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Research Article

Reconstructive Identification of Skeletonized Remains by Intraalveolar Impressions of Teeth Missing Perimortem or Postmortem: An Investigative Study

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Abstract

Advances in various aspects of dental treatment remains to continue at exponential rate with paradigm shift regarding state-of-the-art patient care. Such advancements in dental care makes traditional techniques obsolete and no longer the fillings are available for comparative identification. Moreover, teeth that were lost during (perimortem) or after (postmortem) death further makes identification process more difficult. Smith BC presented a reversible technique for purpose of dental identification by reconstruction of root morphology of missing teeth in skeletonized mandibles. The present study aims to retrieve information from teeth missing perimortem or postmortem, using a method that involves mensuration technique i.e. study of width and area parameters of root. This study was conducted using a dry skull. To simulate postmortem loss, two anterior teeth (incisors) and 2 posterior teeth (premolars) were extracted. Intraalveolar impressions were then taken using alginate and soft putty and light body, addition silicone impression materials. Later, the Intraalveolar impressions were then compared with the teeth extracted from their respective sockets using image editing software. Buccolingual and area measurements were recorded. Statistical analysis revealed that there is no statistical difference between the groups. To conclude, morphometric analysis of Intraalveolar impressions can be used as a source and they provided significant amount of information which can be used for reconstructive identification.

Keywords: *Forensic Science; Root Morphology; Intraalveolar Impressions; Morphometric Analysis; Missing Teeth; Perimortem or Postmortem Loss*

Introduction

Positive identification of dead bodies or skeletal remains is considered one of the important duties of coroners, medical examiners and forensic experts. Identification mishaps is a possibility when there are no proper protocols or well-established policies are in placement which results in dire consequences, thus effecting decedents families and friends [1]. Forensic identification of human remains is a process of legal determination based on scientific matching of missing persons information with unidentified human remains [2]. It is of paramount importance to use reliable methods that are scientific in nature and for any given case where visual identification is not possible (i.e. burned, decomposed or severely damaged), scientific identification is the preferred method for positive identification. Examples of such scientific methods are finger print comparison, dental comparison, DNA typing, X-ray comparison and as per Interpol they are reliable methods for identification [3]. Identification of human or skeletal remains using dental characteristics is well established, reliable, efficient method and is due to uniqueness and individuality of dental patterns among individuals, resiliency and resistance of dental structures to various environmental insults, and also the availability of antemortem dental records for further comparison [4].

Confounding factors in dental identification

Traditional method of dental identification involves comparison of postmortem (PM) findings to the antemortem (AM) data such as dental records/ charts, dental radiographs, study casts, smile photographs showing presence of teeth etc. This process of dental identification becomes further complicated when there is evidence of perimortem (pm) or PM tooth loss. If tooth lost during life (antemortem), both tooth sockets as well as the edges of it are not clearly discernible. By contrast, if lost around time of death (pm) or after death (PM), the socket walls remain identifiable with sharp bone crests and often empty or dirt filled [5,6]. Identification becomes ever more challenging when there are no AM dental restorations present. In such cases, radiographic comparison of root morphology, bony trabecular patterns, sinus morphology or other distinctive radiographic characteristics can be useful anatomic features for comparison [4]. Sholl., *et al.* conducted radiographic comparative study using skulls found that success rates for matching dental radiographs with no restorations varied from 63% to 100%. And also, participants in this study opined that root morphology and alignment is better than crown morphology as an aid in comparison [7].

In addition, it is the duty of forensic experts to interpret any visible bone traumas as well the empty tooth sockets suggesting pm or PM tooth loss. It is due to decomposition of periodontal soft tissues such as the cementum, periodontal ligament fibers and gingiva, typically leading dislodgement of teeth PM [8]. When deciphering such trauma and pm or PM loss of teeth, one of the important function of expert will be to identify from whom these loose teeth originated. In such cases, a direct comparison by placing teeth in sockets might provide a clue for identification. To suggest definitive identification, overall "best fit" is guided between teeth and dental sockets. But in reality, incisors tend to fit into their contralateral sockets with ease due to decomposition of periodontal tissues, thereby further complicating the process of identification. For better understanding of this study design, the authors designed a crime scene which was a simulation of identification of the skeletonized remains using teeth.

Simulated crime scene

On regular police patrolling, the highway patrol officers found two human mandibles. There was no evidence of any other skeletal remains found at the site. They also found two incisor teeth from the site where mandibles were found. The mandibles were handed over to forensic experts for further examination and for reconstructive identification of the remains. While examining, when experts tried to reposition the incisor teeth into their alveolar sockets, these teeth found to be fitting into incisor sockets of both the mandibles without much resistance. This further raised the concerns of experts regarding to which mandible these teeth belong to or they belong to neither of them. In such situations, it is of paramount importance to confirm from which mandible those respective teeth originated, which is indispensable for reconstructive identification.

Subjective analysis Vs metric analysis

It is undoubtedly the experience of forensic expert that plays major role to break down and extract information from any given piece of evidence. As forensic practice often involves assessment and analysis of human remains in order to ascertain identity, much of the work by forensic experts is highly subjective in nature and mainly depends on the experience of the observer [9]. As thorough knowledge of method is required, this experience-based approach at times may result in lesser accuracy rates and more errors. But in contrast, morphometric analysis is often less subjective, as there will be clearly defined landmarks, measurements and also has lower intra- or inter-observer errors. It also can be easy carried out by an expert with lesser experience.

Keeping in mind of above mentioned situations and in recognition of such problems associated with PM or pm tooth loss, issues from experience based approach, a method was sought in order to assist investigators regarding fit of teeth into respective sockets.

Purpose of the Study

The purpose of this paper is to describe a method that involves mensuration technique i.e. study of width and area parameters of roots of teeth lost perimortem or postmortem by which reconstructive identification can be done.

Materials and Methods

A cross sectional, experimental and investigative study was designed and conducted using a human mandible selected from the archives of department of anatomy of a dental institution. Study was carried after the approval of Institutional Ethical committee. Mandible with intact anterior teeth and premolars in posterior dentition was chosen for this study. The mandible presented the presence of following teeth i.e. right second molar (#47), right first molar (#46), right second premolar (#45), right first premolar (#44), right canine (#43), right lateral incisor (#42), right central incisor (#41), left central incisor (#31), left lateral incisor (#32), left canine (#33), right first premolar (#34) and left second premolar (#35) (Figure 1). In present study, teeth #41, #42, #34 and #35 were extracted for further investigation. The dentition and periodontium has not exhibited any gross pathologies, with only evidence of mild attrition in posterior teeth. Further, the selected teeth were removed from their alveolar sockets by immersing the mandible in tap water, followed by careful facial- lingual luxation of individual teeth by hand [10]. After extraction of teeth, made sure that both teeth and morphology of alveolar bone were intact without any gross detectable changes. Hereby the roots of teeth extracted from sockets were considered as controls.

Figure 1: *Human mandible in occlusal view with anterior teeth and premolars.*

Technique

Prior obtaining the negative impressions, thorough inspection of the alveolar sockets was done to check intra alveolar integrity. The sockets were then carefully debrided with soft bristle brush in case of presence of any foreign bodies. A thin layer of Vaseline was applied along the walls of the socket in order to enhance the removal of impression material. Chromatex® alginate impression material (DPI, Mumbai, India) and Photosil® soft putty and light body, addition silicone impression material (DPI, Mumbai, India). Technique #1 involves injection of alginate impression material into the empty sockets of the mandible in syringe form. Technique #2 consisted of inserting light body addition silicone material into the empty intra-alveolar sockets using a syringe in combination with soft putty by manual method. The material was placed into the socket and made sure that it flows beyond the upper limits of the socket, and excess material was removed using surgical scalpel blade no 15. Later, the negative impressions of the empty sockets were then compared directly with the teeth extracted from their respective sockets. The impressions of the alveolar sockets and extracted teeth were recorded digitally with DSLR (digital single lens reflex) Canon EOS Rebel T5 (Canon Inc, Tokyo, Japan) camera by placing scale on either side (perpendicular and parallel) of teeth. As ABFO scale no. 2 was not available at time of investigation, metal scales were used as an alternative for calibration.

Digital measurements of intraalveolar impressions and controls

Images that were taken with digital camera were then imported to Adobe photoshop cc 2017 image editing software (Adobe systems Incorporated, San Jose, CA, USA) for viewing and measuring purposes. Buccolingual and area measurements of roots at different levels were measured in both controls and intraalveolar impressions of all teeth. The length of the root was not taken into consideration for comparative analysis owing to the fact that it is difficult to demarcate the coronal end on the intraalveolar impressions recorded using alginate and putty light body. To ensure equidistant measurements among groups, drawing marks were initiated at apical end (as it is difficult to demarcate coronal aspect on intraalveolar impressions) and then progressed to coronal aspect of the root. Maximum 5 levels were marked, starting with Level 0 that denotes apex of the root. As extends towards coronal side of root, levels from A to E were made at equidistance which is 15 mm (Figure 2). This method was repeated for both controls and intraalveolar impressions.

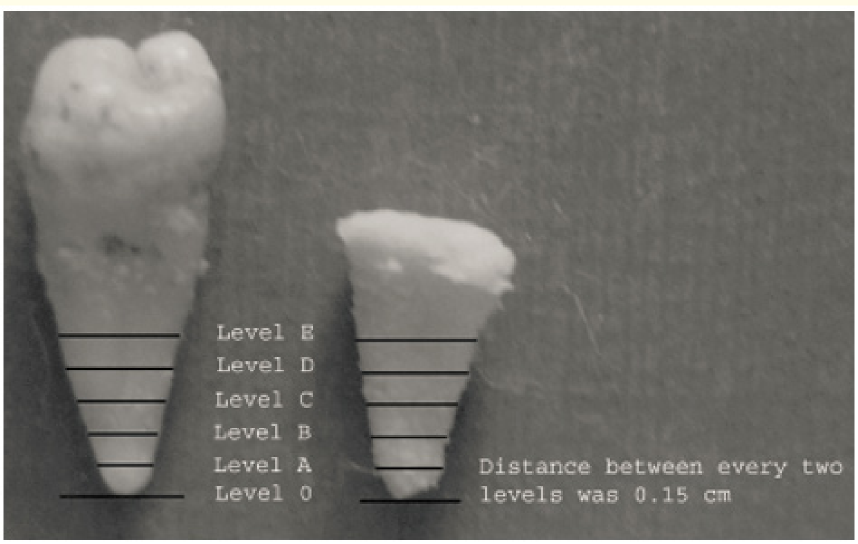

Figure 2: *Measurements carried out in sample. Level 0 refers to the apical end of the tooth; Each level (from A to E) were measured at equidistance i.e. 0.15 cm to measure Mesiodistal measurements at various levels.*

Linear measurements

For measuring buccolingual distance, Photoshop's inbuilt rulers were activated by choosing view > Rulers, on the menu bar or by pressing Ctrl + R, or Command + R for Macintosh systems. The units of the measurements were ensured to be in millimeters by comparing with the reference scales. In order to choose units in required format, choose Edit > Preferences > Units and Rulers and select "mm" under units and click OK. To mark the positions of levels (Level 0 to Level E), guides were placed at respective positions and then lines were drawn using the "brush tool" on toolbox in editing software. This process was repeated for all the levels. Once the respective lines were drawn at all levels, the buccolingual distance was obtained using "measure tool" from the toolbox. Using this tool, a line was drawn extending from buccal to lingual side, and the measured distance will automatically have displayed in the option bar. The measuring line drawn was kept vertical or straight by holding down the 'shift' key. Measurements obtained using this tool were sensitive to 0.1 mm.

Area measurements

To measure area at different levels along the length of the root, the "polygonal lasso tool" from the tool box was selected and then cursor was placed on outline of the section of root and then clicked. This process was repeated along the desired area of root. Once the entire area of root was selected from above mentioned action, it then appears as a dynamic black and white lines, also referred to as "marching ants" (Figure 3) [11]. To note down the measured area of the selected section, choose window option from menu bar and then select 'measurement log'. Then there will be a pop up below the image in photoshop that shows an outline named "record measurements". Clicking on to that option will automatically reveals the values of the selected area on the root (Figure 3).

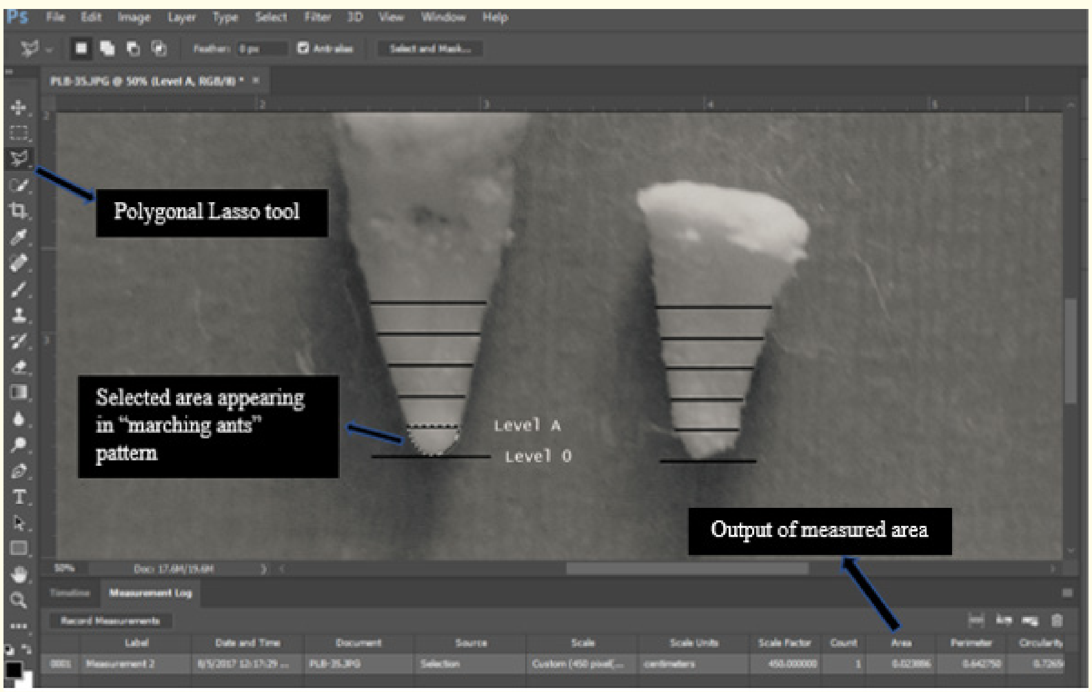

Figure 3: *Measuring area between Level 0 and Level A using Adobe photoshop CC 2017. Arrow pointing out the output of measured area between the levels. Left tooth is the control i.e. extracted mandibular left second premolar and right one is replica of root recorded using putty light bodied impression material.*

Statistical analysis

All the measurements were carried out single investigator. To analyze intra-observer differences, intra-class correlation coefficient (ICC) was calculated, by repeating measurements on all teeth after an interval of one month. All the measurements were entered into Microsoft excel worksheet for further analysis. Descriptive statistical analysis was performed using SPSS version 20 to obtain the means and standard deviations of the both buccolingual and area measurements of both study and control groups. The One- way ANOVA test was performed to compare the mean scores among the groups involved in the study.

Results

Data were recorded for all the teeth (#34, #35, #41 and #42) both in controls as well as in study (alginate and putty light body negative impressions) groups. The reproducibility of buccolingual and area measurements was calculated as intraclass correlation coefficients. The intraclass correlation coefficient for intra-rater agreement was 0.857. One-way analysis of variance (ANOVA) found no statistically significant difference both in mean accuracy of buccolingual distance in incisors and premolars (Table 1 and 2) as well as in mean accuracy of area measurements in incisors and premolars at different levels of the root (Table 3 and 4).

Levels	Study Groups	Mean	Std. Deviation	95% CI for Mean		p-value
				Lower Bound	Upper Bound	
Level A	Control	.24	.005	.2290	.2577	0.064
	Alginate	.25	.011	.2246	.2820	
	Putty	.23	.005	.2190	.2477	
Level B	Control	.32	.010	.2952	.3448	0.072
	Alginate	.32	.005	.3090	.3377	
	Putty	.30	.005	.2923	.3210	
Level C	Control	.39	.005	.3790	.4077	0.121
	Alginate	.41	.010	.3852	.4348	
	Putty	.39	.015	.3287	.4046	
Level D	Control	.46	.010	.4352	.4848	0.093
	Alginate	.47	.005	.4590	.4877	
	Putty	.47	.010	.4052	.4548	
Level E	Control	.50	.015	.4654	.5413	0.067
	Alginate	.51	.015	.4787	.5546	
	Putty	.50	.015	.4287	.5046	

***Table 1**: One-way ANOVA analysis between study groups for labiolingual measurements at different levels (A- E) in Lower right central Incisor (41).*

CI: Confidence Interval.

Levels	Study Groups	Mean	Std. Deviation	95% CI for Mean		p-value
				Lower Bound	Upper Bound	
Level A	Control	0.31	0.005	0.30	0.33	0.072
	Alginate	0.32	0.010	0.29	0.34	
	Putty	0.33	0.005	0.31	0.34	
Level B	Control	0.38	0.010	0.35	0.40	0.870
	Alginate	0.38	0.005	0.36	0.39	
	Putty	0.38	0.010	0.35	0.38	
Level C	Control	0.46	0.010	0.43	0.48	0.422
	Alginate	0.46	0.010	0.43	0.48	
	Putty	0.45	0.010	0.44	0.47	
Level D	Control	0.52	0.017	0.47	0.56	0.609
	Alginate	0.51	0.005	0.49	0.52	
	Putty	0.51	0.010	0.48	0.53	
Level E	Control	0.58	0.010	0.55	0.60	0.085
	Alginate	0.57	0.005	0.54	0.58	
	Putty	0.56	0.013	0.55	0.57	

Table 2: *One-way ANOVA analysis between study groups for labiolingual measurements at different levels (A- E) in Lower Left First Premolar (34).*

CI: Confidence Interval.

Levels	Study Groups	Mean	Std. Deviation	95% CI for Mean		p-value
				Lower Bound	Upper Bound	
Level 0-A	Control	0.022	0.0010	0.019	0.024	0.152
	Alginate	0.022	0.0010	0.019	0.024	
	Putty	0.020	0.0015	0.018	0.025	
Level A-B	Control	0.037	0.0005	0.036	0.039	0.279
	Alginate	0.037	0.0005	0.036	0.039	
	Putty	0.035	0.0010	0.034	0.038	
Level B-C	Control	0.051	0.0010	0.048	0.053	0.079
	Alginate	0.048	0.0010	0.045	0.050	
	Putty	0.046	0.0005	0.043	0.051	
Level C-D	Control	0.054	0.0010	0.051	0.056	0.125
	Alginate	0.055	0.0010	0.052	0.057	
	Putty	0.056	0.0010	0.053	0.058	
Level D-E	Control	0.061	0.0015	0.057	0.065	0.587
	Alginate	0.061	0.0005	0.060	0.063	
	Putty	0.062	0.0010	0.060	0.062	

Table 3: *One-way ANOVA analysis between study groups for area measurements at different levels in Lower right central Incisor (41).*

CI: Confidence Interval.

Levels	Study Groups	Mean	Std. Deviation	95% CI for Mean		p-value
				Lower Bound	Upper Bound	
Level 0-A	Control	0.040	0.0010	0.037	0.042	0.079
	Alginate	0.038	0.0010	0.035	0.040	
	Putty	0.040	0.0010	0.037	0.042	
Level A-B	Control	0.050	0.0010	0.047	0.052	0.236
	Alginate	0.051	0.0010	0.048	0.053	
	Putty	0.051	0.0005	0.049	0.052	
Level B-C	Control	0.061	0.0005	0.060	0.063	0.579
	Alginate	0.061	0.0005	0.059	0.062	
	Putty	0.062	0.0010	0.059	0.064	
Level C-D	Control	0.068	0.0010	0.065	0..070	0.422
	Alginate	0.067	0.0010	0.064	0.069	
	Putty	0.067	0.0005	0.066	0.069	
Level D-E	Control	0.076	0.0010	0.073	0.078	0.236
	Alginate	0.075	0.0005	0.074	0.077	
	Putty	0.077	0.0010	0.074	0.079	

Table 4: *One-way ANOVA analysis between study groups for area measurements at different levels in Lower Left first premolar (34).*

CI: Confidence Interval.

Discussion

When human remains were found, the first priority of investigators is to identify who the individual was in life [12]. To accomplish this goal, the investigators use experts from various of science such as physical anthropologists, forensic odontologists etc. The goals of the forensic anthropological or odontological analysis in victim identification were to use the skeletal remains of unknown individual to determine biological profile i.e. sex, stature, ancestry and to estimate age at death. Forensic odontologists also do comparative analysis which is comparison of postmortem findings of unknown body to the antemortem findings of missing person. As dentistry rapidly changing from a restorative science to conservative concept, it is often the odontologists experience no restorations to compare and has to rely mainly on morphological identifiers [13,14]. In such situations, forensic odontologists increasingly relies on anatomical landmarks and tooth and bone anatomy as well to arrive at identification [15]. At times, if victim's remains are exposed to environmental factors for extended periods, not only the bony pattern but also the status of the dentition gets effected. Biological phenomenon like these may hamper the process of human identification. And also, the distinction of such tooth loss, whether it is AM, pm or PM is paramount in the reconciliation of dental chartings. To halt further delay and to overcome limiting factors of identification process (referred to example in introduction section), it is necessary to adapt alternative technique that confirms from which socket these teeth originated. The purpose of this paper is to describe a method that involves mensuration technique i.e. study of width and area parameters of roots of teeth lost peri or postmortem and comparing them to intraalveolar impressions obtained from alveolar sockets using different restorative materials by which reconstructive identification can be done.

Smith BC in 1992 conducted an investigative study in which the author presented a reversible technique to reconstruct the root morphology of missing teeth for the purpose of radiographic comparison in dental identification [10]. The author injected a mixture of vinyl polysiloxane and barium sulfate into the alveolar sockets of teeth coated with cyanoacrylate cement. Then radiographs were taken with restorative materials in position and then compared with the antemortem morphology of the roots. Upon completion, the author made sure that impression material can be removed safely with no gross alteration of evidence. Later in 1996, Law and Bowers validated the applicability of this technique to evaluate a human skull that showed perimortem and/or postmortem loss. This technique requires radiographic comparison using periapical or orthopantomograms, which are bidimensional (2D) image modalities. In 2017, Lucas., *et al*. studied intra-alveolar morphology of alveolar sockets using impression materials and reconstructed the tridimensional (3D) shape of the roots and concluded that these impressions may contribute significantly as source of PM dental information [14]. The authors also suggested that morphometric analyses through surface scanning and/or photogrammetry of the roots from recently extracted teeth as a potential extension of this investigative study in future.

In the present study, the authors used alginate and soft putty and light body, addition silicone impression materials were used to reconstruct 3D shape of the roots. Then the morphometric data of roots of the extracted teeth were compared with those intra-alveolar impressions using adobe image editing software. Lucas., *et al*. in their study used alginate, condensation silicone and polyether as accuracy impression materials [14]. They recorded intraalveolar impression with alginate using a perforated partial dental tray and suggested that it should be avoided because of poor flow into socket, failed to register apical morphology and does not resist to tearing when removed from socket. But findings in present study contradicted its usefulness, as authors applied alginate in syringe form, which in turn increased its flowable property and ability to record apical morphology. This finding falls in line with literature search which suggested the mixture of alginate with barium sulfate is useful in reconstruction of root morphology and potential application in forensic practice [16]. Morphometric data of the intraalveolar impressions were then compared with extracted teeth (controls) and revealed that there is no statistical significance difference ($p > 0.05$) between the groups, suggesting that impressions with alginate and soft putty and light body, addition silicone can contribute significantly as a source of PM dental information in reconstructive identifications.

Accurate knowledge of 3D Shape of the teeth and anatomical position of roots is of paramount importance in surgical applications, endodontic therapies, treatment simulations etc [17]. For almost as long as they have been in existence, the radiographs have been used for not only for diagnostic purposes, but also for identification purposes of human remains [18]. Classic radiographic modalities used in identification are periapical radiographs, bitewing films, orthopantomograms etc. which are bidimensional (2D). In 2D radiographic comparisons, it is difficult to produce postmortem x-ray images in which the projections match those of given antemortem images. Using Computed tomography (CT) technology, three-dimensional data can be produced in virtual spaces and then simulated x-ray images can be produced matching the projections of antemortem images. In present study, the authors carried out morphometric analysis on the roots that were produced using a simple technique with an advantage of 3D reconstruction over the studies that used radiopaque fillings to reconstruct root morphology in past. Another advantage of this simplified technique is that the analysis can be done in a normal mortuary set up without requirement of any fancy setup.

Limitations and Scope for Improvement

One possible limitation of present approach is the authors did not measure the length of intraalveolar impressions of roots, owing to difficulty in demarcating the coronal end of the intraalveolar impressions. In future, similar morphometric investigations can be done taking length and thickness of the roots into consideration. Also, the authors have used only alginate and soft putty and light body, addition silicone as impression materials for intraalveolar impressions. Further studies can be designed with use of other materials as suggested by Lucas., *et al*. to increase its effectiveness and applicability of this technique [14]. Other possibility for extension of this study is to apply this technique for skeletal remains that have exposed to various environmental insults such as burnt, putrefied or wet remains, by which the efficacy of impression materials in these conditions can be tested.

Conclusion

Using this simplified technique, the root morphology of teeth missing perimortem or postmortem in skeletal remains can be obtained easily by intraalveolar impressions. These impressions of the alveolar sockets can be used as valuable tool for reconstructive identification. All the armamentarium used in this technique are readily available, commercially accessible and cost-effective. The technical aspects of the procedure can be understood easily and well within the capabilities of odontologists and anthropologists and can be done irrespective of any hi-tech laboratory facilities or fancy mortuary set ups. The author also believes that this technique allows the use of dental evidence that can be neglected easily or unavailable for reconstructive identification.

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