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A Study Among General Dental Practitioners, Orthodontists and Forensic Odontologists Regarding Forensic Identification in Orthodontic Context

دراسة بين ممارسي طب الأسنان العامين وأخصائيي تقويم الأسنان وأطباء الأسنان الجنائي فيما يتعلق بتحديد الهوية الجنائية من خلال تقويم الأسنان

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Abstract

The process of dental identification involves comparing the dentition of the deceased with the latest dental records of presumed dead. It may become challenging to identify an individual whose orthodontic treatment records are untraceable for any reason. In such instances the dentition of the dead who underwent orthodontic treatment may need to be compared with the records before orthodontic treatment. The goal of this study was to determine the accuracy of matching pre and post-orthodontic treatment casts among general dental practitioners (GDPs), orthodontists, and forensic odontologists.

Pre and post-orthodontic treatment dental casts from ten patients were used in this study. Pre-orthodontic maxillary and mandibular dental casts were separated from post-orthodontic maxillary and mandibular dental casts. A total of fifteen assessors comprising five orthodontists, five forensic odontologists and five GDPs compared and matched the pre and post-orthodontic dental cast pairs.

Keywords: Forensic science; Orthodontic treatment; Disaster victim identification; Forensic odontologist; Orthodontic casts; Dental identifiers.

المستخلص

تتضمن عملية التعرف على الأسنان مقارنة أسنان المتوفى بأحدث سجلات الأسنان الخاصة بالموتى المفترضين. قد يكون من الصعب تحديد هوية الشخص الذي لا يمكن تعقب سجلات علاج تقويم الأسنان الخاصة به لأي سبب من الأسباب. في مثل هذه الحالات، قد يلزم مقارنة أسنان الموتى الذين خضعوا لعلاج تقويم الأسنان مع السجلات قبل علاج تقويم الأسنان. كان الهدف من هذه الدراسة هو تحديد دقة مطابقة قوالب العلاج قبل وبعد تقويم الأسنان بين ممارسي طب الأسنان العامين (GDPs)، وأخصائيي تقويم الأسنان، وأطباء الأسنان الشرعيين.

تم استخدام قوالب الأسنان قبل وبعد العلاج التقويمي لعشرة مرضى في هذه الدراسة. تم فصل قوالب الأسنان العلوية والسفلية قبل التقويم عن قوالب الأسنان العلوية والسفلية بعد التقويم. قام ما مجموعه خمسة عشر مقيمًا يضم خمسة أخصائيي تقويم الأسنان وخمسة أطباء أسنان شرعيين وخمسة من ممارسي طب الأسنان العامين بمقارنة ومطابقة أزواج قوالب الأسنان قبل وبعد تقويم الأسنان.

الكلمات المفتاحية: علوم الأدلة الجنائية، تقويم الأسنان، تحديد هوية ضحايا الكوارث، طبيب الأسنان الجنائي، قوالب تقويم الأسنان، معرفات الأسنان.

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Results revealed higher correct matches among forensic odontologists (94%) as compared to orthodontists (88%) followed by GDPs (80%). Among the parameters, 'specific features in the dentition' were most successful at correct identification.

Orthodontic therapy causes morphometric changes in the dentition, which can make comparative identification difficult. Unique features in the dentition present before orthodontic treatment and persistent even after orthodontic treatment such as peculiar attrition facets, etc. can prove highly accurate in the identification.

كشفت النتائج عن تطابقات صحيحة أعلى بين أطباء الأسنان الشرعيين (94٪) مقارنة بأطباء تقويم الأسنان (88٪) يليها ممارسي طب الأسنان العامين (80٪). من بين المعلمات، كانت «الميزات المحددة في الأسنان» هي الأكثر نجاحًا في التحديد الصحيح.

علاج تقويم الأسنان يسبب تغيرات مورفومترية في الأسنان، الأمر الذي يمكن أن يجعل التحديد المقارن صعبًا. الميزات الفريدة في الأسنان الموجودة قبل علاج تقويم الأسنان والمستمرة حتى بعد علاج تقويم الأسنان مثل مظاهر التآكل المميزة على الجوانب السطحية للسن، وما إلى ذلك يمكن أن تكون دقيقة للغاية في تحديد الهوية.

1. Introduction

'The branch of forensic science that, in the interest of justice, deals with the right handling and examination of dental evidence, as well as proper appraisal and presentation of dental findings', is forensic odontology according to Keiser-Neilson [1]. The human body's most indestructible part is the teeth. The human dentition, which has withstood the test of time and temperature, is one of the distinctive features of human morphology. The hard tissues of a person's teeth can sustain very high temperatures without losing micro-structure after death [2, 3]. When visual or fingerprint techniques fail to establish a deceased person's identity as the remains have been skeletonized, deteriorated, burned, or dismembered, dental identification becomes critical.

Dental identification is a process of comparative analysis wherein the dentition of the dead, represented as Post-Mortem (PM) records is compared with the dentition of the missing person presumed to be dead, represented as Ante-Mortem (AM) records. Dental identification leverages the irregularities and features present in the dentition in the form of spacing, rotation, crowding, cross bite, etc., for assigning identity to the dead. Artefacts in the form of dental treatment such as restorations, prosthetic work, implants, etc., also serve the same purpose. As such no minimum number of the concordant matches is required for identification, but it is generally accepted that the confidence of identification directly correlates with the amount number of such features. Routine dental treatment increases such points for comparison and overall uniqueness of dentition. During the inspection of the deceased person's dentition, any permanent changes caused by human intervention, such as tooth extraction, restoration, and contouring of teeth, will be noted.

The aim of orthodontic treatment is to restore or realign the dentition to a state of optimum function and aesthetics. The result of orthodontic treatment is an ideal alignment that often looks similar for everyone who underwent complete orthodontic treatment. The very first challenge in the process of comparative dental identification is establishing whether orthodontic treatment was carried out on the dead or not. Indicators such as permanent retainers, perfectly aligned teeth, missing premolars, missing third molars, etc. should be considered as possible evidence of orthodontic treatment.

In all phases of orthodontic therapy, dental casts, radiographs, photographs, and dental appliances are employed and cross-referenced to provide unique data on which the treatment decisions are based. Orthodontic records provide information useful for identification purposes because they may reveal morphological, therapeutic and pathological dental identi-

fiers. When the deceased body of a person who was actively undergoing orthodontic treatment is recovered, the identification isn't a great challenge since the applicance is a substantive proof of the treatment and the records can be traced with relative ease [4, 5]. Photographs, radiographs, dental casts, written notes, and dental appliances are examples of dental records that serve in the process of comparison. Discontinuity in the AM dental treatment records is a routine problem but may not be a major hindrance in the process of comparative dental identification. If dental records of certain phases of treatment are missing, comparative identification becomes challenging, but is still possible by comparing the anatomy of bone, relationship between teeth and other para-dental structures as per the records. Lack of post operative orthodontic treatment records does present challenges.

Dental identification approaches rely on the readiness and completeness of dental records, as well as the presence of adequate dental remains. It is worth noting that dental records aren't always updated for dental treatment in developing countries and in no way it can be ensured that the records are complete.

Government organizations that control the dental profession should take the responsibility to promulgate clear guidelines for dental offices and ensure dental record creation, kept recent, and maintained systematically so that they are made available as and when the need arises. Orthodontic treatment is a long-term treatment and the records should ideally be retained on a permanent basis. However, due to the constraints of physical infrastructure, it may not be practical to maintain such records for life. Maintaining the records in an electronic form offers a promising solution to this problem. A centralized database that stores the health records is also an effective solution. Despite the presence of due dental records, it becomes really difficult for the investigators to establish their trail and collate all the available records so that they are made available for comparison in a limited period.

India is a diverse and vast country with prevalence of dental problems among the population. The occurrence of malocclusion in India is 20% to 43% [6], out of which 5% undergo orthodontic treatment [7]. Considering India's population, this is a large number of patients. Similar trend is observed in other developing nations. A great challenge arises when the records about the orthodontic treatment are not available for comparison since on primary examination the dentition may appear pristine and devoid of any unique dental identifier. There are real chances that the orthodontic treatment records of the person presumed to be dead are untraceable due to varied reasons. The most common reason is that many orthodontists render their services as visiting consultants to a general dental practice. Thus, the general dental practitioner (GDP) may not have orthodontic treatment-related dental records. Other reasons include migration on the part of the patient or the orthodontist and the inability of the investigators to trace the orthodontic records. In such instances, there is no choice but to compare the pre-orthodontic dental treatment records with the dentition of the deceased person who underwent orthodontic treatment.

Due to the nascent nature of forensic odontology in developing countries including India, a GDP or any available orthodontist may be called in to perform the comparative dental identification. Thus, the accuracy of dental identification needs to be compared among different specialists and GDPs. With this in mind, the present study was planned to assess the accuracy of GDPs, orthodontists, and forensic odontologists at matching pre and post-orthodontic treatment dental casts which simulate AM and PM dental records respectively. The study also

Table 1 - *Inclusion and exclusion criteria for the dental casts*

Inclusion criteria	Exclusion criteria
Casts of patients who completed orthodontic treatment	Dental casts with damaged maxillary or mandibular teeth
Casts of patients having minor restorative treatment during the orthodontic treatment	Patients with grossly decayed teeth or root pieces
Non-extraction orthodontic treatment cases	Dental casts that poorly recorded morphological details

assessed different parameters used by each group and their impact on the identification.

2. Materials And Methods

The study commenced after approval of the institutional (Dr. D. Y. Patil Dental College & Hospital, Pune) ethics committee (Approval Certificate No: DYPDCH/IEC/164/169/20). The identity of the participating patients was not revealed at any stage of the study. The study was carried out on 10 sets of pre-orthodontic and post-orthodontic treatment dental casts. A total of 40 casts were considered for the study, 20 maxillary (10 pre and 10 post) and 20 mandibular (10 pre and 10 post). The pre-orthodontic and post-orthodontic dental casts were retrieved from the Department of Orthodontics and Dentofacial Orthopedics. Unsuitable casts were excluded based on the criteria shown in Table 1 and were divided into pre-orthodontic maxillary (PREmax) and mandibular (PREmand) casts and post-orthodontic maxillary (POmax) and mandibular (POmand) casts. Each pair (maxillary + mandibular) of pre and post-treatment dental cast was masked to conceal the identity of the patient and given a random serial number from one to ten, i.e. PREmax 1-10. PREmand 1-10, POmax 1-10 and POmand 1-10. Training was given to all the assessors before selecting them for the study. Calibration was done and reliability was checked with a kappa value of 0.8 agreement. A total of 15 assessors (five GDPs, five orthodontists, and five forensic odontologists) analyzed the casts and identified the pairs. The assessors were given a scale, a divider, and a Boley's gauge to facilitate correct measurements of pre and post-treatment pairs of dental casts. The assessors were also supplied with an assessment sheet wherein they were instructed to write the matched pairs and mention the dentition features or parameters based on which they positively identified the pair.

3. Results

A total of 15 assessors participated in the study of matching 40 pre and post-orthodontic casts. Among the 15 assessors, five were orthodontists, five forensic odontologists and five were GDPs. The maximum correct matches were made by forensic odontologists accounting for 94% followed by orthodontists (88%) and GDPs (80%) (Table 2). The

Table 2 - *Percentage of correct matches for all assessors*

Assessor	Correct/Total matches	Percentage of correct matches
Forensic odontologists	10/10	94%
	10/10	
	7/10	
	10/10	
	10/10	
Orthodontists	8/10	88%
	10/10	
	10/10	
	8/10	
	8/10	
GDPs	7/10	80%
	8/10	
	7/10	
	10/10	
	8/10	

Table 3 - *Comparison outcome of Forensic Odontologists*

	Forensic Odontologists									
	Assessor 1		**Assessor 2**		**Assessor 3**		**Assessor 4**		**Assessor 5**	
Pre-ortho Cast	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome	Parameters	Out-come
1	E (Attrition facet on DB cusp of 37)	Correct	C, E (Mesial cusp slope of 34)	Correct	A, B, C	Correct	C, D	Correct	A, C	Correct
2	C	Correct	A, D	Correct	A, B	Incorrect	A, C	Correct	C, D	Correct
3	C, E (Pre ortho cast was compared with all other post ortho casts and excluded)	Correct	C, E (Exclused the possibility of correct match with all other pre ortho casts)	Correct	B, C, E (Groove and ridge pattern of 47)	Correct	B, E (Groove and ridge pattern of 47)	Correct	E (Groove pattern of 47)	Correct
4	A, E (Incisal chipping of 42)	Correct	C, E (Chipped incisal edge of 42)	Correct	C	Incorrect	E (Attrition facet on DB cusp of 36)	Correct	C	Correct
5	A, C	Correct	A, C	Correct	C	Incorrect	C, E (Attrition facet on MB cusp of 36)	Correct	A, C, D	Correct
6	E (Groove and ridge pattern of 26, 36, 46)	Correct	C, E (Abnormal shape of 14), E (Groove and ridge pattern of 36, 46)	Correct	B, C	Correct	C	Correct	E (Abnormal shape of 14)	Correct
7	A, C	Correct	D	Correct	C, E (Tubercle on occlusal surface of 46)	Correct	E (Eminence on buccal side of DMR of 35, 45)	Correct	A, C, D	Correct
8	C, E (Groove and ridge pattern of 25, 26)	Correct	A, C	Correct	E (DB develop-mental groove of 36, 46)	Correct	E (Groove and ridge pattern of 47)	Correct	A, E (Groove and ridge pat-tern of 47)	Correct
9	C, E (Cavity on mesial side occlusal surface of 45)	Correct	C, E (Cervical abra-sion on 33)	Correct	C, B	Correct	E (Cervical abrasion on 33)	Correct	E (Groove and ridge pattern of 46)	Correct
10	B, C	Correct	A, C, D	Correct	A, B, C	Correct	B, C	Correct	A, E (Contour of mesial cuspal slope of 23)	Correct

Note: FDI system used

Table 4- *Comparison outcome of Orthodontists*

	Orthodontists									
	Assessor 1		Assessor 2		Assessor 3		Assessor 4		Assessor 5	
Pre-ortho Cast	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome
1	C	Correct	C	Correct	C, D	Correct	A, C	Correct	C, D	Correct
2	A, C	Correct	E (Attrited cusp of 33, 43)	Correct	B, C	Correct	A, C	Correct	B, C	Correct
3	C, D	Incorrect	A, C	Correct	B, E (H shaped groove pattern of 35, 45)	Correct	C	Incorrect	B, C	Correct
4	A, C	Incorrect	C	Correct	A	Correct	C	Correct	A, C	Correct
5	A, E (47 anatomy)	Correct	D	Correct	B, C, D	Correct	B, C	Correct	C, D	Correct
6	C	Correct	A	Correct	C	Correct	C	Correct	C, D	Correct
7	B, C	Correct	A, D	Correct	A, C	Correct	B, C	Correct	A, C	Correct
8	A	Correct	C	Correct	A, C	Correct	A	Correct	B, C	Incorrect
9	D	Correct	C	Correct	C, D	Correct	B	Correct	A, C	Incorrect
10	C	Correct	C, E (Buccoversion of 17)	Correct	B, C, D	Correct	C, D	Incorrect	B, C, D	Correct

Note: FDI system used

Table 5- *Comparison outcome of General Dental Practitioners*

	General Dental Practitioners									
	Assessor 1		Assessor 2		Assessor 3		Assessor 4		Assessor 5	
Pre-ortho Cast	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome	Parameters	Outcome
1	B, C	Incorrect	B, C	Correct	C, D	Correct	C, D	Correct	C, D	Correct
2	C	Correct	B, C	Incorrect	C	Incorrect	B, C	Correct	B, C	Correct
3	A, C	Incorrect	C	Correct	A, C	Incorrect	B, C, E (H shaped groove pattern of 35, 45)	Correct	C, D	Incorrect
4	A, D	Incorrect	C	Incorrect	C	Correct	A, C	Correct	A, C	Correct
5	D	Correct	B, C	Correct	C, D	Incorrect	B, D	Correct	C, D	Correct
6	A, C	Correct	B, C	Correct	A, C	Correct	C	Correct	C, D	Correct
7	C, D	Correct	C	Correct	D	Correct	C	Correct	C	Correct
8	A	Correct	C	Correct	A, C	Correct	A, C	Correct	B, C	Incorrect
9	C, D	Correct	C	Correct	C	Correct	C, D	Correct	A, C	Correct
10	C	Correct	B, C	Correct	E (13 morphology)	Correct	B, D	Correct	B, C, D	Correct

Note: FDI system used

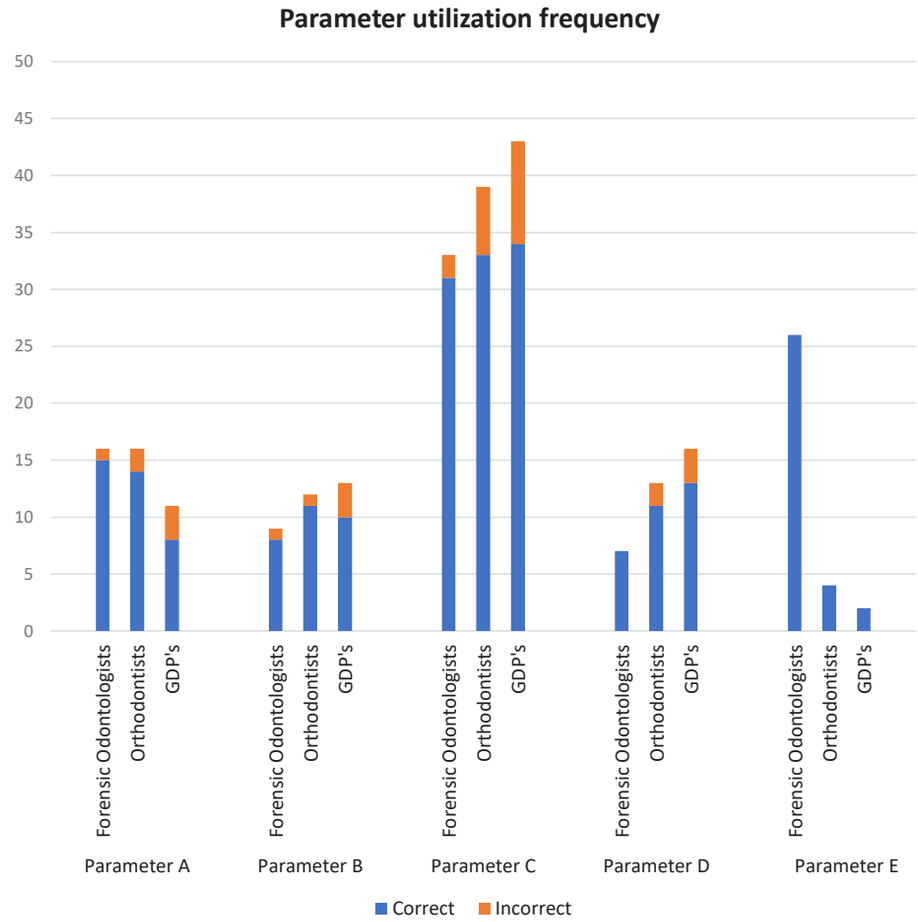

Figure 1- Parameter utilization frequency by different assessor groups

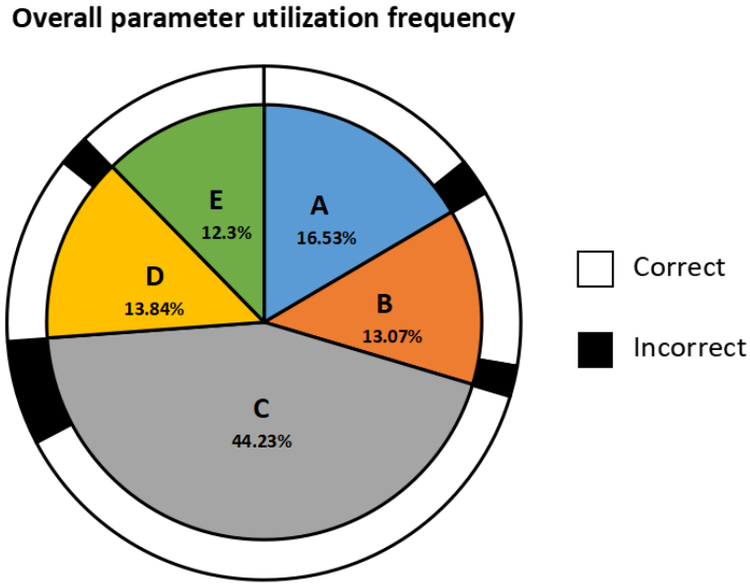

Figure 2- Overall parameter utilization frequency

parameter used most frequently (44.23%) was C - Morphology of teeth including their measurements, while the least frequently (12.30%) used parameter was E - Other specific feature (Figure 2).

The parameters used by the assessors as mentioned in the assessment sheets were binned into following five groups;

A- Palatal rugae
B- Palatal vault depth
C- Morphology of teeth including their measurements
D- Arch morphology
E- Other specific feature (mentioned separately each time)

4. Discussion

Previous studies that observed multiple post-orthodontic treatment dental casts have concluded that orthodontic treatment increased the similarity between dentitions and decreased uniqueness [8]. None of the previous studies [9, 10] were aimed at quantitative (percentage accuracy of identification) and qualitative (parameters relied for identification) comparisons among different assessor groups. This present study compared the accuracy in matching pre and post-orthodontic treatment dental casts and the parameters used to support the match among GDPs, orthodontists and forensic odontologists.

Although every post-orthodontic treatment dentition primarily looks similar, there are minute differences that can still define a particular individual. In the present study, the assessors employed the following parameters to decide a match/positive identification;

A- Palatal rugae
B- Palatal vault depth
C- Morphology of teeth including their measurements
D- Arch morphology
E- Other specific feature (mentioned separately each time)

These parameters were not provided to the assessors in a ready form, however the explanation written by the assessors in the sheets allowed us to deduce to the above five separate parameters.

Since the orthodontic treatment involves moving almost all teeth in the dentition, the relationship between the teeth and arch morphology are not reliable parameters for identification Also, procedure such as proximal stripping which is routinely performed for gaining space in the orthodontic treatment, will change the odontometric parameters of the teeth. Another routinely performed procedure is extraction of premolars, which grossly alters the inter-tooth relationships.

A study [11] that assessed the morphometric changes in the palate (transverse as well as vertical) concluded that rapid maxillary expansion significantly altered the maxillary arch shape by increasing the transverse palatal measurement and decreasing the palate vault depth. Another study that assessed palatal rugae on pre and post-orthodontic treatment dental casts revealed various morphometric changes in the palatal rugae pattern, although changes were not seen to affect the individuality of the palatal rugae pattern [12]. All these changes could complicate the pala- tal based human identification be it based on palatal rugae or palate vault depth. Also, the palatal rugae as a parameter will not be present once decomposition has destroyed the soft tissues.

The parameter E - Other specific feature was used very sparingly by GDPs (two times) and orthodontists (four times) contrary to the prolific use by forensic odontologists (26 times). Various dentition features relied upon in this category included groove pattern, ridge pattern, cusp abrasion pattern, chipping, tubercle, contour of an anatomical landmark, etc. It is interesting to note that other specific features never resulted in an incorrect match. The usage frequency (Figure 1) indicates the greater reliance on parameter E by forensic odontologists and the resultant highest correct matches by this assessor group (Table 2). All forensic disciplines rely on individual

traits for identification, be it about a bite mark or a spent cartridge case (forensic ballistics). The lack of forensic training on the part of GDPs and orthodontists explains the sparse utilization of parameter E.

In this study random numbers were given to the pairs of pre-orthodontic treatment casts and post-orthodontic treatment casts. Randomization was based on a pair of maxillary and mandibular cast, not individually. Thus, the assessors could passively assign a pre-orthodontic maxillary or mandibular cast to a post-orthodontic cast if the other cast was identified as a match. For example, if an assessor was sure that PREmax 1 and POmax 5 were a match, he/she could passively assign PREmand 1 to POmand 5. In real scenarios, this could be problematic in situations wherein disarticulated, commingled, skeletonized or fragmented human remains are recovered, which can happen in mass disaster situations. In such a case it is best to identify the maxillary and mandibular arch separately and then assign them to each other by checking occlusion and/or by using DNA techniques.

Out of total of 19 incorrect identifications, pre-orthodontic cast 3 was the most incorrectly identified pair (five times) among all, thrice by GDP's and twice by orthodontists. This was followed by pre-orthodontic cast 4, which was incorrectly identified four times, twice by GDP's and once each by an orthodontist and a forensic odontologist. The reason for repeated incorrect identifications in these cases can be attributed to a lack of observable peculiarities in the dentition or the inability of the assessors to spot these peculiarities.

Identification by exclusion/elimination is a valid strategy to narrow down and identify human remains in closed cases. This strategy is highly useful for dental identification as well. Among all the assessors only forensic odontologists utilized the technique of exclusion. Forensic odontologists utilized exclusion to correctly identify pre-orthodontic cast 3. This method is highly effective in the identification of victims in a closed disaster, wherein the total number of victims and their presumptive identity is known.

The drawbacks of this study design also need a consideration. This study used post-orthodontic treatment plaster casts to simulate PM remains. Plaster casts are susceptible to suffering damage due to handling, use of dividers, calipers, etc. This damage albeit trivial, gradually increased as the study casts progressed from one assessor to the next. The use of a caliper and divider could scratch the cast and alter the surface details. Other limitations of this study are that only 20 pairs of casts were utilized and the study was not repeated after a time delay to ascertain examiner error.

This study showed that among the three assessor groups, forensic odontologists identified the correct pre and post-orthodontic cast pairs the most, followed by orthodontists and GDPs. Among all the parameters, parameter E 'other specific feature' proved most successful at correct identification.

5. Conclusion

In this limited study, forensic odontologists proved to be more successful over others in the process of human identification due to the knowledge and awareness of PM taphonomic process apart from the knowledge of dental anatomy. With the available AM dental records, the forensic odontologists were able to extract reliable unique information to aid in the process of identification. Unique features in the dentition present before orthodontic treatment and persistent even after orthodontic treatment such as peculiar attrition facets, etc. can prove highly accurate in the identification. It is also to be noted that, reliance on multiple parameters, utilization of exclusion technique and reserving opinion if unsure can prevent erroneous identifications.

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Conflicts of Interest

The authors declare no conflicts of interest.

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