Original

Effect of Acids on Teeth and Restorative Materials: An Aid in Forensic Odontology

Thanuja Seethapathy¹⁾, Sanjeevareddygar Shylaja¹⁾, Manay Srinivas Muni Sekhar²⁾, Suvarna Manthapuri¹⁾,
Oruganti Venkata Ramanand¹⁾, Sharath Kumar Reddy¹⁾, Juliana Beryl Paul¹⁾, Akiyoshi Funato³⁾, Katsutoshi Kubo³⁾, Hatsuhiko Maeda³⁾
and Mohammad Khursheed Alam²⁾

¹⁾ Department of Oral and Maxillofacial Pathology, SVS Institute of Dental Sciences, Mahabubnagar, Telangana, India

²⁾ Department of Preventive Dentistry, College of Dentistry, Jouf University, Sakaka, Kingdom of Saudi Arabia

³⁾ Department of Oral Pathology, School of Dentistry, Aichi Gakuin University, Nagoya, Japan

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Abstract: The nature of crime is changing day by day and the forensic scientists are always facing new problems in human identification. The practice of destroying human body by immersing in an acid is drawing a great deal of forensic interest these days. The present study aimed to identify the acid that is most likely used in such crimes and to determine if the morphological changes in teeth and different restorative materials could predict the approximate duration of time elapsed after immersion of a body in an acid. 240 teeth with and without different restorations were immersed separately in 3 different acids and were observed for morphological changes over a period of 30 days. Teeth dissolved completely in hydrochloric acid (HCl) and nitric acid (HNO₃) by 48 hrs and 20 hrs respectively. Teeth showed precipitation in sulphuric acid (H₂SO₄) with only remnants of white precipitate by the end of 288 hrs. Amalgam restorations in HCl did not show any changes. They exhibited blackish discoloration on the surface when placed in H₂SO₄, but in HNO₃, they settled as silver powder with the release of brown fumes. Composite restorations in HCl and HNO₃ did not demonstrate considerable morphological changes. In H₂SO₄, they showed surface discoloration and softening. Glass ionomer cement (GIC) in HCl and HNO₃ dissolved completely. In H₂SO₄ they settled as white precipitate. When a human body is destroyed using acids, teeth or restorative materials retrieved can serve as an effective tool in crime investigations and can help the investigator to deduce the time elapsed since the commitment of crime.

Key words: Acids, Teeth, Restorations, Investigations, Crime.

Introduction

Human identification is one of the most challenging subjects that man has been confronted with. Forensic odontology has established itself as an important and often indispensable science in medico-legal matters and in particular in identification of the dead¹⁻³⁾. The importance of dental identification is on the rise year after year. With the passage of time, the role of forensic odontology has increased, as very often teeth and dental restorations are the only means of identification²⁾.

Teeth are considered to be essential organs in both living and nonliving population for anthropological, genetic, odontologic and forensic investigations. This is due to the hardness and high resistance of dental tissues to degradation and putrefaction which enable the teeth to survive for longer periods than other human tissues⁴⁾, making them more resistant to trauma, decomposition, water immersion, chemicals and fire, serving as an invaluable evidential source. To match these natural requirements, the foreign materials subsequently placed in the mouth by the dental practitioner such as fillings, dentures, crowns, bridges and implants must be equally resistant to the intense mechanical demands placed upon them and therefore their survivability⁵⁾.

As we enter a new millennium, society is faced with fresh challenges in every conceivable area. Despite leaps in modern technology, medical breakthroughs and the geographical changes that the last century has

brought, crime still persist in all aspects of our lives⁶⁾. The seeds of modern forensic science were sown in the last quarter of the nineteenth century. Progress from that time has been slow but steady⁷⁾.

Moreover, the nature of crime is changing day by day and the forensic scientists are always facing new problems in the process of identification. The practice of destroying the human body by immersing in an acid is drawing a great deal of forensic interest these days. Crimes of this nature have been frequently reported in Italy^{1,8)}. The forensic scientist needs to know whether it is possible to destroy the human body partially or totally by immersing it in an acid and, if so, how much time is necessary for its complete destruction. Another important question that arises in this context is whether there are any means of identifying the deceased individual from the residual remains⁹⁾.

John George Haigh, commonly known as the Acid Bath Murderer, was an English serial killer in the 1940s. In the Acid Bath murders committed by John George Haigh at Crawley, Sussex in 1949, it was the dentures that proved the identity of one of his victims. What Haigh did not know was that, the acrylic dentures dissolve very slowly in concentrated sulphuric acid (H₂SO₄)¹⁰⁻¹²⁾.

Following a literature review, there have not been many studies performed in the past using teeth as an aid in identifying a person, when they were immersed in an acid. No positive identifications related to events of acid dissolution were reported. Keeping this in mind, the present study was carried out to see if the morphological changes on the teeth as well as restorative materials when placed in contact with differ-

Correspondence to: Dr. Manay Srinivas Muni Sekhar, Department of Oral Pathology, College of Dentistry, Jouf University, Sakaka, 42421 Kingdom of Saudi Arabia; Tel: +966502899178; Email: drmunisekhar@gmail.com

Figure 1. Sequential morphological changes observed in teeth after immersion in hydrochloric acid

Figure 2. Sequential morphological changes observed in teeth after immersion in nitric acid

Figure 3. Sequential morphological changes observed in teeth after immersion in sulphuric acid

Figure 4. Sequential morphological changes observed in amalgam after immersion in hydrochloric acid

ent acids are of any help in identifying the acid used in such crimes and also to deduce the time elapsed from committing the crime.

The aims of the study are, to identify the agent (acid) that is most likely used in the crimes, where acids are employed to mask the human identification and to analyze the morphological changes in the teeth and different restorative materials namely Amalgam, Glass Ionomer Cement (GIC) and Composites, induced by acids such as Hydrochloric acid (HCl), Nitric acid (HNO_3) and Sulphuric acid (H_2SO_4) at various time intervals of 30 mins, 1 hr., 2 hrs., 4 hrs., 8 hrs., 15 hrs., 20 hrs., 24 hrs., and subsequently for every 24 hrs until 30 days. As well as, to determine, if the morphological changes in the teeth and restorative materials could be used to predict the approximate duration of time elapsed after immersion of a body in an acid.

Materials and Methods

240 extracted human natural teeth used for the study were obtained as per the protocol approved by the institutional ethics committee of SVS Institute of Dental Sciences, Mahabubnagar.

Inclusion Criteria: Teeth extracted for orthodontic purposes (Therapeutic extractions) and impacted teeth free of any defects.

Exclusion Criteria: Teeth with carious defect, teeth with pulpal, periapical or periodontal diseases, teeth with attrition, abrasion, and erosion or any developmental anomalies, and fractured teeth were excluded from the study.

The following acids were used in the study

- 37% Hydrochloric acid (HCl)–Finar Chemicals, Pune, India.
- 65% Nitric acid (HNO_3)– SDFCL, Mumbai, India.

- 96% Sulphuric acid (H_2SO_4)– Merck Specialities Private Limited, Mumbai, India.

The different restorative materials used in the study were

1. Amalgam

Silver powder- Dental products of India a division of The Bombay Burmah Trading Corporation Ltd. Mumbai, India

Mercury liquid- Prime dental products Pvt Ltd. Mumbai, India

2. Zinc phosphate cement – PyraxPolymars, Roorkee, India

3. Glass Ionomer Cement (GIC) – GC Corporation, Tokyo, Japan

4. Composite – Ivoclarvivadent marketing Pvt Ltd. Mumbai, India

Curing light – LED curing light, LEDition, Ivoclarvivadent marketing Pvt Ltd. Mumbai, India

The teeth used in the study were divided into following 3 groups:

- Group 1: 80 extracted teeth (20 intact teeth+ 60 teeth restored with different restorative materials of 20 each) + HCl solution
- Group 2: 80 extracted teeth (20 intact teeth+ 60 teeth restored with different restorative materials of 20 each) + HNO_3 solution
- Group 3: 80 extracted teeth (20 intact teeth+ 60 teeth restored with different restorative materials of 20 each) + H_2SO_4 solution

Out of 240 extracted teeth, cavity preparations were done on 180 teeth of which, a set of 60 were restored with different restorative materials namely amalgam (after zinc phosphate base application), GIC and composite. The teeth with and without restorations from Group 1, Group 2 and Group 3 were immersed separately in 3 different acids in different containers. At intervals of 30 mins, 1 hr., 2 hrs., 4 hrs., 8 hrs., 15 hrs., 20

Figure 5. Sequential morphological changes observed in amalgam after immersion in nitric acid

Figure 6. Sequential morphological changes observed in amalgam after immersion in sulphuric acid

hrs., 24 hrs., and thereafter for every 24 hrs until 30 days, the teeth and the restorations were examined for any morphological changes and photographed.

Sample size calculation

The sample size formula is given by:

$$n = \frac{\left\{ Z_{1-\alpha/2} \sqrt{P_0(1-P_0)} + Z_{1-\beta} \sqrt{P_a(1-P_a)} \right\}^2}{(P_a - P_0)^2}$$

Where,

P_0 = Complete dissolution of teeth proportion (0.5)

P_a = Duration proportion (0.41)

α = level of significance (0.05)

$1 - \beta$ = Power of the study (0.80)

The time taken for the teeth to dissolve completely was 0.41. The complete dissolution of all the teeth in all the acids was 0.5. The level of significance was 0.05 and the power of the study was 0.8.

On simplification, after applying the formula, the total number of teeth required for the present study was 240 (i.e, $n = 240$).

Results

Changes seen in teeth

Morphological changes seen in teeth when placed in HCl

Effervescence was seen in acid solution after 30 mins. After 1 hr, the teeth were translucent only at the incisal edge or at the occlusal surface at 2 hrs and this translucency progressively increased all around the teeth in the following hours of observation. Concentric circles appeared on the root at 4 hrs. After 8 hrs, teeth were gelatinous and eventually started floating in the acid solution. After 48 hrs of immersion, all the teeth were completely dissolved, and the solution was clear (Fig. 1).

Morphological changes seen in teeth when placed in HNO_3

Akin to HCl, there was effervescence observed in HNO_3 at 30 mins.

Figure 7. Sequential morphological changes observed in composite after immersion in hydrochloric acid

After 1 hr, the teeth were translucent only at the incisal edge/occlusal aspect and this translucency progressively increased all around the teeth in the following hours of observation. At this point, the teeth in HCl and HNO_3 showed similar morphological changes, but the teeth in HNO_3 were yellow in color which is helpful in differentiating which acid has been used. After 2 hrs, vertical fissure developed starting from incisal edge to the cervical third of the crown, which eventually deepened into a split extending towards the pulp by 2 hrs and there was marked reduction in the tooth structure as well. Teeth became gelatinous at 8 hrs and were completely dissolved by 20 hrs (Fig. 2).

Morphological changes seen in teeth when placed in H_2SO_4

There were no morphological changes observed until 8 hrs, later precipitation on the teeth was noticed. In the following hours of observation, the precipitation on the teeth increased relatively and there was deposition of this precipitate at the bottom of the container as well. As the precipitate increased, there was reduction in the size of the teeth. After 72 hrs of observation there was fragmentation of the teeth. Finally, the teeth were not recognizable and only precipitate was remaining at 288 hrs (Fig. 3).

The teeth that were restored with different restorative materials showed the same sequential changes as described above, irrespective of the type of restorations used to restore it. The only difference that was noted in case of teeth with restorations was that, there were delayed appearances of the morphological changes from the time that have been mentioned above.

Changes seen in restorations

AMALGAM

Morphological changes seen in amalgam when placed in HCl

After 1 hr, the restorations started to dislodge from the teeth and only 50% of the teeth showed intact restorations in them. As the time progressed, at each time interval during the experiment, the restorations eventually dislodged, and all the teeth were completely devoid of restorations by 15 hrs. The zinc phosphate cement applied as base was not appreciated after the restorations were dislodged. The amalgam restorations whether intact or dislodged did not show any morphological

Figure 8. Sequential morphological changes observed in composite after immersion in nitric acid

Figure 9. Sequential morphological changes observed in composite after immersion in sulphuric acid

Figure 10. Sequential morphological changes observed in GIC after immersion in hydrochloric acid

changes throughout the observation period of 30 days and was in the same size and shape as it was during the commencement of the experiment (Fig. 4).

Morphological changes seen in amalgam when placed in HNO_3

Bizarre changes were noted with respect to amalgam restorations. As soon as the teeth restored with amalgam were placed in HNO_3 , they got dislodged, in due course of time transformed into granules and settled at the bottom of the jar. The acid solution turned green. Another interesting finding that was noted at 30 mins was the emission of brown fumes probably because of the reaction between the acid and the amalgam restoration. As the time progressed, there was reduction in the amount of brown fumes emitted and completely disappeared by 28 hrs. At 192 hrs, the solution appeared slightly turbid. There were no further changes except for the fact that the solution was no longer turbid after 288 hrs. The granules at the bottom of the jar were not dissolved even after 720 hrs

(Fig. 5).

Morphological changes seen in amalgam when placed in H_2SO_4

Restorations started to dislodge from the teeth at 120 hrs. The dislodgement progressed slowly throughout the observation period and all the teeth were devoid of restorations by 360 hrs. Amalgam when placed in H_2SO_4 did not show any changes except for the surface of the restoration turning black which was noted at 240 hrs (Fig. 6A). There were no other morphological changes appreciated and were in the same size and shape as it was during the commencement of the experiment (Fig. 6B).

COMPOSITE

Morphological changes seen in composite when placed in HCl

The composite restorations started to dislodge from the teeth at 2 hrs with eventual dislodgement on hourly basis and all the teeth were completely devoid of restorations by 24 hrs (Fig. 7B). There were no considerable morphological changes appreciated in the composite restorations except for color change. The restorations were slightly brown at 144 hrs (Fig. 7C) and the color intensified eventually until the last day of observation (i.e 720 hrs / 30 days) without any dissolution.

Morphological changes seen in composite when placed in HNO_3

25% of the restorations got dislodged at 1 hr. The restorations were getting dislodged eventually as the time progressed and all the teeth were completely devoid of restorations by 28 hrs. The restorations appeared slightly brown in color at 96 hrs (Fig. 8B). There was progressive increase in brown color up to 312 hrs (Fig. 8C and D). At 312 hrs, the restorations at the periphery became translucent because of which

Figure 11. Sequential morphological changes observed in GIC after immersion in nitric acid

Figure 12. Sequential morphological changes observed in GIC after immersion in sulphuric acid

they appeared slightly smaller (Fig. 8D inset). No further morphological changes were observed at 720 hrs. As the changes seen in composite when placed in HCl and HNO₃ are quite similar except for peripheral translucency, it is very difficult to identify which acid has been used and therefore further biochemical analysis has to be performed to recognize the acid.

Morphological changes seen in composite when placed in H₂SO₄

Unlike the changes seen so far in different restorations when placed in different acids, there were many changes noticed in composite restorations when placed in contact with H₂SO₄. The changes started to appear at 30 mins, where the restorations turned slightly yellow in color. At 8 hrs, the restorations changed their color from yellow to yellowish red. There were changes in color on the surface of the restorations from time to time, from being red to pink, later into brown (Fig. 9A).

At 15 hrs, the surface of the restorations appeared soft and eventually the softened surface got dissolved in the acid. The subsurface restoration (below the softened surface) that was not exposed to the acid was still hard in consistency and intact. The restorations started to dislodge from the teeth at 48 hrs and this process of dislodgement continued slowly. By 384 hrs, all the teeth were completely devoid of restorations.

The restorations, both intact or dislodged, showed similar changes that were mentioned at 15 hrs, i.e the surface becoming soft and getting dissolved, and later the subsurface restoration gets exposed to acid becoming soft and dissolves eventually. This process continued till the restorations were completely dissolved. Except for 11 restorations that were still present even at 720 hrs but showed reduction in their size.

Not only the restorations, even the solution in which the restored teeth were placed also showed changes in terms of color from time to time. First the solution was red in color at 8 hrs, and then turned into a darker shade of red at 15 hrs. Later, at 48 hrs the solution turned pink and finally into brown color by 96 hrs and henceforth till 720 hrs (Fig. 9B).

GIC

Morphological changes seen in GIC when placed in HCl

After 1 hr of immersion of the teeth restored with GIC, half of the

teeth (50%) showed dislodged restorations. There was complete dislodgement of GIC from the teeth by 4 hrs, which was quite fast when compared to the time taken for the remaining 2 types of restorative materials to dislodge. The GIC, unlike the remaining restorations was collected as powder at the bottom of the jar. At 8 hrs, approximately half the amount of powder content got dissolved and the solution was clear with no evidence of powder by 120 hrs (Fig. 10).

Morphological changes seen in GIC when placed in HNO₃

Almost 50% of the teeth showed dislodgement of the restorations at 1 hr. By 2 hrs, except for one tooth, all the teeth were devoid of restorations. There was complete dislodgement of GIC from all the teeth by 4 hrs, which was quite fast when compared to the time taken for the remaining 2 types of restorative materials to dislodge. The GIC, unlike the remaining restorations was collected as powder at the bottom of the jar. At 8 hrs, the powder content was slightly reduced. As the time progressed, the powder got dissolved eventually and the solution was clear with no evidence of powder by 312 hrs. As the changes seen in GIC when placed in HCl and HNO₃ are similar, it is difficult to identify which acid has been used and therefore further biochemical analysis has to be performed to recognize the acid (Fig. 11).

Morphological changes seen in GIC when placed in H₂SO₄

The restorations took longer time to dislodge when compared to those placed in HCl or HNO₃. Restorations started to dislodge from the teeth at 120 hrs and the dislodged restorations were brittle in nature. At 144 hrs, 65% of the teeth showed intact restorations. At this hour, even the intact restorations became brittle. All the teeth were completely devoid of restorations by 288 hrs. As and when the restorations were dislodged, they became brittle and were easily manipulated with the slightest amount of pressure and transformed into powder which was indistinguishable from the white precipitate formed by the teeth at 288 hrs. Therefore, it was assumed to have been completely dissolved (Fig. 12).

Table 1 explains the sequential morphological changes seen in teeth and different restorative materials at various time intervals when placed in 3 different acids.

Table 1. Morphological changes observed in teeth and different restorative materials when placed in 3 different acids

HYDROCHLORIC ACID					
DURATION	TEETH	TEETH WITH RESTORATIONS	AMALGAM	COMPOSITE	GIC
30 mins	Effervescence (20/20)	Effervescence (60/60)	No change	No change	No change
1 hr	Translucency started to appear (20/20)	Minimal reduction in the size of the teeth were noted	Dislodged restorations (10/20)	No change	Dislodged restorations (10/20)
2 hrs	Translucency all around the teeth	No change	Dislodged (16/20)	Dislodged (3/20)	Dislodged (17/20)
4 hrs	Concentric circles started to appear	Translucency started to appear	Dislodged (18/20)	Dislodged (10/20)	All the teeth were devoid of restoration
8 hrs	Teeth started to become gelatinous	Concentric circles started to appear	Dislodged (19/20)	Dislodged (14/20)	After getting dislodged, the restoration turned into powder, 50% of which got dissolved.
15 hrs	Few teeth started to fragment (anterior), posteriors became gelatinous	Translucency all around the teeth	All the teeth were devoid of restorations	Dislodged (16/20)	Further dissolution of the powder content
20 hrs	Anteriors- near complete dissolution, posteriors - fragmentation	Fragmentation of 1 or 2 teeth. No other changes	The dislodged restorations did not show any changes. Were in the same size and shape	Dislodged (18/20)	No change
24 hrs	Anteriors- completely dissolved	Teeth started to become gelatinous. Fragmentation- 5/60	No change	All the teeth were devoid of restorations	No change
28 hrs	No change	Fragmentation- 20/60	No change	No changes were observed neither in shape nor in size	No change
36 hrs	No change	Nearly 50 teeth got fragmented	-	-	-
48 hrs	Complete dissolution of all the teeth	Almost all the teeth showed near complete dissolution complete dissolution- 5/60	-	-	-
72 hrs		Complete dissolution- 36/60			
96 hrs		Complete dissolution- 54/60			
108 hrs		Complete dissolution of all the teeth			
120 hrs					The solution was clear with no evidence of any powder
144 hrs				The restorations turned slightly brown	
NITRIC ACID					
DURATION	TEETH	TEETH WITH RESTORATIONS	AMALGAM	COMPOSITE	GIC
30 mins	Effervescence (20/20)	Effervescence (60/60)	The solution turned green with emission of brown Fumes. The restorations were getting dislodged, deformed and were settling at the bottom of the container	No change	No change
1 hr	Teeth started to become translucent	Minimal reduction in the size of all the teeth were noted	All the teeth were devoid of restorations	Dislodged (5/20)	Dislodged (9/20)
2 hrs	Vertical split appeared in few teeth	Teeth started to become translucent	No further changes	Dislodged (9/20)	Dislodged (19/20)
4 hrs	Reduction in the size of the teeth	Further reduction in size, few of the teeth showed concentric circles	"	Dislodged (12/20)	All the teeth were devoid of restoration. The restorations turned into powder and settled at the bottom
8 hrs	Marked reduction in size Fragmented – few teeth	Vertical split was noted	"	"	Reduction in the powder content
15 hrs	Near complete dissolution of few teeth	Marked reduction in the teeth, they started to become gelatinous	"	Dislodged (17/20)	"
20 hrs	Complete dissolution of all the teeth	Near complete dissolution- few teeth Fragmentation- few teeth	"	"	The solution had some powder
24 hrs		Almost all the teeth were fragmented with near complete dissolution	Solution- green Reduction in the amount of brown Fumes released	Dislodged (18/20)	"

28 hrs		Complete dissolution-10/60 Rest all near complete dissolution	Solution- green No brown Fumes were released	All the teeth were devoid of restoration, restorations were slightly brown in colour	"
48 hrs		Complete dissolution-31/60	"	No change	"
72 hrs		Complete dissolution-57/60	"	"	"
96 hrs		All the teeth were completely dissolved			
120 hrs					The solution was almost clear with the powder hardly evident
192 hrs			Slight turbidity was noted in the solution		
312 hrs				The periphery of the restoration turned slightly white	Completely dissolved
SULPHURIC ACID					
DURATION	TEETH	TEETH WITH RESTORATIONS	AMALGAM	COMPOSITE	GIC
30 mins	No change	No change	No change	Turned Yellow	No change
8 hrs	White precipitate appeared on the crown and the roots were comparatively darker	White precipitate appeared on the crown and the roots were comparatively darker	"	Restorations- yellowish red, Solution - red	"
15 hrs	White precipitate appeared even on the root, deposition of the ppt at the bottom of the container	White precipitate appeared even on the root, deposition of the ppt at the bottom of the container	"	Restorations turned Red and soft on the surface, rest of it was still hard and intact	"
20 hrs	Uniform increase in the precipitate on the teeth	Uniform increase in the precipitate on the teeth	"	"	"
24 hrs	Progressive increase in the deposition of the precipitate on the teeth as well as in the solution	Progressive increase in the deposition of the precipitate on the teeth as well as in the solution	"	" Colour of the restoration on the surface turned Dark Red from pink	"
48 hrs	White precipitate deposition	Fragmented – 10/60	"	Dislodged – 1/20, Restorations of solution were Pink in color	"
72 hrs	Fragmented – 1/20	Fragmented – 32/60	"	"	"
96 hrs	Fragmented – 2/20	Fragmented – 40/60	"	" Solution turned brown	"
120 hrs	Fragmented – 6/20	Fragmented – 43/60 Unidentifiable- 24/60	Dislodged – 4/20	Dislodged – 2/20	Dislodged – 5/20 The dislodged restoration were brittle and can be easily crushed, those that were intact were still hard
144 hrs	Increase in the precipitate deposition with further reduction in the teeth size	Increase in the precipitate deposition with further reduction in the teeth size. Fragmented – 48/60 Unidentifiable – 35/60	No change	Dislodged – 4/20	Dislodged – 7/20
168 hrs		Fragmented – 53/60 Unidentifiable – 45/60	Dislodged – 5/20	Dislodged – 8/20	Dislodged – 15/20
192 hrs		Fragmented – 56/60 Unidentifiable – 50/60	Dislodged – 7/20	Dislodged – 12/20 Restorations- brown	" The dislodged restoration could not be differentiated from the white precipitate of teeth
216 hrs		Fragmented – 56/60 Unidentifiable – 53/60	Dislodged – 8/20	Dislodged – 12/20	Dislodged – 19/20
240 hrs		Fragmented – 59/60 Unidentifiable – 56/60	Dislodged – 15/20	Dislodged – 13/20	Dislodged – 19/20
288 hrs		All the teeth were fragmented and unidentifiable	Dislodged – 17/20	Dislodged – 14/20	Dislodged – 20/20 Restorations if any were not distinguishable from the white precipitate of teeth
312 hrs		Reduction in teeth size Increase in white precipitate	Dislodged – 18/20	Dislodged – 15/20	"
360 hrs		"	All the restoration were dislodged from the teeth	"	"

Discussion

Identification of humans using the unique features of teeth and jaws has been used since Roman times^{13,14}. Human being has come a long way from the early caveman age to the present day of covering nothing less than astronomical heights to sea bed depths. His zeal to conquer new heights has created a world full of scientific advancement and technology. However, his intelligence has also led to a surge in crime rate, terrorism, wars, mass disasters, road traffic accidents and dreadful diseases. In all such incidents the identity of the deceased, assailant or the cause of death becomes important as the core of various investigations are based on the mode of crime^{15,16}.

Practice of forensic sciences often involves person/victim identification. As methods in personnel identification have increased or improved, so have the attempts of perpetrators of crime in circumventing those methods. Destruction of evidence including dead bodies by the use of concentrated inorganic acids is one such attempt. This was not entirely a novel method and came out to the fore of public realm probably half a century ago¹⁷.

There is a paradigm shift in the treatment protocol from extraction to restorative procedures. Hence the major agenda of every dentist in the present scenario is preservation of the tooth structure rather than extraction and subsequent replacement. Now-a-days, with increasing incidence of caries, wider population have their teeth restored with different restorative materials, hence there is a need not only to know the changes in the tooth structure when subjected to different concentrated acids, but also to know the changes in various restorative materials. Though teeth are considered hardest structures in the human body, they can at times get destroyed at unusual circumstances, in such cases when restorations are retrieved, they could serve as a useful tool in identifying an individual by approaching a step closer in solving the case in acid crimes.

Teeth react with acids in different ways and the chemical reaction between teeth and different acids are given below:

Teeth in HCl

The calcium present in the teeth reacts with the acid to form completely soluble salt i.e. CaCl_2 , which results in the complete dissolution of the teeth and the reaction is as follows:

Teeth in HNO_3

The calcium present in the teeth reacts with HNO_3 to form $\text{Ca}(\text{NO}_3)_2$, soluble salt. The following reaction takes place between the acid and the teeth:

The following chemical reaction possibly explains the color change that is seen in the teeth when placed in nitric acid:

Calcium sulphate reacts with nitric acid and forms calcium nitrate and sulphuric acid. The $\text{Ca}(\text{NO}_3)_2$ is responsible for the yellowish deposit on the teeth^{1,9}.

Teeth in H_2SO_4

The teeth placed in H_2SO_4 solution behaved completely different when compared to those that were placed in HCl and HNO_3 solutions, presumably because of the following reaction

The calcium present in the teeth reacts with H_2SO_4 and formed an insoluble CaSO_4 salt that got precipitated.

In the literature, to the best of the present knowledge no studies have been performed where the morphological changes in various restorative materials when placed in contact with different acids were done to compare. Except for a brief mention by Mazza *et al.*,⁸ wherein, as an experimental note, it was mentioned that one sample showed a residual central structure not destroyed by the acid and was identified as guttapercha bulk. Later as a part of the experiment, they have sectioned the guttapercha into 2 fragments. One fragment was submerged in pure HCl and the other in HNO_3 . Following an observation period of 50 hrs, none of the fragments showed dissolution.

In conclusion, morphological changes in teeth and different restorative materials can help the forensic investigator to deduce the time elapsed since immersion of body in an acid. The present study could be of great help when it is no longer possible to identify dental structures that have been dissolved in acid, the restorative materials if retrieved in such a situation could serve as a useful tool in forensic investigations. Additionally, to compare the residuals of dissolution with the ante-mortem records would be an aid in dental human identification.

It may be possible to identify the acid used to destroy a body based on these morphological changes. However, biochemical analysis helps in recognizing the acid as a more dependable tool. Additional studies and further investigations that look into the effect of acids on other dental materials could develop useful data in such crimes.

Conflict of Interest

The authors declared that they have no conflict of interest.

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