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Dental health status of skeletal remains excavated from an abandoned well at Ajnala, India: a bioarchaeological study

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Abstract: Present study was conducted to assess dental health status of the mid-19th century skeletal remains excavated from an abandoned ancient well and to scrutinize the demographic affiliations of the remains. Thousands of bones, teeth and contextual items were excavated non-scientifically from an abandoned well situated underneath a religious structure at Ajnala (Amritsar, India). Four thousands four hundred and seventy five teeth of each type were examined for presence of dental pathologies of caries, wear and linear enamel hypoplasia (LEH). The frequency distribution of each pathological state was calculated for each tooth type using international dental standards available in the literature. The overall dental status was characteristic of young individuals having low prevalence of dental caries and enamel hypoplasiac lesions. Very few teeth had seriously exposed dentine and pulp cavity; indicating consumption of some cariogenic food items. The maxillary and posterior teeth were more affected with dental caries than the mandibular and anterior teeth. LEH defects were found more commonly distributed in the lower canines (44.9%) and upper incisors (34.8%) than their corresponding counterparts and statistically significant differences were noticed in LEH prevalence between anterior and, posterior dentition. The overall percentage of LEH has been found as 15.8%; with 15.4% maxillary and 16.2% mandibular teeth being affected with LEH. The paleodontological examinations, contextual items and the preliminary molecular findings supported the written versions that victims of Ajnala skeletal remains had sound dental health status and probably belonged to adult males who were killed in 1857 as per written versions.

Key words: paleodontological examinations, dental carries, enamel hypoplasia, Ajnala skeletal remains

Introduction

Bones and teeth are dynamic and resistant biological entities which can unravel hidden biological information about lifetime events encoded within them. The reconstruction of the past life histories from human hard tissues, archaeological finds, and written records is an important aspect of bioarchaeological investigations (Zuckerman et al. 2011; Fujitha, Adachi 2017). The teeth, often survive the mechanical, physical, chemical or biological degradations and destructions to retain their structural details for a comparatively longer period of time than the bones. Teeth have remained the preferred and an indelible piece of evidence to reveal man's antiquity and his interactions with the prevailing physical, social, cultural and economic environments. At time of its eruption, the tooth surfaces are devoid of any attrition marks and the cusps are sharp with distinctly visible

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gullies. With advancing age, the cusps become dull, faceted, depressed; dentine or pulp cavity get exposed and then completely gets worn away.

Dental pathologies like caries, hypoplasias and wear estimated in archaeological remains reflect the adaptive failures of an individual to his physical, behavioural and cultural environment; are of particular interest for the anthropologists to reconstruct past life (Hillson 2003, 2005). Dental caries are a localized, progressive demineralization of the hard tissues of the crown and root surfaces of teeth which are generally initiated in the complex systems of fissures, fossae and grooves of the occlusal surface of molar and pre-molar crown (Manji et al. 1989). The prevalence frequency of dental caries have been used to compare the oral hygiene and dental health status of past versus contemporary populations; and to distinguish between the individuals of non-industrialized or industrialized nations. The maxillary and the posterior teeth are more commonly affected with dental caries than the mandibular and anterior teeth, respectively (Hillson 2011; Palubeckaite-Miliauskiene et al. 2006). In modern industrialized societies, the coronal caries are much more common than the root or cemento-enamel junction (CEJ) caries in adults.

Tooth wear is the loss of dental hard tissue in the region of tooth cervix or on occlusal surface. Wear may be taken as a normal degenerative process or some chemical or mechanical processes may be responsible for it. Tooth wear patterns vary within and among populations with regard to the age, sex and cultural, dietary, environmental or health status of an individual (Kaidonis et al. 2012). Anthropologists have studied relationships between dental wear and the abrasiveness of food, cultural practices, and the use of teeth as manipulative tools (Molnar 1972). Wear is a gradual and patterned loss of dental substances like enamel and dentin during natural mastication and; its occurrence is also strongly associated with the age and type of food eaten by an individual (Manji et al. 1991).

Enamel hypoplasia is an observable quantitative dental defect wherein enamel thickness is decreased locally on tooth surface during childhood (Ubelaker 1989). Enamel hypoplasia is unrelated to changes with aging process and it appears due to stressful conditions (malnutrition, weaning, infections, congenital abnormalities etc) in childhood when enamel formation is disturbed during active teeth formation period (Skinner, Goodman 1992; Fujitha, Adachi 2017). The linear enamel hypoplasia (LEH) is a general-systemic hypoplastic change in enamel matrix of tooth appearing as linear furrows or ridges or series of pits; which can be taken as a general indicator of childhood stress (metabolic, nutritional or environmental), intoxications or growth defects of an individual (King et al. 2005; Griffin, Donlon 2009; Tomczyk et al. 2012).

Historical background of Ajnala skeletal remains

In April 2014, a large number of human skeletal and dental remains were excavated by amateur archaeologists from an ancient well situated underneath a religious structure in a North Indian suburb of Ajnala (Amritsar, India). The written records mentioned that 282 Indian origin soldiers of British army were killed in July 1857 and their dead bodies were disposed off in an abandoned well at Ajnala (Amritsar, India); and then a religious structure was erected over the periphery of the sand-filled . It is alleged in the book that the slain soldiers had murdered British officers before fleeing away from a cantonment; however, they were captured, imprisoned and murdered by the colonial rulers under lordship of writer of the said book, citing sanitary concerns and socio-political scenario of the region at that time. It was only in early 2014 that someone from the region happened to read the book written by British administrator of Ajnala at the time of said massacre. The state authorities didn't bother to the media coverage given to the incident fearing it wouldn't turn another hoax; as a similar forecast about the availability of huge amount of gold beneath an old temple in Unnao (Uttar Pradesh, India) had already been proved a gimmick by Archaeological Survey of India (ASI) in early 2014. The widespread media coverage to the written records and the availability of human remains in the questioned well underneath a religious structure (worshiped by local dominant community) and the resultant public opinion pressure aroused curiosity among some local amateur archaeologists who got the remains exhumed hurriedly and non-scientifically. The religious structure was dismantled and relocated to an adjoining place. The heaps of badly damaged human skeletal remains were exhumed (without involvement of trained human archaeologists or any other experts) by digging down the well up to its sterile sedimentary layer. As the entire excavation process was executed by some amateur excavators, it resulted into thousands of badly damaged skeletal remains belonging to multiple individuals, found commingled with many items of personalized identity like coins, medals, arm-bracelets, metalled rings, stone bullets/bolas etc. The most immediate reason for the excavation of these remains was cited as to scrutinize the truthfulness and authenticity of the written records about these remains. After much hue and cry, the remains were handed over to the first author for their biological profiling purposes. Some amateur historians doubt the written versions and argue that these remains allegedly belong to the victims of Indo-Pak partition conflicts of 1947 when India got independence from British rule and not to the incident mentioned in the written records (Cooper 1858; Bates, Carter 2017). This manuscript aims to provide an overview of dental health status of individuals representing Ajnala skeletal assemblage and to ascertain their demographic affiliations in context to their pathological conditions and associated contextual items. Thus, main objective of author was to report the dental health status of individuals on the basis of prevalence and degree of dental caries, wears and Linear enamel hypoplasia (LEH) in some randomly selected loose teeth from the Ajnala skeletal assemblage. The hypothesis was to match the demographic credentials of the skeletal sample revealed by the written records and then determine whether it matches with the revelations about their military affiliations, with focus on assessing the dental health of individuals at the time of their death.

Materials and methods

Present study was conducted on 4475 teeth (1365 incisors, 724 canines, 1276 premolars and 1110 molars) collected from Ajnala (Amritsar, India) skeletal assemblage presently housed in the laboratory of the author in the Department of Anthropology, Panjab University, Chandigarh (India). All maxillary and mandibular molars couldn't be included for analysis of dental health status in present study as few of them have been processed for mtDNA and stable isotope analysis being undertaken at some national and international research laboratories. The age, sex, population affinity and socio-economic status of the individuals were preliminarily analysed from their anthropological, radiological and mitochondrial DNA analysis of few randomly studied teeth and other contextual items. The radiological examinations found that average age of individuals was 30.3 years (Sehrawat, Singh, Pathak, 2017). All the teeth were thoroughly cleaned, washed, dried and macroscopically examined under a moving microscope piece with magnification 300x magnifications (USB Digital Microscope,CEF@RoHS) for examining the presence of dental caries, attrition wear and enamel hypoplasia in them. The frequency distribution of each pathological condition was calculated for each tooth type (incisors, canines, premolars and molars) using international dental standards available in the literature. Number of tooth affected was calculated as counting of individuals was not feasible in this case. The frequency of carious teeth is calculated as the total number of teeth having at least one carious cavity divided by the total number of observed teeth. Dental caries were assessed by macroscopic examination on all tooth surfaces like occlusal, interproximal, cervical, buccal/labial, lingual, mesial and distal ones. Visual macroscopic examination is taken as the most suitable method for recording dental caries

The caries that disrupted the enamel or dentin and had a basin-like cavity with smooth walls were counted as caries. Slightly different colourations of the enamel (representing the initial phase of caries) were not taken as a dental caries, unless cavitations or defects were present in the tooth tissues. A dental probe was also used to verify the development of carious lesion in doubtful cases. The analyses were carried out by first author only and the intra-observer Kappa index was calculated as 0.81. The signs and stains of any dental restoration, fillings and tobacco smoking or nut-chewing etc., were also noticed in the studied dental sample to support or negate the geographic affiliations of the remains as habits of smoking and '*gutaka*' chewing are predominately practised even today in the reported region.

The extent and quantification of tooth wear was recorded for each tooth by using a five- scale grading system (0-4) proposed by Brabant index; commonly used to study differences in tooth wear among individuals of different subsistence levels. As dental wear encompasses attrition, erosion and abrasion and the three types of wear cannot be distinguished only attrition types of wear were recorded for present study. Smith's criterion was to categorize mild, moderate and severe wear depending upon the degree of dentine exposure as it is the most frequently recognized standard of recording dental wear. Each tooth was also examined for occurrence and severity of linear hypoplasiac lines on the buccal side of enamel (Schultz 1988). Only moderate and severe types of LEH lesions were taken as better indicators of stress. No attempt was made to correlate LEH with the time of its appearance as it was beyond the scope of this manuscript. The four-grade dental wear scoring scale used by Brabant index is as under (Figure 1):

Level (0): no wear, no loss of surface features
Level (i): wear limited to enamel
Level (ii): presence of dentin clusters
Level (iii): most dentin still covered
Level (iv): involvement of pulpal horns or pulpal exposure

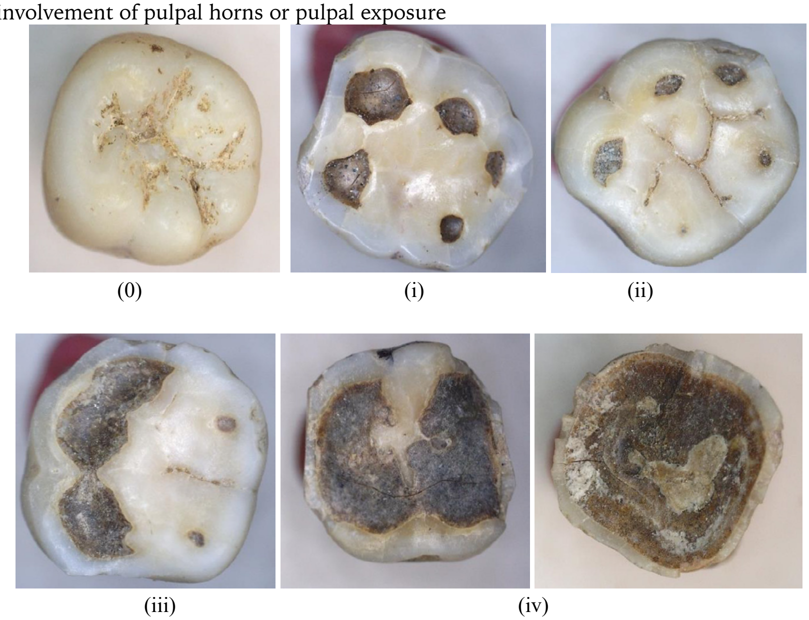

Figure 1. Different levels of dental wear in Ajnala teeth samples as per Brabant index (1966)

Results

A sum total of 4475 mandibular and maxillary teeth of all types have been used for pathological analyses in present study. The anthropological and radiological examinations, contextual items and the preliminary molecular findings supported the written versions that Ajnala skeletal remains belonged to young adult males (Sehrawat et al. 2016, 2017; Bandyopadhyay et al. 2017). The sex of individuals was assessed from overall size and robustness of skulls, femur heads, clavicles, prominent development of occipital protuberance (inion hook), brow ridges and confirmed by mtDNA analyses. The average age of remains was estimated around 30.3 years from PTR ratio and average attrition stage ASA methods. More than 85% teeth (1st and 2nd molars) were put into the age-group of 20-50 years of age when their average attrition values were put in the regression equation models suggested for Indians (Babshet et al 2011). The carious lesions were examined macroscopically in displaced maxillary (N=2146) and mandibular (N=2329) teeth of each type (Table 1).

More maxillary (n=189) teeth were affected with dental caries than the mandibular (n=142) ones, however these differences were not statistically significant. The highest prevalence of caries was observed for the molars followed by premolars; without any significant differences between upper/lower dentition. Anterior teeth (incisors and canines) were com-

Table 1. Frequency distribution of dental pathologies (caries, attrition wear and LEH) in Ajnala teeth samples

Tooth types	N	Carries		Attrition Wear		LEH	
		n	%	n	%	n	%
Maxillary teeth N=2146							
Incisors	589	26	4.4	442	75.0	205	34.8
Canines	374	16	4.3	304	81.3	106	28.3
PM-1	333	23	6.9	309	92.8	51	15.3
PM-2	299	29	9.7	274	91.6	47	15.7
M-1*	185	36	19.5	174	94.1	9	4.9
M-2*	259	44	16.9	241	93.1	16	6.2
M-3*	107	15	14.0	88	82.2	3	2.8
Mandibular teeth N=2329							
Incisors	776	13	1.7	603	77.7	243	31.3
Canines	350	7	2.0	291	83.1	157	44.8
PM-1	293	15	5.1	277	94.5	38	12.9
PM-2	351	26	7.4	314	89.5	63	17.9
M-1*	194	31	15.9	186	95.9	5	2.6
M-2*	226	34	15.0	216	95.6	7	3.1
M-3*	139	16	11.5	117	84.2	1	0.7

* Remaining molars have been processed for mtDNA and stable isotope analyses
PM-1: First Premolar; PM-2: Second Premolar; M-1: First Molar; M-2: Second Molar; M-3: Third Molar

paratively least affected than the posterior teeth (premolars and molars), and such differences in caries prevalence were highly significant in teeth of both upper (Chi-square=9.487, $p<0.001$) and lower (Chi-square=7.186, $p<0.001$) jaws. Within the upper and lower teeth individually, statistically significant differences were observed between anterior and posterior dentition; with Chi-square value 8.423 ($p<0.01$) and 5.916 ($p<0.01$), respectively. The upper incisors and canines were comparatively more affected than their lower counterparts, though differences were statistically insignificant. The overall percentage of caries in present study sample has been found as 9.61 %; with 10.82% maxillary and 8.39% mandibular teeth being affected with this dental defect (without any statistically significant difference). More than 16.8% upper and 14.2% lower molars were carious in nature; first and third molars being the most and least affected teeth, respectively in both upper and lower dentition. The upper premolars were more carious (8.3%) than their lower counterparts (6.3%). Thus, lower anterior teeth were the least affected and upper 1st molars were the most carious teeth in the present study sample.

Table 2 shows the frequency of location and penetration surface of caries in maxillary and mandibular teeth separately.

An analysis of caries location indicated that occlusal surface was the most frequently affected surface of the teeth (upper as well as lower). The cervical and mesial levels of mandibular teeth were comparatively more affected than their

Table 2. Location of caries on different tooth surfaces

Location of Caries	Affected teeth surface		Penetration surface	Affected teeth	
	n	%		n	%
Maxillary teeth N=189					
Occlusal	53	28.0	Enamel	136	71.0
Approximal	43	22.7			
Cervical	34	17.9			
Mesial	20	10.6	Dentin	43	22.7
Distal	22	11.6			
Buccal/labial	7	3.7			
Lingual	8	4.2	Pulp	10	5.3
Gross	2	1.1			
Mandibular teeth N=142					
Occlusal	42	29.6	Enamel	97	68.3
Approximal	30	21.1			
Cervical	39	27.5			
Mesial	16	11.3	Dentin	29	20.4
Distal	8	5.6			
Buccal/labial	4	2.8			
Lingual	2	1.4	Pulp	16	11.3
Gross	1	0.7			

maxillary counterparts whereas interproximal and distal sides of upper teeth were highly carious than their lower counterparts. The lower buccal and lingual sides were least affected than the corresponding surfaces of upper teeth. About 1% teeth (upper as well as lower) were grossly damaged to the extent that localisation of caries couldn't be established whether the lesion was initiated in the crown or root. However, no significance differences were noticed in the localization of caries between maxillary and mandibular teeth. Majority of dental caries were restricted either to enamel or cementum (71.9% and 68.3% lower), followed by dentin in both upper as well as lower dentition. However, 20.4% caries in lower and 5.3% caries in upper teeth were severe enough to expose the pulp chamber of the teeth. The occlusal surface caries were more common than the caries on other tooth surfaces like modern day populations.

All tooth types in both upper and lower arcade had some sort of attrition wear on their occlusal, crown or root surfaces. It can be observed that mandibular teeth had more wear attritions than the maxillary ones; molars and premolars being the most affected teeth than the incisors or canines in both jaw teeth. Amongst the molars, the degree of wear decreased from M1 to M3. Differences in attrition wear were found highly significant between maxillary and mandibular anterior teeth (Chi-square 11.477; $p<0.001$), though such differences were not significant in posterior teeth. Within upper jaw and lower jaw, differences between anterior and posterior dentition were found statistically significant (Chi-square:5.335; $p<0.05$) and highly significant (Chi-square:40.911; $p<0.001$), respectively. Majority of root surface wear were post-dislocation damages. The extent of occlusal dental wear was calculated according to Brabant index, indicated that maximum quantity of wear were limited to enamel and only a negligible number of teeth had wear exposing pulpal chamber in both upper and lower dentition. Non-cariogenic attrition wear on anterior dentition indicated use of non-dietary use of teeth as manipulative tools.

The frequency distribution of enamel hypoplasia has been shown in Table 2. It can be concluded from the table that LEH was more frequently distributed in the lower canines (44.9%) and upper incisors (34.8%) than their corresponding counterparts, followed by lower 2nd premolar and the upper premolars. Statistically significant differences were found in LEH prevalence between anterior and posterior dentition of both upper (Chi-square: 5.9338; $p<0.01$) and lower (Chi-square: 31.0786; $p<0.01$) dentition. Anterior teeth had significant differences between incidence of LEH in upper and lower teeth (Chi-Square= 11.5228; $p<0.05$). In total, 15.82% (15.43% maxillary and 16.21 % mandibular) teeth exhibited the signs of LEH and lower teeth had statistically higher prevalence of LEH defects than their upper counterparts (Chi-Square= 5.195; $p<0.05$). The overall percentage of LEH in the studied teeth has been found as 15.82%; with 15.43% maxillary and 16.21% mandibular teeth being affected with this dental defect, however no statistical differences were observed. As majority of teeth had mild type of LEH markers, no attempt was made to distinguish different manifestations of this defect.

Discussion

The pre-existing structures like abandoned wells, waterways, sewage systems, potholes, caves, pits, natural ravines, roadside trenches, etc., have remained the preferred sites for clandestine disposal of human cadavers throughout human history. Mankind has witnessed several disease epidemics, natural calamities, wars, genocidal conflicts, terrorist massacres, dictatorial atrocities etc., resulting into uncountable number of unknown human cadavers. Post-conflict recovery of human remains from abandoned wells has been reported from a number of countries like Spain, Guatemala, Croatia, Kosovo and Iraq however, no such recovery has been reported from India till-date. This paper highlights the dental health status of mid-19th century skeletal remains excavated in early 2014 from an abandoned well situated underneath a religious structure at Ajnala, india (Ajmal et al. 2001). All the orthodontic features like crown morphology, occlusal wear patterns, restorations, metallic crowns, fillings and any evidence of tobacco smoking or nut chewing etc., were carefully examined in all the teeth. The sound anatomy of teeth reflected that the victims had sound state of dental health; though negligible number of teeth had antemortem stains, post-mortem discolorations and taphonomic damages.

The unscientific excavation of the site resulted into heaps of badly damaged and commingled human remains. In addition to some intact skulls, jaw fragments and displaced teeth, some infra-cranial elements like hand and foot bones, clavicles, vertebrae, fragments of long bones, EAM portions of temporal skull, cranial fragments etc., were also retrieved from the Ajnala skeletal assemblage. Recovery of these skeletal elements signifies that they resisted all sorts of bioarchaeological degradations and taphonomic destructions. More than 6400 loose teeth were screened off from the well sediments by the author who was asked to take over the custody of the remains and the site late 2015 (after complete excavation by amateur archaeologists).Teeth are the hardest and well-preserved structures of human body, commonly found well protected under almost all traumatic or taphonomic conditions like incinerations, submersions/immersions, decomposition or putrefaction, mutilation, post-mortem proteolysis, etc (Fiorenza, 2015). In present case also, teeth have been found well preserved compared to other skeletal elements of 282 individuals reported in the written records. Human teeth have been frequently used in palaeoanthropological research work for assessment of the biological conditions and ecological interactions of past populations like evaluation of socioeconomic status, cultural and demographic aspects of health and disease status of past populations. Dental pathologies have been extensively studied in diverse population groups to investigate their prevalence and association with different subsistence levels and it has been found that frequency of dental pathologies (specifically caries) increased with inclusion of modern cariogenic food items in modern populations (Muller, Husseina 2017). Lifestyle, dietary habits and hygienic practices of an individual or a population greatly influence the dental health status than their socio-economic conditions (Stranska et al. 2015)

The dental health of Ajnala sample is compatible with the inferred military affiliations of the victims. Low degrees of dental caries in Ajnala sample further implied that the individuals were young and had good dental health at the time of their death. The anterior teeth were more expectedly used for the purposes like holding nails or pins, tearing or opening objects, breaking pork- or beef-greased cartridges by the victims during military operations as per the order by colonial rulers at that time (David 2003).

The blackish-brown or reddish-black stains on extraneous surface of a few teeth and darkly stained tarter rims on teeth of very few individuals could indicate that the victims had a habit of betel-nut/'*pan masala*' or tobacco chewing during their lifetime. Betel nut chewing leaves extrinsic reddish brown stains on the tooth crown whereas post-mortem stains are intrinsic in nature which may be pinkish (asphyxiation), grey, yellow or blue (tetracycline use), green (bacterial infection) and of many other colours. Betel nut chewing was commonly practised in South Asia and Oceania for several thousand years (Oxenham et al. 2002; Schuurs 2013). This habit of chewing 'gutaka' and other tobacco products is common among the people of reported Indian states even today. Unbalanced diet, poor sanitation conditions in the cantonment camps, excessive physical or dietary stress, inherent risks of injury or death in the battlefield etc., might have inflicted disease susceptibility or deleterious effect on health status of the recruits and their decreased resistance to dental defects like attrition wear in mid-19th century Ajnala skeletal remains (Signoli et al. 2004; Caglar et al. 2007). In those days, people are expected not to be as wary about their dental health as on today. Broadbent (2016) found that dental health was significantly poor in soldiers enlisted during 1917-18 than that of 1914-15 periods. The recruits of low socioeconomic status, lower ranks and those belonging to urban areas had comparatively poorer dental health; though the differences were statistically insignificant. Most of Ajnala individuals supposedly belonged to rural areas dependent upon staple foods like cereals or vegetables as reflected by the low frequency of dental pathologies. Higher rates of dental pathologies may reflect increased use of dietary carbohydrates or fibrous foods, low socio-economic status or non-dietary uses of the dentition (Sheiham 1984). The absence of any dental treatments like restorations, fillings or oral surgical implants (if any) in past dental remains may further help in understanding paleohealth status of individuals (Watt et al. 1997)

The scientific documentation of the proof of any torture or trauma was analysed from anthropological examinations of all the available human remains and contextual evidences. The overlapping, disorganized and diverse positioning of individual skeletons and their stratigraphic patterning in the well sediments (as narrated by the excavators and revealed by photographs provided by them) theorized that corpses were thrown into the well from its top at one time. The peri-mortem or post-mortem nature of trauma was assessed from the coloration pattern and radiating patterns of the fractures and impact patterns of injury. Majority of the skulls had the some kind of trauma and it was observed that blunt-force traumatic lesions (as probable cause of medicolegal death) were present on the frontal and temporal portion of few skulls as potential indicators of violent homicide. The skeletal evidences of trauma supported the inferences that this is a military sample of massacred soldiers. The items of personal identity like coins and medals (having indented with Queen Victoria's photograph and year of their make) further showed that the remains were thrown into the well around the reported year (i.e., 1857) as none of them have inscriptions after 1856.

Dental caries may be due to certain environmental (trace elements in food and water), pathogenic (bacterial decomposition), endogenous (shape and structure of tooth) or exogenous factors like diet and oral hygiene of a person. Caries is characterized by demineralization of dental tissues by fermentation products of carbohydrates done by oral bacteria. Analysis of carious lesions is considered crucial for bio-archaeological interpretations as they are one of the most common pathological signatures detected in archaeological human remains (Lanfranco, Eggers 2010). The visual method of caries identification has previously been shown to be reliable when compared to both radiographic and histological studies and serves to minimize inter-observer error. Also the dry surfaces, bright lighting and use of a microscope greatly improve the visibility of lesions. Various paleodontological studies have been conducted to investigate the patterns of dental caries and have found an increase in rates of dental caries through time and a shift in location of carious lesions has been reported from the cemento-enamel junction towards the biting surfaces of the teeth (occlusal fissures) and at inter-proximal contact areas of adjoining teeth (Brothwell 1985).

The low percentages of dental caries in present study teeth show that the victims consumed less sugary diets and had fairly good dental hygienic conditions. Most studies have found molars to be the most commonly affected tooth group, while canines and incisors are the least affected. It may be due to the fact that molars have large coronal surface area, deep occlusal fissures, and are posterior located in the jaw to receive less oral hygiene. More maxillary molars were affected than the mandibular ones. Saunders et al. (1997) didn't find any sexual differences in prevalence of dental caries and, both sexes tend to have similar rates of caries. The sex of present study teeth was not confirmed at the time of their paleopathological analysis, however, contextual and textual evidences supported that the victims were young adult male recruits at the time of their death. The low frequencies of dental caries in the studied sample may further signify their maleness, though dental caries are not a sufficiently sensitive indicator of social class.

No Indian study was available in the literature to compare the carious status of Ajnala dental remains. Present study observations were compared with findings of other authors who investigated the frequency and distribution of caries in Indian populations. The results of present study are comparable with military samples studied by Palubeckaite-Miliauskiene et al (2006) who reported that slain soldiers of Napolean's Great Army and German soldiers had around 11% dental caries at the time of their death (Table 3). However, present study teeth had lower dental caries than the contemporary medieval Londoners or Coimbra skeletal remains (Wasterlain et al. 2009; Mant, Roberts 2015). It may be due to the fact that European people might have been using more carbohydrate-rich diets than the Indian people at that time. The prevalence and severity of dental caries tends to be higher in industrialized nations or affluent urban areas than their counterparts as the developed and urban communities are habitual to more sugary foods (Touger-Decker et al. 2003).

Table 3. Frequencies of dental caries in contemporary skeletal samples

Skeletal sample and period	Number of teeth studied	% of dental caries	Reference/citation
Ajnala skeletal remains (1857 ???)	4475	9.6% (10.8 % Upper and 8.4% Lower)	(Present study)
Napolean's Great Army soldiers (1812)	6528	11% (13.3 Upper; 10.1% Lower)	Palubeckaite-Miliauskiene et al. (2006)
Napolean's Lithuanian 14(1812) and German Soldiers (1915-1917)	8258 1730- Germans; 6528 Napoleon's Army	11.5%	Miliauskienė and Jankauskas (2009)
St. Thomas' Anglican Church in Belleville, Ontario (1821-1874)	4605	31.1% (37.8% Upper and 25.7 % Lower)	Saunders et al. (1997)
St. Bride's sample, post--medivial Londoners	2466	26.5%	Mant and Roberts (2015)
Coimbra skeletal collection (19^{th}-20^{th} century)	9562	27.9%	Wasterlain et al. (2009)

The heavy reliance on bread, in addition to the use of corn, cooked, sweetened flour mixtures and sweetened fruits probably contributed to the carcinogenicity of the diet in 19th century European soldiers (Sauders et al., 1997). The advent of modern diets and incorporation of cariogenic food like carbohydrates could be the underlying factors that led to minor to moderate shift in prevalence of dental caries in mid-century Ajnala samples. Corbett and Moore (1976) reported that increase in consumption of sugar and other refined carbohydrates occurred in late 19th century, leading to secular changes in prevalence and distribution of caries only after that. So, the diet of Ajnala recruits consisted of items of low carcinogenicity. The dental caries and consumption of carbohydrates (sugars and starch) are directly associated with each other so caries can reflect differences in socio-economic conditions and environmental interactions in archaeological populations (Burt, Ismail 1986; Lingstrom et al. 2000).

The occlusal and interproximal surfaces were most affected with caries in present study sample and the enamel was the involved dental tissue in 70% cases. Mesial and distal surfaces were found equally affected. The localisation of carious teeth and the number of carious tooth surfaces did not change significantly over time as biting and contact surfaces have remained main areas of dental caries. Together with the introduction of refined sugars into the diets of the19th and 20th century, the caries shifted from preferentially cervical to occlusal locations. But no such findings were observed for Ajnala dental remains as these remains were comparatively modern in nature belonging to young adult army recruits who died around mid-19th century. The sound dental health of Ajnala skeletal remains may be explained as a consequence of simple subsistence and dietary patterns without consumption of any complex carbohydrates. Extrinsic stains present on some tooth surface were mostly non-metallic in nature and they are commonly found in people addicted to certain beverages, smoking or betel nut chewing (Watts, Addy 2001)

Age dependent variations in the prevalence of dental caries have been widely reported in the literature, though no significant differences have been reported in their prevalence rates between two sexes (Fujita et al. 2011)

The attrition wear analysis in present study sample shows that the anterior teeth (incisors and canines) were heavily worn than the posterior teeth (molar and premolars). Heavy tooth wear with pronounced attrition of anterior teeth indicates a consumption of rough, fibrous, hard-textured food products requiring heavy mastication and intensive use of teeth for non-masticatory purposes like use of pork- or beef- greased cartridges by Ajnala victims during military operations (Miliauskiene, Jankauskas 2009).

Dental wear patterns can distinguish between the hard fibrous diet typical of a hunter-gatherer, and a diet primarily consisting of softer plant foods consumed by an agriculturist. Most of the recruits in army battalions happen to come mostly from rural areas (even today) that are generally dependent upon more fibrous foods or home-made rough preparations having more grits in their food items than in urban areas. Attrition, abrasion and erosion are the major manifestations of dental wears (Hunter 2009).

Dental wear is a multifactorial phenomenon caused by various mechanical, chemical and biological factors which occur at a specific linear rate throughout adult life of an individual. Advancing age, hard diet or chronic occlusal overloads are other crucial contributing factors for the progression of occlusal wear facets (Grippo et al. 2004).

Dental wear is a common finding in pre-18th century cohorts but appears to be less frequent in people since the 18th century. Present study teeth have comparatively higher rates of attrition wear at the cost of dental caries and it seems to be an advantageous mechanism. Caries-attrition wear competition hypothesis states that increase in tooth wear is to avoid the development of caries wherein potentially carious surfaces are removed from teeth by an act of smoothing the cusps and fissures of teeth (Maat and derVelde 1982). It is a general trend that caries increased and wear decreased with introduction of softer and carbohydrate-rich food items in modern times and present study observations corroborated this generalization. Dental wear rates are highly influenced by the consistency and texture of food and by the manner of its preparation. A marked reduction in the coarseness of foods might have resulted in decrease in mastication load and hence dental wear during 19th century. However, extensive use of grinding stones for flour preparation might have added sand particles as abrasives in the consumable foods during 18th-19th century. Non-cariogenic wears of anterior dentition (incisor and canine) reflected the use of some fibrous foods by the victims in the dietary intakes. Posterior dentition (molar and premolar) crowns were found comparatively intact, though a few of them had occlusal attritions and serious wear facets. No tooth showed any sign of dental treatment work (like fillings or restorations). The agricultural practices were predominately carried out by Indian people during mid-nineteenth century, so a decline in tooth wear frequencies and wear patterns compared to ancient populations may be due to the fact that people starts consumption of softer food sources, so they had fewer but angled attrition wear (Walker, Hewlitt 1990; Eshed et al. 2006).

Enamel Hypoplasia (LEH) comprises of formation of furrows or incremental microstructures around the crown of teeth due to systemic stress during childhood. The anterior teeth, particularly maxillary incisors and mandibular canines, are more susceptible to hypoplastic defects than other teeth (Goodman, Rose 1990; Gonzalez-Garcin et al. 2012). Canines, particularly lower ones, tend to have higher frequency of LEH compared with incisors (Oyamada et al. 2012; Nakayama 2016) and this fact was found true for present study incisors also. In present study, lower canines and upper incisors were most affected than molars or premolars of lower or upper dentition. In non-industrialized nations, it may be correlated as a stress marker due to increased population density or social complexity (Keita et al. 2001). The family size in 1857 or before was quite larger compared to present day Indian facilities which might have caused restricted availability of sufficient diet to each and every member of a larger family. Some bioarchaeologists consider growth of LEH furrows or lines on anterior tooth surface as a ‘catch-up growth,’ rather than indicator of any stressful event while evaluating the paleohealth status of past individuals. Anterior dentition hypoplasias generally reflect the incidence and distribution of stress episodes whereas in posterior teeth, LEH may provide information about variations in timings and magnitude of stress during childhood. Individuals belonging to lower socio-economic status have less favourable life conditions and more stressful childhood, so are expected to have more enamel hypoplastic lesions compared to well-off children. Present study incidence rate of LEH is comparatively lower than the studies by Tomczyk et al (2012) and Nakayama (2016), but higher than some studies conducted on modern teeth samples.

Dental hypoplasias and socioeconomic status have consistent associations; the low socioeconomic group individuals having higher levels of childhood stress and hence hypoplasias and *vice-versa* (Cucina and Iscan, 2002). LEH in human skeletal remains do not persist for longer and the high frequencies of LEH markers do not always indicate unhealthiness. Increased prevalence rates of LEH may also reflect increased dependence upon agriculture (Wood, 1996) and is a fact that even today more than 80% Indian population is dependent upon agriculture and allied professions, so dietary habits, sedentism and population density might had enhanced stress levels among the victims during their childhood. The low prevalence and severity of LEH indicators among present study teeth signified that majority of victims might had congenial environmental conditions and had better socioeconomic status during their childhood. Though the teeth of present study are reported to be of male recruits, no sexual differences have been reported in severity and frequency of LEH (Sledzik and Sandberg 2002). The relative homogeneity of army soldiers (mostly males at that time) is usually restricted to healthiest or above-average healthy young male individuals without any bodily deformities (Palubeckaite-Miliauskiene 2006, 2007, Goodman and Armelagos 1985) and it is corroborated by relatively low percentage of dental pathologies in Ajnala skeletal remains. Though clinical and archaeological examinations of dental pathologies are fundamentally different, the results of present study might have some possible applications from public health and welfare administration viewpoint in terms of the dental health and nutritional status of contemporary populations.

Conclusions

Among all the human remains, teeth were found in a fairly good condition to be used for paleopathological dental health status of the individuals. Dental pathological analysis has proved useful to give a glimpse of living conditions and health status of past people. Dental caries, attrition wear and enamel hypoplasia were evaluated to opine oral hygiene status and possible dietary patterns of individuals reportedly representing Indian-origin army recruits during 1857 British rule in India. The general dental status was characteristic of young individuals with fewer dental caries and enamel hypoplasiac lesions. Very few teeth have seriously exposed dentine and pulp cavity, indicating consumption of cariogenic food items. Absence of severe LEH signs reflected that individuals were most fitted to have military affiliations. Low prevalence of LEH showed that the victims' had better living conditions during their childhood. Though clinical examinations of living people and archaeological examinations of skeletal remains are fundamentally different, the results of present study may have possible application to public health and welfare administration today in terms of the dental health and nutritional status in contemporary populations.

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Authors' contributions

JSS conceptualized and designed the outline (objectives, materials and methods) of present research article, analyzed and presented different types of dental pathologies in textual, tabular and diagrammatic forms and compared/ discussed the results with other similar studies in relation to aims and objectives of present research article; MS contributed valuable inputs to the conceptualization and designing of the article by searching and reading relevant research articles, preparing tables and taking photographs of teeth samples and providing her scientific inputs in final edited draft of this paper.

Conflict of interests

There are no conflicts of interest of any kind in this research work

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