any other study.

CONCLUSIONS

Dental professionals continue to under-report child maltreatment; thus, they must be inspired to become more aware of their moral, ethical and legal responsibilities in identifying and reporting child maltreatment. The findings of our study point towards a serious need to include training in child maltreatment during bachelor's curriculum and then augmentation of knowledge through workshops/CDEs during continuing professional life.

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Child abuse and neglect: oral and dental signs and the role of the dentist

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ABSTRACT

Historically, the law, dental and forensic literature has included numerous articles concerning abused children. The orofacial structures are injured frequently in the maltreated child. Injuries of the neck, head, face, and oral cavity represent the most affected areas of the victim's body that routinely sustain physical trauma in child maltreatment cases. This literature review aimed to report the state of art of child abuse from the point of view of the dentist with focus on studies in dental aspects of child abuse and neglect of the last ten years. Considering the time slot, 20 papers were included with the following inclusion criteria: papers published in English, all keywords included in the title, articles available on PubMed. Many of the injuries are within the scope of dentistry or easily observed by the dental professional during routine dental treatment, and it is essential that the dentist recognizes them. Concerning neglect, it is appropriate to make a distinction between deliberate parental behavior that has the consequence of unavoidable and voluntary neglect towards their children and those conditions of involuntary carelessness determined by socio-economic and cultural factors such as family isolation, lack of finances, parental ignorance, or lack of perceived value of oral health. Therefore, it is relevant that the dentist pays attention to the cases to report and those that only need help

INTRODUCTION

The Center for Disease Control and Prevention (CDC) define child maltreatment as any act or series of acts of commission or omission by a caregiver that threatens or impairs a child [1]. It is a relevant theme in all social, ethnic, religious, and professional settings.[2]

The full extent of the problem is unknown because of the lack of notification of many cases.[3] Some reports stated that 3-30% of children experienced abuse, and the prevalence of this phenomenon is increasing.[4–6] Most maltreatments occur in the family setting, and a smaller amount occurs in schools and other communities attended by children.[7]

Child Maltreatment could be distinguished into many categories that could exist separately or in association: physical abuse (including bruises, burns, fractures, head trauma, and abdominal injuries), sexual abuse (involving children in sexual acts for which they cannot give consent), emotional abuse (acts that negatively affect patient's self-confidence), physical neglect (failure to provide food, clothing, etc.), emotional neglect

(dysfunctional parent-child relationship), medical care neglect (failure to provide adequate care to children), and Munchausen syndrome by proxy (simulation or creation of symptoms in a child).[7]

To summarize, child abuse comprehends physical abuse, sexual abuse, psychological abuse, and neglect.[8] Therefore, children could experience many different types of maltreatment that could impair their emotional, physical, and sexual health and development.[9]

Concerning physical abuse, several studies reported that 50%-70% of traumas occur in the craniofacial district [10–16], while untreated dental caries lesions are the most prevalent.[17–19] A large survey reported that besides caries, other oral lesions reported in cases of suspected child abuse are tooth fractures (32%), oral bruises (24%), oral lacerations (14%), fractures of the mandible or the maxilla (11%), and oral burns (5%).[11]

In addition, while it is true that abusers avoid returning to the same physician, this does not apply to dental professionals: abusers don't seem to avoid the same dental service probably because it is percieved more as a technical service than a healthcare service.[20] For these reasons, dental professionals are in a central position to identify possible cases of abuse. Furthermore, it is an ethical duty and a legal obligation to report child maltreatment in Italy and many other States.[21–26] For example, in most US States, it is mandatory by law to report child abuse for professionals that work with children, such as social workers, teachers, physicians, medical examiners or coroners, and law enforcement officers.[21] In other States, not all the types of abuse are reported by law. For instance, in some parts of Australia, only reporting physical and sexual abuse is required, but reporting child abuse and neglect is not required in Western Australia.[26]

Therefore, recognizing oral and dental signs related to child abuse is of great importance to correctly report of maltreatment to law enforcement and the early identification of violence cases for social purposes. Furthermore, the failure to report cases of abuse or suspected abuse can result in criminal and civil consequences for the healthcare professionals, including the disbarment or suspension.[27]

The role of the dentist in preventing child abuse is well explained by the so-called "four R's of responsibility": recognize (recognition of risk factors and manifestations), record (collection of information), report (possible report to Judicial Authority), and refer (reference and support for patients).[10] These guidelines aim to protect patients from violence and its consequences.

Considering the relevance of this issue, although many studies have been published for many years, this remains a relevant problem that is still much debated in the literature especially because child abuse identification remains underreported by healthcare professionals.[3,27]

This brief review aims to report the state of the art in the child abuse field over the last ten years with focus on the most treated topics in the literature, concentrating on oral and dental signs more evocative of abuse and neglect, and noting whether there have been any shortcomings in one or more relevant topics. The aim is also to contribute to help dentists and any other physician and dental professionals in diagnosis and reporting suspected child abuse situations.

DATA COLLECTION

The searches were carried out until 18 January 2022 using the PubMed database. The search criteria were keywords for child abuse and dental (child abuse AND dental). The search criteria keyword retrieved 705 records from 1968 to 2022. Because of the large number of sources and the purpose of evaluating what the scientific community is focusing on today, we selected articles published in the last ten years and articles published before 2012 were excluded. Considering this time slot, a total of 705 records were found. Among these records, 367 studies were selected according to the following criteria: only English articles with all keywords in the title were included as well as articles available via PubMed; review, commentary, and letters were excluded. Following this inclusion and exclusion criteria, a total of 20 studies were analyzed. The papers were grouped according to the topic covered (Table 1): dental signs (which included physical abuse and bitemarks, sexual abuse, and dental neglect), and knowledge of dental professionals. In the first category, we collected a total of 11 papers, in the second one a total of 13 articles.

Table 1. Data collection and types of articles

Topic covered in the articles	Total number of articles	References
1. Dental signs	11	
1.1. Physical abuse and bitemarks	5	(10,15,28–30)
1.2. Sexual abuse	4	(28,30–32)
1.3. Dental neglect	5	(33–37)
2. Knowledge of dental professionals	13	(15,29,30,36,38–46)

DISCUSSION

Child abuse is a dramatic social problem involving dental professionals in detecting oral signs of abuse and reporting these cases to child protection services or law enforcement. This literature review focused on the last ten years of studies in this field, pointing out any significant gap in one of the relevant topics and bringing out that most of the recent articles focused on the knowledge of dental professionals on child abuse issues rather than on the dental signs of abuse and neglect. The details of each paper are reported in Table 2.

Table 2. Articles' details

First author	Year of pub	Country	Type of article	Type of topic
S. Karthika Nagarajan [10]	2018	India	Review article	Craniofacial injuries of physical abuse Role of the dental professionals
A. S. Hussein [15]	2016	Malaysia	Original article with a questionnaire submission	Craniofacial injuries of physical abuse Issues on knowledge of dental professionals
S. A. Fisher-Owens [28]	2017	USA	Clinical report	Craniofacial injuries of physical abuse Sexual abuse
A. Al-Ani [29]	2021	Germany	Original article with a questionnaire submission	Craniofacial injuries of physical abuse Issues on knowledge of dental students
C. Duman [30]	2021	Turkey, Turkish Republic of Northern Cyprus, Jordan, Pakistan, Cambodia, Poland, Nigeria, USA, Republic of South Africa, Australia	Multicenter study with a questionnaire submission	Craniofacial injuries of physical abuse Sexual abuse Issues on knowledge of dental students
T. V. Fredriksen [31]	2020	Norway	Origilan article with a questionnaire submissionn	Sexual abuse

E. Wolf [32]	2021	Sweden	Original article with partecipants' intervew	Sexual abuse
A. Sorca [33]	2013	Italy	Original article with questionnaire submission	Childhood caries and dental neglect
S. A. Fisher-Owens [34]	2017	USA	Review article	Dental neglect
H. Sillevis Smith [35]	2017	Netherlands	Original article with evidences' acquisition	Childhood caries and dental neglect
C. M. Harris [36]	2013	UK	Original article with questionnaire submission	Dental neglect, knowledge of dental professionals
I. V. Brattabø [37]	2018	Norway	Original article with questionnaire submission	Dental neglect
S. Kugananthan [38]	2021	Australia	Original article with questionnaire submission	Knowledge of dental professionals
H. M. A. Khan [39]	2021	Pakistan	Original article with questionnaire submission	Knowledge of dental professionals
L. S. Nunes [40]	2021	Brazil	Original article with questionnaire submission	Knowledge of dental professionals
A. Rønneberg [41]	2019	Norway	Original article with questionnaire submission	Knowledge of dental professionals
U. Jakobsen [42]	2019	Faroe Islands	Original article with questionnaire submission	Knowledge of dental professionals
R. Bjørknes [43]	2018	Norway	Original article with questionnaire submission	Knowledge of dental professionals
I. V. Brattabø [44]	2019	Norway	Original article with questionnaire submission	Knowledge of dental professionals
E. H. Bodrumlu [45]	2016	Turkey	Original article with questionnaire submission	Knowledge of dental professionals

Dental signs

This review focused on the craniofacial district and dental signs suspected of child abuse, although dentists could perform a thorough physical examination, especially when abuse is suspected.

Dental symptoms and signs in children are more frequent in victims of abuse than in those who are not, with no influence of socio-demographic characteristics. De Silva-Jùnior et al. found no relevant association between child abuse and sex, age, type of school, skin color, and family income [47]. No other variables like weight, hairstyle, clothing, etc. were studied. Hence, the correct recognition of signs of abuse is a fundamental step in child protection programs. Dental professionals must be careful in treating young patients, with particular attention to sexual abuse: a high prevalence of up to 20% is reported in some studies.[48,49]

Physical abuse and bitemarks.

Physical abuse signs occur in the craniofacial district in more than half of child abuse cases. So, a careful oral examination is necessary, especially in suspected cases.[10] It is reported that lips are the most common site of traumatic injuries related to physical abuse: almost half of the injuries are found on lips. Therefore, scars on the lips should alert healthcare professionals. Other areas frequently traumatized are oral mucosa, teeth, gingiva, tongue, and oral frena frequently as a consequence of blunt force trauma.[28,30] Duman et al. hypothesize that because of its importance in nutrition and communication, the oral cavity is the primary target of physical abuse; hence, injuries may develop from hand or force-feeding assault. In these cases, traumas are contusions, burns, lacerations of soft tissues as well as broken, displaced, or avulsed teeth and fractures of the facial bone and jaw.[30] Other injuries involved pulp necrosis; bruises, lichenification, and scarring of the corners; pharyngeal and retropharyngeal injuries.[28] It is also reported that it is crucial to distinguish between child abuse and unintended or accidental injuries: as a general indication, suspected signs of abuse are multiple injuries, injuries in different stages, or a discrepant history. Therefore, dentists should pay more attention in case they approach patients reporting these types of lesions.

Furthermore, dental professionals consider bruises on children's cheeks the most suspected facial sign of physical abuse, followed by burns and bitemarks.[15,29] Although the last ones could indicate child abuse, some authors suggest paying particular attention to differentiating from bites produced by animals: authors suggest that an intercanine distance of more than 3.0 cm is suspicious for an adult human bite.[28] In addition, bites produced by animals tend to tear flesh, whereas human bitemarks more frequently cause abrasions and contusions. Fischer-Owens et al. also suggest that the evaluation of bitemark patterns should be performed by a forensic odontologist or a forensic pathologist and that to examine the lesions using photographic documentation should be gathered. Finally, they suggest collecting dental casts of a suspect abuser to match with the photographs of the bite.[28] So, an interdisciplinary approach in suspected cases should be applied whenever possible.

Other pathological conditions of the oral cavity, such as caries, could be associated with child neglect rather than with physical abuse, usually related to traumatic injuries.

Sexual abuse.

As oral abuse is the most frequent, carefulness is needed by dentists in children's dental examinations [31]. Oral injuries in sexual abuse are rare, so a relationship between sexual abuse and trauma is difficult to assess.[28] In case of reported history of oro-genital contact, universal testing for sexually transmitted infections could be performed, even though it is a rare finding.[28] It is reported that oral and perioral gonorrhea is a pathognomonic sign of sexual abuse but is extremely rare: authors reported a prevalence of 12% of gonorrhea and 14% of chlamydia in sexually abused adolescents.[28] In addition, some cases of pharyngeal gonorrhea are not reported as asymptomatic. In these cases, even if the culture is the gold standard and preferred method to detect an infection, the nucleic acid amplification test is less invasive for the patient and could be preferred in some circumstances such as vaginal swab specimens or urine.[28] On the contrary, as the transmission of HPV is uncertain, oral HPV could not be considered a pathognomonic sign: vertical and non-sexual transmission is also described.[28]

Considering the difficulty in the association between the evidence of oral injuries and sexual abuse, attention is needed in case of unexplained palate injuries or petechiae because these lesions may result from forced oral abuse.[28,30]

For these reasons, Frederiksen et al. suggests dentists should pay much attention to those patients who previously had been abused because dental treatments could be experienced as a

reminder of previous unpleasant experiences.[31] These situations might result in relevant dental fear, so particular care for these patients is needed.[31,32] For example, Frederiksen et al. report the need for specific communication and behavior skills to reduce the anxiety and fear in these patients [31], and Wolf et al. underline the importance of an individually tailored approach to recognizing the signs of discomfort.[32] They also emphasize the need for the dental nurse to observe each patient's expression and emotional status. Therefore, even in this eventuality, a multidisciplinary approach should be applied.

Dental neglect.

Although caries is a common dental problem in many children, when a high number of teeth is damaged child neglect should be suspected. Severe early childhood caries (s-ECC) and consequent multiple teeth extraction should be considered a sign of child neglect.[17,28,35,36] This is supported by Sillevis Smith et al. that report a strong association between severe caries and child neglect and found that 23% of children with multiple tooth extractions for caries are victims of neglect.[35] Caries also represents the sign that mostly instills suspicion in dental professionals, followed by the lack of hygiene.[37] Besides caries and lack of hygiene, some authors considered continuously missed dental appointments as an indicator of child neglect that could be used as a tool for the early identification of abuse.[37] For this reason, Brattabø et al. suggest that dental practitioners are in a unique position in identifying suspected cases of abuse and neglect: patients with oral health deficiencies are suspected to be neglected.[37] For these reasons, dentists should pay close attention to these different aspects of dental clinical practice that could lead to a concrete suspicion of child neglect.

Furthermore, other conditions different from neglect are associated with s-ECC. A strong correlation between the frequent use of pacifiers and s-ECC is reported, and between low socioeconomic status and ECC.[17]

Even for these reasons, some authors suggest caution when considering a parent as negligent. It is reported that some factors are useful in the diagnosis of neglect: the child could be harmed by lack of dental care; dental treatments could have a significant benefit for the child; considering the benefits of treatment, parents should choose rather than avoid it; the access to care is not used even if it is available for the family; the parents comprehend the importance of dental treatment.[28] Some families are unable to receive dental care because of a lack of funds or transportation issues. So, first, health care providers should evaluate if dental services are accessible to this kind of family. If the parent fails to obtain therapy, despite the correct information, some authors suggest that the case should be reported to social services or other child protective services.[28]

Knowledge of dental professionals

Approximately half of the dentists are exposed to children with dental neglect and special needs, so dentists, oral hygienists, and other dental professionals should be able to detect suspected cases and report them to local authorities.[38] For this reason, many studies in the last years addressed the issue of recognizing and reporting child abuse situations.

The reporting rate is one of the most relevant problems in child abuse. Many studies reported that the major barrier to reporting cases is the uncertainty of diagnosis.[30,36,38–44] A significant association between specific programs in childcare and a high rate of reported child abuse cases is reported.[40] In addition, the length of work experience is significantly associated with a great rate of reported cases.

Furthermore, it is reported that other causes of underreporting are the fear of consequences for children and the inadequate training to report cases.[30,36,38,39,42,44]

Some studies underlined that dental students did not receive enough formal training about child abuse, although students' knowledge about child abuse, ethical and legal responsibility. In addition, the rate of reported cases increases along with the increasing length of time being trained and after graduation.[29,30,36,40,41,45,46]

It is reported that most dentists need further training on the identification of child neglect and abuse and on the mechanisms of reporting suspected cases [15,30,36,40]; Duman et al. report a better level of knowledge in the field among students from Australia, Jordan, and the United States whereas a poorer level was found in Turkey students.[30] They also reported that this could be due to the national action plans: Australia, Jordan, Nigeria, and the Republic of South Africa plans include the specific training of health

personnel.[30] Therefore, it follows that healthcare workers have a greater awareness of child abuse and better skills in detecting cases and managing the issue.

In many cases, the internet is the major source of information even for healthcare professionals.[15,30] Hussein et al. reported that almost 50% of dental professionals collect information on child abuse and neglect on the internet, followed by education programs, dental meetings and conferences, journals, and books or brochures.[15]

The uncertainty in recognizing child abuse situations might be a sign that dental professionals need further education on this subject. A high rate of students with specific training is related to a high rate of reporting suspected cases.[41,43] For this reason, Bjørknes et al. reported a significantly higher rate of barriers to not reporting suspected cases in dental personnel who did not receive specific training.[43]

On the other hand, Rønneberg et al. state that the rate of reported cases could be higher in professionals with the lowest rate of undergraduate specific training: authors postulated that this could be due to the fear to not comply with the law.[41]

CONCLUSIONS

Child abuse and neglect are relevant issues, not only in the social context but also for healthcare professionals who could face children victim of abuse. As more than half of lesions occur in the head and neck, dental professionals could provide valuable information in case of child abuse and have a relevant role in detecting oral signs suggestive of abuse and neglect.

There is a bulk of literature on this field, so this review focused on the last ten years of research in order to evaluate the most in-depth issues. In the study period, most of the published studies have focused on the approach of dental professionals to child abuse, but few studies on the suggestive signs of abuse are available so with this review we tried to synthetize the most relevant findings in dental clinical practice in order to help dentist in the correct recognition of cases of abuse. In further studies, one of the topics to focus attention on should be the ability of the dentist to evaluate whether the injury is accidental or non-accidental. Based on the child's age and the pattern of the bruises, non-accidental bruises can be distinguished from accidental bruises.

This review has also shown that the knowledge of dental students and dental professionals about child abuse and neglect is not sufficient. Research has shown that many dentists feel unprepared for this role, and it could be related to the need for practical training rather than theoretical lessons, both to recognize situations at risk of abuse and to know the protocols to be followed in these cases.

Recognizing child abuse is not an easy task and requires a multidisciplinary approach among healthcare professionals as well as it could be necessary for the connection between professionals working with children and children welfare services.

When doubts arise or consultation is needed, a pediatric dentist or a dentist with formal training in forensic odontology can ensure appropriate testing, diagnosis, and treatment. In other cases, the implication of a forensic odontologist could help to detect peculiar child abuse cases where the uncertainty of the diagnosis could be a barrier to reporting the case.

Therefore, on the one hand, better undergraduate training is essential, and on the other hand, a major use of the forensic odontologist in clinical practice could be appropriate.

In conclusion, with this review, we would encourage the scientific community to focus more on the different lesions suggestive of child abuse rather than on the knowledge of dental professionals on this topic as it is too clear that they are not well prepared in recognizing dental signs. For this reason, if the scientific community will focus more on the type of lesions, we trust that we will create a future community of dentists more prepared in this field.

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Artificial intelligence in forensic medicine and forensic dentistry

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KEYWORDS

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ABSTRACT

This review article aims to highlight the current possibilities for applying Artificial Intelligence in modern forensic medicine and forensic dentistry and present the advantages and disadvantages of its use. For this purpose, the relevant academic literature was searched using PubMed, Web of Science and Scopus. The application of Artificial Intelligence in forensic medicine and forensic dentistry is still in its early stages. However, the possibilities are great, and the future will show what is applicable in daily practice. Artificial Intelligence will improve the accuracy and efficiency of work in forensic medicine and forensic dentistry; it can automate some tasks; and enhance the quality of evidence. Disadvantages of the application of Artificial Intelligence may be related to discrimination, transparency, accountability, privacy, security, ethics and others. Artificial Intelligence systems should be used as a support tool, not as a replacement for forensic experts.

INTRODUCTION

Artificial Intelligence increasingly permeates the lives of modern humans, and it is increasingly difficult to find areas where it is not present in at least some form. We find it in our smartphones, cars, aeroplanes, banks, healthcare, agriculture, science, entertainment, and almost everywhere; it is becoming, in some ways, frighteningly ubiquitous. All of this is not happening (at least for now) because Artificial Intelligence is so intelligent and superior, but instead because we humans are inventive, innovative, and curious, but also often lazy, too comfortable, and unwilling to look critically at the future.

The best and most recent example of this is Open Al ChatGPT. The chatbot ChatGPT (Chat Generative Pre-trained Transformer) was introduced to the public in November 2022; from then until now, its use has spread rapidly around the world, gaining several million users in just a few weeks and is considered the fastest-growing application of all time.[1] People first recognized it as a new way of entertainment. However, they quickly realized how useful it could be. They started using it increasingly as a fast and reliable assistant in doing their daily work tasks, whose shortcomings were more or less rightly neglected compared to the benefits it offers. In a very short time, it became a topic of discussion in leading scientific journals such as Nature.[2] There is still debate about the extent to which it may be used, for example, in writing scientific articles and whether it should be cited as an

author. Research has shown that Open Al ChatGPT can independently write a scientific summary at such a level of quality that human experts can no longer distinguish which summaries are written by humans and which by Artificial Intelligence.[3]

To gain a better grasp of Artificial Intelligence, it is essential to clarify the distinctions among Artificial Intelligence, deep learning, machine learning, and data science. Although these fields are interconnected, each has its own unique characteristics. Artificial Intelligence serves as the overarching domain, encompassing a wide range of techniques and methodologies designed to create intelligent machines capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and natural language processing. Within Artificial Intelligence, machine learning and deep learning operate as subsets.[4] Data science, on the other hand, draws from all of these fields to extract insights and knowledge from data.

Artificial Intelligence branches out into various areas, including expert systems, robotics, and natural language processing. Deep learning, a subfield of Artificial Intelligence, employs neural networks inspired by the structure of the human brain to acquire knowledge from vast datasets. By automatically identifying and extracting features from raw data like images, sounds, and text, deep learning algorithms can make predictions or decisions. Notable applications of deep learning encompass image recognition, speech recognition, and natural language processing.

Machine learning, another subfield of Artificial Intelligence, concentrates on developing algorithms and statistical models that enable computers to learn from data without explicit programming. Machine learning techniques can be supervised (learning from labeled data), unsupervised (learning from unlabeled data), or semi-supervised (learning from a combination of labeled and unlabeled data). Use cases for machine learning include recommendation systems, fraud detection, and predictive modeling.

Data science, an interdisciplinary domain, merges statistical and computational techniques with specialized knowledge in various fields to extract insights and knowledge from data. It encompasses a wide array of activities, including data acquisition, cleaning and preprocessing, exploratory data analysis, statistical modeling, and machine learning. Data science finds applications in diverse sectors such as healthcare, finance, social media, and e-commerce.

Various studies show that people's opinions about Artificial Intelligence are divided and that almost half of people fear it. In contrast, the other half enthusiastically welcome it in their daily use.[5]

Artificial Intelligence can be used in a variety of everyday applications, including:

- Personal assistants for smartphones such as Siri, Bixby, and Alexa
- Chatbots for online customer service
- Image and voice recognition in cameras and virtual assistants
- Recommendation systems in streaming services and e-commerce websites
- Fraud detection in banking and financial services
- Predictive maintenance in manufacturing and industry
- Self-driving cars and transportation
- Healthcare, e.g., medical diagnosis and personalized treatment plans
- Speech translation and natural language processing in communications.

These are just a few examples, but Artificial Intelligence has the potential to be used in many other areas as well.

The fears that Artificial Intelligence raises in people are mostly related to potential job loss, loss of privacy and lack of security, the possibility of misperceptions, lack of transparency, lack of understanding of how it works, lack of warmth and understanding that human contact provides, and numerous ethical issues that its application raises in everyday life.[6,7]

Artificial Intelligence has long been used in various fields of medicine and dentistry. In medicine, it is used in radiology[8–10], in the diagnosis and treatment of various diseases and conditions (in gastroenterology[11], oncology[12], cardiology[13], dermatology[14], intensive care[15] and others), for new drug discovery and development[16], as an aid in clinical decision-making[17], in personalized medicine[18], for chronic disease monitoring[19], for predictive analysis[20], and, of course, in numerous medical researches[21].

In dentistry, Artificial Intelligence is used in numerous fields[22], such as dental radiology[23,24], dental diagnostics[25], dental therapy planning[26], orthodontics[27], dental prosthodontics[28], periodontology[29], endodontics[30], oral pathology[31],

dental implantology[32], dental robotics[33], and other areas of dentistry[34–37].

A broader practical application of Artificial Intelligence in forensic medicine and forensic dentistry has yet to emerge. This paper aims highlight the current possibilities of applying Artificial Intelligence in modern forensic medicine and forensic dentistry. For this purpose, the relevant academic literature was searched using PubMed, Web of Science and Scopus. The keywords for searching these databases were: Artificial Intelligence; Machine Learning; Forensic Medicine; Forensic Dentistry. This review paper analysed and used articles that met the stated conditions. All articles used are listed in the reference list.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN FORENSIC MEDICINE

Forensic medicine is a branch of medicine that combines medicine and law. It involves the application of medical knowledge, skills, and competencies for judicial and legal purposes, which may or may not include criminal matters. For example, forensic medicine is concerned with, among other things, the investigation of deaths (forensic thanatology), the determination of the cause of injury or death, the examination of evidence, the examination of living persons, e.g., in cases of sexual offences, the preparation of wound reports, age estimation, and the assessment of the physical and mental condition of persons involved in legal cases.

Considering that Artificial Intelligence has long been used in medicine, but also in law, where it is already widely used to find relevant documents and evidence in legal disputes, it is logical to expect its application in forensic medicine.[38,39]

Artificial Intelligence can be used in forensic medicine and related fields in several ways[40]:

- Autopsy analysis: Artificial Intelligence algorithms can be used to analyze medical images, and help identify injury patterns, diseases, postmortem interval estimation, and cause of death.[40–44]
- Age and sex estimation: Artificial Intelligence can be trained to assist forensic experts in age estimation based on various parameters.[45,46]
- Facial recognition: Artificial Intelligence algorithms can be trained to recognize facial features at crime scenes and compare them to a database of known offenders.[47–51]
- Forensic toxicology: Artificial Intelligence can analyze the sample more accurately, and the method will be less time-consuming than the traditional way of analysis and can also be combined with robotics to automate some aspects of toxicology testing.[40,52]
- DNA analysis and "omics" data mining: omics is the suffix used in various branches of biology such as genomics, proteomics, metabolomics, toxicogenomics, etc.; Artificial Intelligence can be used for more efficient investigation of such data.[40,53,54]
- Fingerprint analysis: Artificial Intelligence can be used to automate the process of fingerprint analysis and match fingerprints found at a crime scene with those in a database.[55]
- Gunshot analysis: Artificial Intelligence algorithms can analyze audio recordings of gunshots to determine the type of firearm used and the number of shots fired.[56,57]
- Digital forensics: Artificial Intelligence can be used to analyze digital devices and data to uncover hidden evidence and track criminal activity.[58,59]

Overall, Artificial Intelligence can help forensic professionals work more efficiently, accurately, and objectively, leading to better investigative results.[60–62]

APPLICATION OF ARTIFICIAL INTELLIGENCE IN FORENSIC DENTISTRY

As in forensic medicine, Artificial Intelligence is increasingly used in forensic dentistry. Although this is mainly a practical application with a relatively narrow purpose, there are also examples, albeit rare, where Artificial Intelligence has become almost commonplace in the work of forensic dentists. Artificial Intelligence-based technologies used in forensic dentistry include deep neural networks, Artificial neural networks, machine learning, and computer technology. [63]

Artificial Intelligence can be used in a variety of ways to improve forensic dentistry, including:

- Dental identification: Artificial Intelligence can assist forensic dentists in analyzing dental images, such as radiographs, in identifying and matching individuals based on their teeth and jaws.[64–68]
- Age and sex estimation: Artificial Intelligence can be used to analyze dental images to help forensic dentists estimate the age and sex of individuals.[67,69]

- Facial reconstruction: Artificial Intelligence can be used to create 3D models of teeth and jaws for use in the facial reconstruction of unidentified remains.[70]
- Bite mark analysis: Artificial Intelligence can be used to analyze and match bite marks that can be used as evidence in criminal cases.[67]
- Dental databases: Artificial Intelligence can be used to search and match dental data in databases, which can help identify individuals.
- Chatbots: Artificial Intelligence-powered chatbots can be used to answer questions and educate people about forensic dentistry.
- Automation of tasks: Artificial Intelligence can be used to automate specific tasks such as dental image analysis, reducing the need for manual human labour and increasing the speed and accuracy of identification.[71]

Artificial Intelligence is a technology still evolving in forensic dentistry, and its utility depends on the particular use case and implementation. It is also essential that adequate regulations and controls are in place to ensure that AI systems are safe, effective, and ethical.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN AGE ESTIMATION

Age determination is a necessary procedure in forensic medicine and forensic dentistry. The appropriate procedure choice depends on many factors, including the material available for analysis, the time and facilities available, and, of course, the experience of the expert. No ideal, universal method for age estimation can be applied universally.

One of the goals of forensic work is to estimate the age of individuals in order to establish their biological profile, which is critical in criminal investigations and disaster scenarios because skeletal remains are often fragmented and complex to identify.[72] Both anthropological methods and new biochemical techniques must be used to to estimate age accurately. For subadult individuals, age is estimated using forensic anthropology and dentistry methods based on changes in bones and teeth caused by growth and development. In contrast, age estimation in adults is based primarily on degenerative changes in bones and teeth and is less accurate than in subadult individuals. Because age estimation becomes less accurate with age, alternative methods have been developed to estimate adult age by examining biochemical changes resulting from the physiological ageing process. While these biochemical methods are accurate, they also have limitations. Therefore, the combined use of anthropological and biochemical methods can lead to more accurate age estimation.[73]

An ideal age estimation method should have the following characteristics:

Accuracy, reliability, noninvasiveness, ease of use, inclusiveness, acceptability, privacy, cost-effectiveness, and speed. Accuracy: The method should provide accurate results consistent with actual age. Reliability: Results should be consistent regardless of the individual or circumstances and should not vary significantly from one measurement to the next. Non-invasive: The method should be non-invasive, i.e. nobody samples should be taken, or the person should not be exposed to harmful substances. Easy to use: The method should be easy to use, requiring minimal training and resources and no special equipment. Comprehensive: The method should be able to estimate the age of individuals from a wide range of age groups, races, and ethnicities. Acceptability: The method should be socially and culturally acceptable to the individual and should not discriminate against any particular group. Privacy: The method should protect the individual's privacy and not reveal personal information beyond age. Cost-effectiveness: The method should be cost-effective and not require a significant financial investment. Speed: The method should produce results in a reasonable amount of time without undue delay or inconvenience to the individual.[74] The methods most commonly used by forensic anthropologists to estimate age in adults are based on examination of the pubic symphysis, sternal rib end, the auricular surface of the ilium, teeth, and cranial sutures.[75] Several parameters are used in forensic dentistry for age estimation in adults. These include tooth wear, absence/presence of wisdom teeth, a fusion of cranial sutures (palatal), degeneration of jaw bones, radiographic appearance of tooth roots on radiographs, transparency of root dentin, presence of secondary dentin, etc.[76] In addition, for age estimation in subadult individuals in forensic dentistry, we can use the development and eruption of deciduous and permanent teeth and the degree of root development, including the closure of the apical foramen.[77]

Artificial Intelligence can be used to estimate age by analyzing various features of a person, such as images of their face, teeth, or bones[78]. The Artificial Intelligence system can be trained to recognize patterns and features associated with different ages and then use this knowledge to estimate the age of an unknown person. In dental age estimation, Artificial Intelligence can be used to analyze dental images, such as x-rays, to estimate a person's age based on the development and wear of their teeth.[63,79–85] In skeletal age estimation, Artificial Intelligence can be used to analyze skeletal images such as X-rays or CT to estimate a person's age based on the development and degeneration of their bones.[86–88] Seo et al. used a deep-focus approach for bone age estimation from lateral cephalograms. They included 900 participants aged 4 - 18 years, and the regression model for estimating bone age from segmented cervical vertebrae images yielded average mean absolute error and root mean squared error values of 0.300 and 0.390 years.[89] Artificial Intelligence can be used to estimate facial age: Artificial Intelligence can be used to analyze images of a person's face, such as photographs, to estimate their age based on the appearance of wrinkles, skin texture, and other features.[90] In addition, Artificial Intelligence can build predictive models to estimate a person's age based on various data, such as images, measurements, and demographic information.

Today, several Artificial Intelligence-based algorithms have been developed to determine a person's age or skeletal remains. These algorithms typically use different types of radiographs for these purposes.[79,91,92] Kluck et al. used Artificial Intelligence for hand and wrist skeletal age estimation. They concluded that the results of skeletal age estimation by artificial intelligence were generally more outstanding than the results of skeletal age estimation performed by humans using the Greulich and Pyle method. [93] Many conventional methods for determining tooth age have also been tested in the environment provided by Artificial Intelligence.[79,94] Shen et al. tested Cameriere's method for determining tooth age on a sample of 748 children. They concluded that the accuracy of tooth age determination was higher with machine learning methods based on Cameriere's maturation stages than with Cameriere's formula. The study results suggest that machine learning algorithms may be better than the traditional Cameriere formula.[95] Third molars are very often used for age estimation. Upalananda and Wantanajittikul developed a semi-automated technique to assess the developmental stage of mandibular third molars. The overall accuracy of this method was 82.5%, whereas the accuracy in each developmental stage ranged from 87.5% to 97.5%.[96]

It is important to note that age estimation is complex, and no single method can provide an exact age. Therefore, various methods, including Artificial Intelligence, should be used to obtain the most accurate age estimate. In addition, age estimation may be more difficult in children younger than three years of age than in adults because dental and skeletal development is different in children. Artificial Intelligence can be used to automate specific tasks such as analyzing imaging and patient data, reducing the need for manual labour and increasing the speed and reliability of the process.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN SEX DETERMINATION

Sex determination is an essential aspect of forensic medicine and is performed in a variety of situations, such as criminal investigations, when determining the sex of a victim or suspect can help with identification; in the identification of victims of mass disasters; in missing person cases, when determining the sex of the remains can help with identification and provide closure for families; in genealogical research, sex determination can help confirm family relationships and establish family trees; in specific medical investigations, such as autopsies, sex determination is performed to determine the cause of death and to gather additional information about the person's anatomy and physiology. Sex determination in forensic medicine must be performed with extreme care and accuracy to ensure that the results are reliable and not influenced by bias or error. Several parameters can be used to determine the sex of a person in forensic science, depending on the state of preservation of the material being examined. If the state of preservation is good, examination of the external genitalia, such as the presence or absence of a penis and testes, can be used to determine sex. In addition, other parameters may be used. Skeletal structure: The size and shape of bones, such as the pelvis, can explain a person's sex. Cranial measurements:

Cranial measurements, such as the size of the forehead, jaw, and brow ridge, can also help determine sex. Dental characteristics: Differences in tooth size, shape, and eruption between males and females can be used. DNA analysis is a very accurate method of determining the sex of an individual. It involves analyzing the presence of the Y chromosome, which is present in males. Hormones such as testosterone and estrogen are present in different amounts in males and females and can be used to determine sex. The accuracy of sex determination can vary depending on the methods used and the individual's developmental stage. A combination of several methods is often used to increase the accuracy of the results. Sex determination in forensic dentistry in children without distinct sexual characteristics is complicated and challenging, almost impossible.

Artificial Intelligence can be used for sex determination by analyzing various features of a person, such as images of the face, teeth, or bones.[39,69,85] Research performed by Oura et al. about deep learning in sex estimation from knee radiographs reached the highest overall testing accuracy of 90.3% in sex estimation.[97] The Artificial Intelligence system can be trained to recognize patterns and features associated with different sex and then use this knowledge to determine the sex of an unknown person. Artificial Intelligence and artificial neural networks [98] can be used to analyze dental images, such as x-rays, to determine a person's sex based on the size, shape, and development of their teeth and jaws.[99,100] Artificial Intelligence can be used to analyze skeletal images such as X-rays or CT to determine a person's sex based on their bones' size, shape, and development.[101] In addition, Artificial Intelligence can be used to analyze images of a person's face, such as photographs, to determine sex based on wrinkles, skin texture, and other features. Bianchi et al. developed a semi-automatic method for estimating sex based on the shape of the crown of upper posterior teeth.[102]

Sometimes, Artificial Intelligence can be used to create predictive models that estimate a person's sex based on various data, such as images, measurements, and demographic information. In some instances, Artificial Intelligence can automate some tasks, such as analyzing imaging and patient data, reducing the need for manual labour and increasing the speed and accuracy of the sex determination process.

Sex determination is a complex process, primarily using only dental material. To increase reliability and accuracy, other methods such as skeletal sexing, facial sexing, and predictive models should also be used. Artificial Intelligence-based sex determination is a technology still under development, and its accuracy may vary depending on the specific use case and the quality of the data used to train the system.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN DENTAL IDENTIFICATION

Tooth identification is important in dental identification because teeth are unique to each individual and provide a reliable way to identify a person.[103]. Teeth are not only unique in size and shape, but also have specific patterns of grooves and ridges that can be used for identification.[104] In forensic science, dental identification can be used to identify human remains in cases where other forms of identification are not possible, such as in mass disasters or when a body is decomposed or mutilated.[105] Dental identification involves comparing dental records, including radiographs, dental charts, and dental models, with the body's teeth to determine a match. Dental identification is considered one of the most reliable forms of identification because teeth are often well preserved even in the presence of fire, trauma, or other destructive forces. In addition, dental records are often available and can provide quick and accurate identification. Therefore, tooth identification is an essential part of dental identification and plays a critical role in forensic science, providing evidence that can help solve crimes and assist families in missing persons cases.

There are several ways in which Artificial Intelligence can be helpful in tooth identification.[64] Identification of individual teeth on x-rays: Artificial Intelligence can independently identify specific tooth types on radiographs with a high degree of precision and reliability.[106–110] In addition, recently there has been an increasing amount of research indicating the possibility of Artificial Intelligence recognizing the types of dental implants on radiographs.[111,112] Image analysis: Artificial Intelligence can help forensic dentists analyze dental images, such as x-rays, to identify and

match individuals based on their teeth and jaws.[113] Dental databases: Artificial Intelligence can be used to search and match dental records in databases, which can help identify individuals. Automation: Artificial Intelligence can be used to automate certain tasks, such as dental image analysis, which can significantly reduce the need for manual labor and improve the speed and accuracy of the identification process.[114] Predictive analytics: Artificial Intelligence can help predict the likelihood of certain dental conditions and diseases based on a patient's data, contributing to prevention and treatment. Age estimation: Artificial Intelligence can be used to analyze dental images to help forensic dentists estimate the age of individuals, which can be helpful in cases where the person's identity is unknown. Facial reconstruction: Artificial Intelligence can be used to create 3D models of teeth and jaws, which can help in facial reconstruction of unidentified remains.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN THE DETECTION OF BITE PERPETRATORS

Bite mark analysis is a forensic science concerned with examining and comparing human bite marks on the skin, food, or other objects. [115] The goal of bite mark analysis is to determine if a particular person caused the bite mark and to provide evidence that can be used in court.[116] The bite mark analysis typically involves taking and preserving the bite mark, examining and documenting the bite mark, comparing the bite mark to known dental impressions or records, and interpreting and analyzing the results.[117]

Artificial Intelligence can be helpful in bite mark analysis in several ways.[118,119] Image enhancement: Artificial Intelligence can enhance images of bite marks, making it easier for forensic dentists to analyze them and identify patterns and features. Matching: Artificial Intelligence can be used to analyze and match bite marks, which can be used as evidence in criminal cases. A person can be classified as a suspect or ruled out by comparing bite marks found on a victim or object with a suspect's dental records. Automation Artificial Intelligence can automate specific tasks like analyzing dental images. This can have a positive impact on the speed and accuracy of the identification process and reduce the possibility of human error and the need for manual labour. Predictive analytics: Artificial Intelligence can help predict the likelihood of certain dental conditions and diseases based on patient data, contributing to their prevention and treatment. Dental databases: Artificial Intelligence can be used to search and match dental records in databases, which can help identify individuals. Age estimation: Artificial Intelligence can be used to analyze dental images to help forensic dentists estimate the age of individuals in the context of bite marks, which can be helpful in cases where the individual's identity is unknown.

CONCLUSIONS

The application of Artificial Intelligence in forensic medicine and forensic dentistry is still in its early stages. However, the possibilities are tremendous, and the future will show what is applicable in daily practice.

- The use of Artificial Intelligence in forensic dentistry has several advantages: Improved accuracy and efficiency: Artificial Intelligence can help forensic dentists analyze large amounts of dental data, such as imaging and patient records, to identify and match individuals more quickly and accurately.
- Automation of tasks: Artificial Intelligence can be used to automate certain tasks, such as dental image analysis, which can reduce the need for manual labour and increase the speed and accuracy of identification.
- Improving the quality of evidence: Artificial Intelligence can be used to enhance images and better represent teeth and jaws, which can help improve the quality of evidence in forensic cases.

In addition, as mentioned earlier, Artificial Intelligence can be used to analyze dental images to assist forensic dentists in estimating the age of individuals; Artificial Intelligence can be used to create 3D models of teeth and jaws that can be used to assist in the facial reconstruction of unidentified remains; Artificial Intelligence can be used to analyze and match bite marks, which can be used as evidence in criminal cases; Artificial Intelligence can be used to assist in searching and matching dental records in databases, which can help identify individuals.

In addition to the advantages, the application of Artificial Intelligence also has some disadvantages, which may be related to discrimination, transparency, accountability, privacy, security, ethics and others. Bias and discrimination: Artificial Intelligence systems can

perpetuate and even amplify bias and discrimination in the data on which they have been trained. This can lead to misidentification or misestimation of the age and sex of individuals and even misidentification of bite marks. Lack of transparency and accountability: It can be challenging to understand how Artificial Intelligence systems make decisions, making it difficult to explain or hold them accountable. All of this makes them difficult to use as evidence in court. Privacy and security concerns: Artificial Intelligence systems require large amounts of patient data to function, which can lead to privacy and security concerns, especially given the proliferation of electronic dental records. Dependence on technology: Artificial Intelligence may become a crutch that forensic dentists rely on too heavily, to the point that some may only be able to perform tasks with the assistance of Artificial Intelligence. Currently, this problem is in its infancy, with few examples of Artificial Intelligence being used daily in the work of forensic dentists. Limited understanding: Artificial Intelligence systems may be limited in their understanding of context and may need help understanding nuances and subtleties of human oral health and disease, especially in the legal context required by forensic dentistry. Job displacement: Artificial Intelligence can automate specific tasks, such as analysing dental imaging and patient data, leading to job displacement and unemployment. In some fields, job displacement has become a severe problem, but this is different from the work of forensic dentists. Ethical concerns: Artificial Intelligence can raise ethical concerns such as autonomy and decision-making in healthcare. Ethical issues will become more critical as the application of Artificial Intelligence becomes more prevalent in forensic medicine and forensic dentistry. Ethical issues are primarily related to the origin of the samples on which Artificial Intelligence is trained.

It is essential to consider these potential advantages and disadvantages when developing and implementing Artificial Intelligence systems in forensic medicine and forensic dentistry and to have regulations and controls in place to mitigate potential negative impacts. It is also essential to ensure that Artificial Intelligence systems are used as a support tool rather than a replacement for forensic experts.

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