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A systematic review and meta-analysis of the association between poor oral health and substance abuse

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ABSTRACT

Background and aims Substance use disorders are associated commonly with comorbid physical illness. There are fewer data on dental disease in these conditions, in spite of high rates of dry mouth (xerostomia), as well as the associated indirect or life-style effects such as poverty and lack of access to care. We compared the oral health of people with substance use disorders (SUDs) with non-using controls. **Method** This was a systematic search for studies from the last 35 years of the oral health of people reporting SUDs. We used MEDLINE, PsycInfo, OVID, Google Scholar, EMBASE and article bibliographies. Results were compared with the general population. Oral health was assessed in terms of dental caries and periodontal disease using the following standardized measures: the mean number of decayed, missing and filled teeth (DMFT) or surfaces (DMFS) and probing pocket depth. Non-carious tooth loss was assessed clinically. **Results** We identified 28 studies that had sufficient data for a meta-analysis, comprising 4086 SU patients and 28 031 controls. People with SUD had significantly higher mean scores for DMFT [mean difference = 5.15, 95% confidence interval (CI) = 2.61–7.69 and DMFS (mean difference = 17.83, 95% CI = 6.85–28.8]. They had more decayed teeth but fewer restorations, indicating reduced access to dental care. Patients with SUD also exhibited greater tooth loss, non-carious tooth loss and destructive periodontal disease compared to controls. **Conclusion** Patients with substance use disorders have greater and more severe dental caries and periodontal disease than the general population, but are less likely to have received dental care.

Keywords Addiction, caries, dental decay, dental wear, edentulism, oral health, periodontitis, substance use.

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INTRODUCTION

Globally, it is estimated that 246 million, or one in 20 people between the ages of 15 and 64 years, used substances in 2013 alone [1]. Approximately 10% have drug dependence or substance use disorders (SUDs) [1]. While the more serious side effects of drug-use, such as HIV/AIDs, hepatitis C and overdose, have received some exposure in the literature, oral diseases are identified less commonly as consequences of SUDs. These include dental decay, periodontal disease, dental wear and oral cancers. The precise dental consequences vary by substance and route of administration. For instance, cannabis use is associated with significant xerostomia [2,3], increased caries [4], and possibly increased oral cancers [5]. People who use amphetamines present with accelerated tooth wear as a result of associated bruxism, in addition to advanced caries, severe xerostomia and an overall dental status that is significantly poor for their age [6,7]. Opioid users tend to present with the consequences of personal neglect and environmental risk factors such as poverty and increased consumption of sweetened foods. These include dental decay, increased periodontal disease and poor oral hygiene and care [8]. The preference for sweet foods in people who use opiates is thought to be due to activation of the mu-opiate receptor leading to changes in glucose intake and glycaemic control. Importantly, this also applies to people on methadone maintenance, and this may be aggravated by the use of methadone preparations that have a high sugar content [9]. Cocaine can be applied to the gums, snorted, smoked or injected intravenously. From a dental perspective, patients using cocaine may present with oronasal defects, periodontal disease and increased dental attrition from bruxism [10,11].

The reality is that these substances are rarely used alone [3]. A large majority of patients report using two or more of illicit substances [12–18]. Similarly, substance use is combined routinely with smoking and alcohol consumption, both of which have negative effects on the oral cavity [19].

The impact of SUD on oral health can be attributed to direct physiological effects such as xerostomia, an increased urge for snacking, sympathetic activation and the associated dental clenching or grinding, as well as chemical dental erosion from applying cocaine to teeth. The indirect effects and life-styles associated with SU include a lack of priority of oral health and poor oral hygiene. Furthermore, issues regarding to the access of dental care can also contribute to oral diseases [3,17]. This is compounded by neglected oral hygiene, malnutrition, high sugar diets and sporadic dental appointment patterns. Dental care is compromised further by these patients' tolerance to analgesics.

We conducted a systematic review and meta-analysis on the prevalence and extent of dental decay and periodontal disease among substance users in comparison to controls without substance use disorders.

METHOD

The review was registered with the International Prospective Register of Systematic Reviews (PROSPERO), an international database of prospectively registered systematic reviews in health and social care based in the United Kingdom (CRD42015029874). We followed recommendations for the reporting of Meta-Analyses of Observational Studies in Epidemiology (MOOSE), including background, search strategy, methods, results, discussion and conclusions, as well as the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA).

Oral health outcomes

The two main outcomes of the present study were tooth decay and periodontal disease. We also assessed clinically for the presence of dental wear. Tooth decay is the result of demineralization and cavitation of teeth via acids produced by fermentation of sugars by bacteria [20]. It is assessed by two indexes used frequently in epidemiological studies: the number of decayed, missing and filled teeth (DMFT) and/or the number of decayed, missing and filled surfaces (DMFS). The unit of measurement in the DMFT score is each tooth, while that of the DMFS is the dental surface. Anterior teeth have four surfaces, while posterior teeth have five. The maximum possible DMFT is therefore 32 (although wisdom teeth are often excluded, making the maximum 28), while the maximum DMFS is 148 (or 128 if wisdom teeth are excluded) [20]. By contrast, non-carious tooth loss (NCTL) is not associated with bacteria. This term combines dental attrition (tooth wear from tooth on tooth contact, e.g. grinding), abrasion (tooth wear from non-tooth on tooth contact, e.g. toothbrush or hair pins) and erosion (tooth wear from non-bacterial acids, e.g. acidic foods and carbonated drinks). Non-carious tooth loss is measured by the Smith & Knight Tooth Wear Index (TWI Index), whereby a value between 0 and 5 is assigned based on progressive extent of loss of tooth structure [21]. Periodontal disease is a chronic inflammatory disease of the supporting structures of the teeth. It starts as gingivitis (reversible destruction limited to the gingiva), and leads to the periodontitis (irreversible destruction of the gingiva, bone and periodontal ligaments that that hold teeth in place). Severity is measured commonly with a manual probe to assess pocket probing depth (PPD) or clinical attachment level (CAL) [22]. In general, a PPD of more than 3 mm or CAL of more than 2 mm is the threshold for periodontitis [23], although other authors suggest that the PPD threshold should be 4 mm [24]. A PPD of 7 mm, for instance, indicates that the tooth has lost 4 mm of bone in that region. In general, once more than 4–5 mm of bone around a tooth is lost, the tooth becomes progressively mobile until it falls out. During assessment, a PPD of 4–5 mm is assigned as a 'shallow' pocket, while 'deep' pockets are 6 mm or greater [25].

Inclusion and exclusion criteria

We included cross-sectional or cohort studies that reported the oral health of patients with substance use disorders. Substances used included amphetamine, cocaine, inhalants, marijuana, opioids, phencyclidine and heroin products. The oral health outcomes were experience of dental caries, NCTL and periodontitis, and we therefore excluded studies of less severe dental outcomes such as poor oral hygiene. We also excluded studies focusing on purely alcohol or tobacco abuse.

Search strategy

We searched Medline, PsycInfo, OVID, Google Scholar and EMBASE from January 1981 until October 2016 using the following text, MeSH or Emtree terms as appropriate: Substance-Related Disorders, Amphetamine-Related Disorders, Cocaine-Related Disorders, Inhalant Abuse, Marijuana Abuse, Opioid-Related Disorders, Phencyclidine Abuse, Psychoses, Substance-Induced, Substance Abuse, Morphine Dependence, Heroin Dependence, Oral Health, Dental Health Survey, Dental Care, Edentulous Mouth, Edentulous Jaw, Dental Caries, Toothloss, Periodontitis, Periodontal Disease, Non-carious

Tooth Loss, Dental Erosion, Dental Wear. Other descriptive words associated with the above MeSH terms were also used as key terms. A sample of search terms are included in the Appendix in the Supporting information. We searched for further publications by scrutinizing the reference lists of initial studies identified and other relevant review papers. Two reviewers (H.B. and M.F.) assessed abstracts independently, and extracted and checked the data for accuracy. E.S. assessed the quality of the included studies and S.K. provided content expertise and acted as supervisor to H.B.

For inclusion in the meta-analysis, studies had to have data on suitable controls, either collected by the study authors themselves (internal controls) or from a survey of a similar community and age group, conducted within 10 years of the index study (external controls). External controls were either identified by the study authors or, where absent, we searched for a survey of the general population that met our inclusion criteria as above. This protocol has been used in a number of similar reviews [26,27]. We included all outcomes for which there were at least two studies for one of the substance use categories.

Study quality

The quality of the studies was assessed using the Newcastle–Ottawa Scale (NOS) [28]. This assesses the quality of non-randomized studies in meta-analyses in three areas: the selection of the study groups; the comparability of the groups; and the ascertainment of outcome.

Statistical analysis

Review Manager version 5.3 was used for the main analysis. We calculated the mean differences for continuous data, as studies used the same scale for each outcome [e.g. DMFT, DMFS, decayed teeth (DT), filled teeth (FT), missing teeth (MT)]. We calculated odds ratios for NCTL and periodontitis (prevalence of periodontitis, prevalence of shallow and deep pockets). Studies that presented only measures of association without raw numbers were included in the meta-analysis using WinPepi version 11.34 [29] or Comprehensive Meta-Analysis (CMA) software [30].

We assessed heterogeneity by using the *I*-squared statistic. A random-effects model was employed due to significant heterogeneity in the majority of our analyses. In addition, where possible, we investigated heterogeneity by performing analyses both with and without outlying studies as part of a sensitivity analysis. Sensitivity analysis was also attempted for studies with internal versus external controls; samples from prison versus the community; route of administration; and duration of substance use. In the case of studies with internal controls, we investigated the effect of restricting analyses to those that assessed for comparability of substance users and controls in terms of socio-demographic differences and the use of tobacco or alcohol.

Where there was a sufficient number of studies ($n > 10$), we tested for publication bias using the both the fail-safe *N* statistic and funnel plot asymmetry. The fail-safe *N* statistic is the number of non-significant studies that would be necessary to reduce the odds ratio or effect size to a negligible value. In tests for a skewed funnel plot, low *P*-values suggest publication bias.

RESULTS

Study inclusion and characteristics

Total of 6101 citations resulted from the electronic search. Of these, 5989 were excluded based on title. The abstracts of the remaining 112 potentially relevant papers were read and a further 52 were excluded, as they had a different primary focus. All remaining studies were obtained and scrutinized. Another six studies were discovered from the bibliographies of the full texts, making a total of 60 full texts. Of those, 32 were excluded for the following reasons: no suitable controls ($n = 10$); insufficient data ($n = 7$); not an outcome of interest ($n = 8$); use of only alcohol and/or tobacco ($n = 6$); or follow-up of an included study ($n = 1$). This left 28 studies that could be included in the meta-analysis (Fig. 1).

Table 1 gives details of these 28 papers. Nine were from Europe and eight from the United States. The remainders were from China ($n = 2$), India ($n = 2$), Australia ($n = 2$), Iran ($n = 1$), Argentina ($n = 1$), Brazil ($n = 1$), New Zealand ($n = 1$) and Saudi Arabia ($n = 1$). The most commonly used substances in these studies were heroin and methamphetamines. Participants' ages ranged from 13 to 79 years.

Study quality was variable. One study [31] did not indicate the substances used by subjects, and a further 15 did not provide details of the duration of use (Table 1). Similarly, the recency of use was not clear in all studies, particularly in the case of incarcerated samples, although one study was restricted to newly arrived prisoners [12]. Another study divided participants in a rehabilitation programme into life-time use and use within 30 days [32]. While most studies used participant questionnaires and interviews to diagnose substance use, six studies [4,15,33–36] failed to outline how they made the diagnosis (Table 1). Similarly, only two studies [37,38] mentioned the use of DSM or ICD diagnostic criteria. Twelve of the studies described their subjects as 'addicts' or 'dependent on substances' [4,13,14,16,32–35,37,39–41]; however, none described the differentiation of dependence from substance use. In terms of group comparability, only

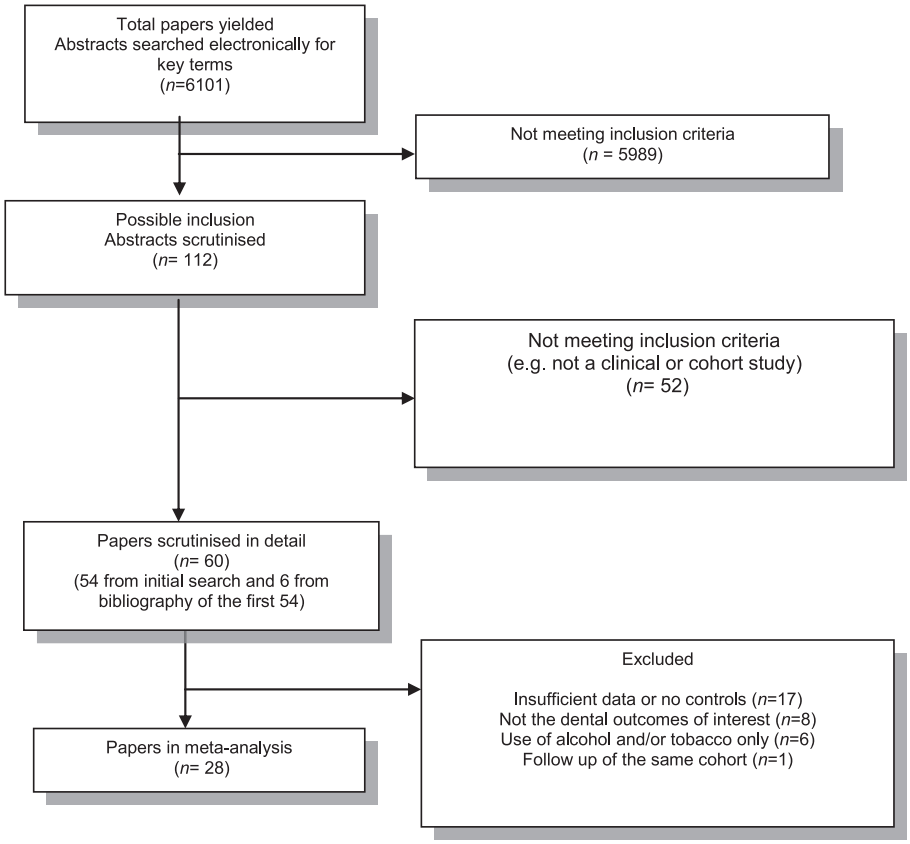

Figure 1 Number of papers yielded by search strategy

19 of the 28 studies had internal controls (Table1), including one study in which the controls were non-users and mild users of cannabis [42]. Of these, three studies considered the impact of alcohol as a potential confounder and found no differences in alcohol use between substance users and non-users [12,19,43]. In terms of tobacco use, one study found no differences in smoking between substance users and non-users [19]. Another two stratified substance users by smoking status [43] or alcohol use [44]. Fifteen studies checked that SUD cases and controls had similar socio-demographic characteristics such as gender, education and socio-economic status and/or used multivariate analyses to adjust for these, as well as tobacco ± alcohol use [4,12,16,19,32,33,36–38,42–47]. Five studies considered differences between cases and controls in brushing, flossing or previous dental care [12,19,37,43,44] and two adjusted for these in multivariate analyses [37,43].

In terms of assessing outcome, ascertainment of dental status in most studies was conducted by trained dental examiners using some, or all, of the decayed, missing and filled classification. Periodontal disease was measured generally by PPD or CAL. However, dental examinations in one study were performed by a general medical practitioner [16] and in another two by senior dental students [40,48]. Two studies used radiographic aids to confirm the results of dental examinations [12,31].

Data for meta-analyses were available for 4086 SUD patients and 28 031 controls. Data on gender were available for 2921 SU cases, 2141 of which (73.2%) were males. Nineteen studies had data on control groups collected by the authors themselves, with similar characteristics to the SUD cases (Table 1). There were 2199 SUD cases and 2964 controls in these studies. Six studies used community surveys of a similar age group and country as external controls (Table 1), two of which used propensity score matching to ensure that SUD cases and controls were as alike as possible in age and gender [32,45] For the remaining three studies, we found comparison dental survey data from the same nation and age group collected within 10 years of the study (Table 2). Data on gender were available for only 13 977 controls but, where available, 66% were male (n = 9289) (Tables 1 and 2). Males predominated in the data derived from both the studies and the community surveys, albeit to differing degrees. Most studies (n = 5) with internal controls had a greater ercentage (15–17 %) of males in their SUD group compared to the control group. The opposite was true for five studies with males making a greater portion of the controls (11–51%). Of the remaining studies that reported

Table 1 details of included studies.

Author	*Year*	*Country*	*Setting*	*n*	*Gender (male)*	*Age, years mean (range)*	*Control*	*Substance used*	*Duration of SU*	*Route of use*	*SU assessment (DSM or ICD)*	*Dental assessment*	*Dental decay*	*Decay score*	*Periodontal status (protocol)*	*Periodontal cut-off*	*% Perio-dontal disease*	*Wear*
Antioniazzi [38]	2016	Brazil	Rehab	SU: 106 control: 106	74.5% (SU) 74.5% (control)	25 (SU) 22.5 (control) (13–46)	Internal	Crack cocaine (100%) Cannabis (79.2%) Cocaine (87.7%) Solvents (34%)	5.0 (mean)	Smoking	S (ICD)	Clinical[h]	–	–	% periodontitis deep pockets (6 site per tooth)	≥ 2 sites with PPD > 3 mm CAL ≥ 6 mm	43.4 64.2	–
Becart [33]	1997	France	Prison	SU: 47 control: 46	66% (SU) 83% (control)	25 (16–35)	Internal	Heroin	4.3 (mean)	–	–	Clinical[h]	DMFT DT FT MT	13 6.8 3.3 2.9	–	–	–	–
Boyer [12]	2015	USA	Prison	SU: 95 control: 79	79% (SU) 94% (control)	30 (17–53)	Internal	Methamphetamine, marijuana cocaine, heroin	–	–	S	Clinical and Radiographic[i]	DT MT	7.8 4.7	–	–	–	–
Brown [44]	2013	USA	Prison	SU: 59 control: 40	80% (SU) 80% (control)	33 (18–63)	Internal	Methamphetamine	–	Oral (78%) IV/IN (22%)	S	Clinical[h]	DMFT DT FT MT	15 8.8 3.4 3.1	–	–	–	–
Di Cugno [4]	1981	Argentina	Rehab	SU: 198 control: 50	100% (SU) 100% (control)	21	Internal	Amphetamine	1+	–	–	Clinical[j]	DMFT DMFT	13.7 15	–	–	–	–
Du [54]	2000	China	Rehab	SU: 123	77% (SU)	(35–44)	External	Heroin, others (2%)	2+ (76%)	Oral/ smoking (72%) IV/IN (28%)	I	Clinical[j]	DMFT DT FT MT	5.4 4.7 0.02 0.6	% participants with shallow pockets Deep pockets (CPITN)	PPD 4–5 mm PPD ≥ 6 mm	45 10	–
Gibson [31]	2003	USA	Veterans in rehab	SU: 339 control: 6259[a]	100% (SU) 100% (control)	44 (24–79)	External	–	–	–	I	Clinical and Radiographic[j]	DMFT DT FT MT % Edentulism	16 3.2 5.1 7.6 7.4%	Mild, moderate, severe periodontitis[b,d]	Subjective[b]	–	–
Gupta [37]	2010	India	Rehab	SU: 126 control: 126	99% (SU) 99% (control)	36 (18–66)	Internal	Opioids, Cannabis,	12 (mean)	–	S (using DSM IV)	Clinical[j]	DMFT DT FT MT	3.5 2.5 0.01 0.98	% participants with shallow pockets Deep pockets (Mod CPI)	PPD 4–5 mm PPD ≥ 6 mm	43 12	–
Jamieson [43]	2009	Australia	Community	SU: 169 control: 256	48% (SU)	18 (16–20)	Internal	Cannabis, petrol sniffing	–	–	S	Clinical[j]	–	–	% Periodontitis (CAL/PPD from MB and B of each tooth)	2× PPD ≥ 5 mm	32	–
Kayal [13]	2014	Saudi Arabia	Rehab	SU: 57	100% (SU)	(20–40 = 74%)	External		5+ (81%)	Oral (67%)	S	Clinical[h]	–	–	% Periodontitis (6 sites per tooth)	[d]	100	–

(*Continues*)

Table 1. (Continued)

Author	Year	Country	Setting	n	Gender (male)	Age, years mean (range)	Control	Substance used	Duration of SU	Route of use	SU assessment (DSM or ICD)	Dental assessment	Dental decay	Decay score	Periodontal status (protocol)	Periodontal cut-off	% Perio-dontal disease	Wear
								Cannabis, amphetamine, heroin, cocaine		IV/IN (39%)								
Ma [34]	2012	China	Rehab	SU: 216	71% (SU)	35 (20–59)	External	Methadone programme	1–32	–	–	Clinical[k]	MT[b]	–	% participants with shallow pockets Deep pockets (CPI)	PPD 4–5 mm PPD ≥ 6 mm	38 4	–
Mateos-Moreno [14]	2013	Spain	Rehab	SU: 64 control: 34	79% (SU) 94% (control)	(30–56)	Internal	Heroin, cocaine methadone benzodiazepine, cannabis	6–30	–	I	Clinical[j]	DMFT DT FT MT DMFS	23 10 0.7 12 91	% Periodontitis [d]	[d]	87	–
Milosewvic [39]	1999	United Kingdom	Community	SU: 30 control: 28	–	–	Internal	Ecstasy, amphetamines, cocaine, ketamine, LSD, magic mushrooms, cannabis	–	–	S	Clinical[j]	–	–	–	–	–	TWI 0.63
Morio [48]	2008	USA	Community	SU: 18 control: 18	76% (overall)	31	Internal	Methamphetamine	–	–	S	Clinical[e,j]	% anterior, premolar and molar teeth with decay	61 61 86	–	–	–	–
Molendijk [15]	1997	Netherlands	Mixed	SU: 121 control: 1532[a]	76% (SU)	30.5 (20–40)	External	Heroin, cocaine	–	–	–	Clinical[j]	DMFS	49	–	–	–	–
Nixon [47]	2002	United Kingdom	Community	SU: 13 control: 13	62% (SU) 62% (control)	20 (18–23)	Internal	Amphetamine, Ecstasy	–	Oral	S	Clinical[j]	–	–	–	–	–	TWI 1.4
Pourhashemi [40]	2015	Iran	Rehab (32%) and community (68%)	SU: 95	0% (SU)	38	External	Opiates, methamphetamine	11.6 (mean)	Smoking (79%) IN (14%) Oral (20%) IV (11%)	I	Clinical[e,j]	DMFT DT FT MT	20 8.2 0.8 11	% participants with s hallow pockets Deep pockets[b] (CPI)	PPD 4–5 mm PPD ≥ 6 mm	48 –	–
Protrka [41]	2013	Croatia	Rehab	SU:100 control: 100	53% (overall)	35.15	Internal	Heroin methadone cannabis hashish	5+	–	S	Clinical[i]	DMFT DT FT MT DMFS	18.78 12.57 4.59 1.6 5.32	–	–	–	–
Ravenel [19]	2012	USA					Internal				S	Clinical[j]	DMFS	29	–	–	–	

(*Continues*)

Table 1. (Continued)

Author	*Year*	*Country*	*Setting*	*n*	*Gender (male)*	*Age, years mean (range)*	*Control*	*Substance used*	*Duration of SU*	*Route of use*	*SU assessment (DSM or ICD)*	*Dental assessment*	*Dental decay*	*Decay score*	*Periodontal status (protocol)*	*Periodontal cut-off*	*% Periodontal disease*	*Wear*
			Rehab and community	SU: 28 control: 16	50% (SU) 39% (control)	30 (19–45)		Methamphetamine, cocaine	7.2 (mean)	Smoking (100%) IN (15%) Oral (8%) IV (13%)								Bruxism 31%
Reece [16]	2007	Australia	Community	SU: 233 control: 47	77% (SU) 59% (control)	31 (19–45)	Internal	Cannabis, heroin, morphine, methadone, amphetamine	7.27 8.97 1.19 1.21 1.89 (mean)	–	S	Clinical[f,j]	MT	4	–	–	–	–
Rommel [49]	2015	Germany	Rehab	SU: 100 control: 100	79% (SU) 94% (control)	–	Internal	Crystal methamphetamine	–	–	I	Clinical[h]	DMFT DT DMFS	12 3.4 33	PSI[c]	PPD > 3.5 mm	2.75	–
Rooban [18]	2008	India	Rehab	SU: 100 control: 100	79% (SU) 94% (control)	33 (18–48)	Internal	Heroin, cocaine, morphine, benzodiazepine, cannabis	8 (mean)		I	Clinical[h]	DMFT	4.8	% Periodontitis [d]	[d]	7%	–
Scheutz [35]	1984	Denmark	Community	SU: 134	66% (SU)	25 (18–37)	External	Opiates	–	IV (100%)	–	Clinical[j]	DMFT	18.3	% Periodontitis (MB of 6 preselected teeth)[b]	Nil: mean attachment loss figures given	Up to 40%	–
Shariff [42]	2016	USA	Community	Total: 1938	50% (combined)	(30–59)	Internal but included both rare and non-users	Cannabis	–	–	S	Clinical[h]	–	–	Mean number sites with PPD ≥ 4 mm, ≥ 6 mm, and ≥ 8 mm (6 sites per tooth)	PPD ≥ 4 mm, ≥ 6 mm, and ≥ 8 mm	29.2 24.8 24.5	–
Shetty [32]	2010	USA	Rehab	SU: 250 control: 7630	38% (SU)	36.5	External	Methamphetamine	–	Smoking (64%) IN (14%) IV (21%)	S, I	Clinical[h]	% Edentulism Missing teeth	13%	–	–	–	–
Shetty [45]	2016	USA	Community	Su: 552 control: 2755	–	44.4	External	Methamphetamine	–	Smoking (64%)	S	Clinical[h]	Mean difference of DMFT	2.04	–	–	–	–
Silvestre [36]	1990	Spain	Prison Addiction Services source of controls unclear	SU: 66 control: 30	98% (SU) 47% (control)	SU: 24.6 control 26.3	Internal	Heroin, cocaine, morphine, benzodiazepine, cannabis, barbiturates hallucingens	–	–	–	Clinical[h]	DMFT	12.3	–	–	–	–

(*Continues*)

Table 1. (Continued)

Author	Year	Country	Setting	n	Gender (male)	Age, years mean (range)	Control	Substance used	Duration of SU	Route of use	SU assessment (DSM or ICD)	Dental assessment	Dental decay	Decay score	Periodontal status (protocol)	Periodontal cut-off	% Perio-dontal disease	Wear
Thomson [46][g]	2008	New Zealand	Community	SU: 182 control: 293	51.1 (SU)	SU: 32 control: 32	Internal	Cannabis	–	–	S	Clinical[h]	–	–	% Participants with shallow pockets Deep pockets (2 quadrants, MB, B and DL measured)	CAL ≥ 3 mm CAL ≥ 5 mm	51% 25%	–

SU = substance User; DMFT/S = decayed, filled and missing teeth/surfaces; DT = decayed teeth; FT = filled teeth; MT = missing teeth; F = female; M= male; S = survey; I = interview; PSI = Periodontal Screening Index. [a]From external control. [b]Data not used due to lack of controls. [c]Data not used as not able to compare with other studies. [d]Undefined. [e]Senior dental students. [f]General medical practitioner. [g]Same cohort was followed-up 6 years layer in Merier [43]. [h]third molars excluded in assesment (i.e. DMFT out of 28 and DMFS out of 128). [i]third molars included in assessment (i.e. DMFT out of 32 and DMFS out of 148). [j]not clear if third molars were included or excluded. [k]if third molars are present, they're included, if missing excluded. TWI: Smith and Knight Tooth Wear Index [54].

gender, all had similar distributions (Table 1). Participants were either from correctional institutions (n = 267), rehabilitation centres (n = 1779), the community (n = 1796) or a combination of these (n = 244) (Table 1).

Substances used

A majority of the papers (n = 18) reported the use of a combination of two or more substances by their participants, with amphetamine-like drugs such as methamphetamine and methylenedioxy-methamphetamine being the most commonly used substances (Table 1). Other substances included heroin, opioids, cannabis, cocaine, benzodiazepines, barbiturates, solvents, petrol and methadone (Table 1). Six studies [4,32,44,45,48,49] reported use of methamphetamine alone, two studies [42,6] reported cannabis use alone, one study [34] looked at heroin users on a methadone programme and another [33] reported the use of heroin alone (Table 1). The heroin users and those on the methadone programme were combined for analysis. While studies of benzodiazepines and methadone were of pharmaceutical products, and those of cannabis, methamphetamine, methylenedioxy-methamphetamine, cocaine and heroin of non-pharmaceutical products, the source of others, such as opioids, was less clear, given that categories were based on self-report. Of the 13 studies that reported on the duration of substance use, the range was between 1 and 32 years (Table 1). In the following paragraphs, we have presented the results of caries and NCTL by type of substance use. In the case of periodontal disease, we combined all the studies as there was less differentiation between SUD types.

Opiate users

Two studies reported on the prevalence of dental caries. Opiate users had greater decay experience when compared to controls in terms of DMFT scores (Fig. 2). They also had a greater mean number of decayed teeth (3.5) and fewer restored teeth (Fig. 2). The latter finding may be indicative of unmet needs. There was one study that reported an increased prevalence of shallow periodontal pockets compared to controls (Fig. 4).

Amphetamine users

Four studies reported on the prevalence of dental caries. In two studies, patients who reported using solely amphetamine-like drugs also demonstrated an increased experience of caries compared to controls in terms of decayed and missing teeth, as well as overall DMFT and DMFS scores (Fig. 2). In one study, they were significantly more likely to have lost all their teeth (edentulism) (Table 1) [32]. There was no difference in the number of filled teeth (Fig. 2). It was possible to combine data

Table 2 Description of control samples derived from community surveys.

Author	*Year*	*Country*	*Study name*	*n*	*Mean age/ range*	*Male (%)*
Hong-Ying	2002	China	The Second National Survey of Oral Health Status in children and adults in China	1420	35–44	–
Hessari	2007	Iran	Oral health among 35–44-year-old Iranians	2786	35–44	0[a]
Hossain	2013	Saudi Arabia	Prevalence of periodontal diseases among patients attending the out-patient department at the College of Dentistry, King Khalid University, Abha, Saudi Arabia	2739	32	86

[a]To reflect the 100 % female sample of substance use study.

from two other studies on the presence of caries as a dichotomous variable [45,48] and, again, amphetamine use was associated with increased decay [odds ratio (OR) = 4.41, 95% confidence interval (CI) = 2.53–7.69; $P < 0.001$].

Three further studies assessed the presence of NCTL as noted on dental examination [19,39,47], When the results were combined, amphetamine users were almost six times as likely to have NCTL (95% CI = 1.68–20.62; $P = 0.006$).

Mixed substance users

Seven studies reported increased DMFT scores compared to controls (Fig. 3). This was illustrated further in their DMFS values (Fig. 3). The SUD group had an average of 3.5 more decayed teeth compared to controls, but in contrast had fewer restorations (Fig. 3), again possibly suggesting a greater level of unmet needs. Lastly, the mixed substance users had approximately 3.5 less teeth compared to their controls (Fig. 3), although they were no more likely to be completely edentulous in the one study where it was reported [31].

Periodontal disease

There were eight studies that reported on one or more aspects of periodontal disease with data that could be incorporated into a meta-analysis. Adjusted results from one further study on marijuana [42] that could not be added to the main meta-analysis were included in subsequent sensitivity analyses using WinPepi software (see below). With the exception of one study that reported on heroin use [34] and one on marijuana users [46], all the others were of mixed substance use. We therefore analysed all the studies together. There were eight studies that reported the presence of overall periodontal disease and another four gave results for deep pockets. In both cases, substance users had higher rates of periodontitis (Fig. 4).

Heterogeneity

Aside from studies of amphetamine use (Fig. 2), all the comparisons showed evidence of heterogeneity (Figs 2 and 3).

Sensitivity analyses

In terms of decay, there were insufficient studies to undertake any further sensitivity analyses for outcomes as measured by DMFS and FT, but it was possible for the DMFT, DT and MT results. Excluding the prison-based studies or only including studies with similar gender ratios did not affect the results. Two studies reported that longer duration of use was associated with poorer oral health [16,44]. Others analysed the effect of age and found that older users with presumably longer histories had absolute worse dental outcomes [15,32,44]. Similarly, including only the results from studies that categorized their subjects as 'addicts' or 'substance dependants' [13,14,16,32–35,37,39,40] increased the overall dental caries experience across all dental measurements. One of these studies also compared oral and non-oral use of methamphetamines after adjusting for duration of use, comorbid substance use and socio-demographic factors. Oral use was associated with significantly greater dental decay [44]. Another found that intravenous use had still worse dental outcomes [32].

There was little difference in the results when we included only studies that reported on internal controls where it was possible to take into account variables such as socio-demographic factors, alcohol/tobacco use, past dental care and access or tooth brushing and flossing. For instance, in the case of mixed substance use, participants who were using had more missing teeth (MD = 3.23, 95% CI = 0.14–6.31, $P = 0.04$) and higher DMFT scores (MD = 5.01, 95% CI = 1.36–8.65, $P = 0.007$). Missing teeth scores were the only measure of dental decay where it was possible to undertake sensitivity analyses of including only results adjusted for socio-

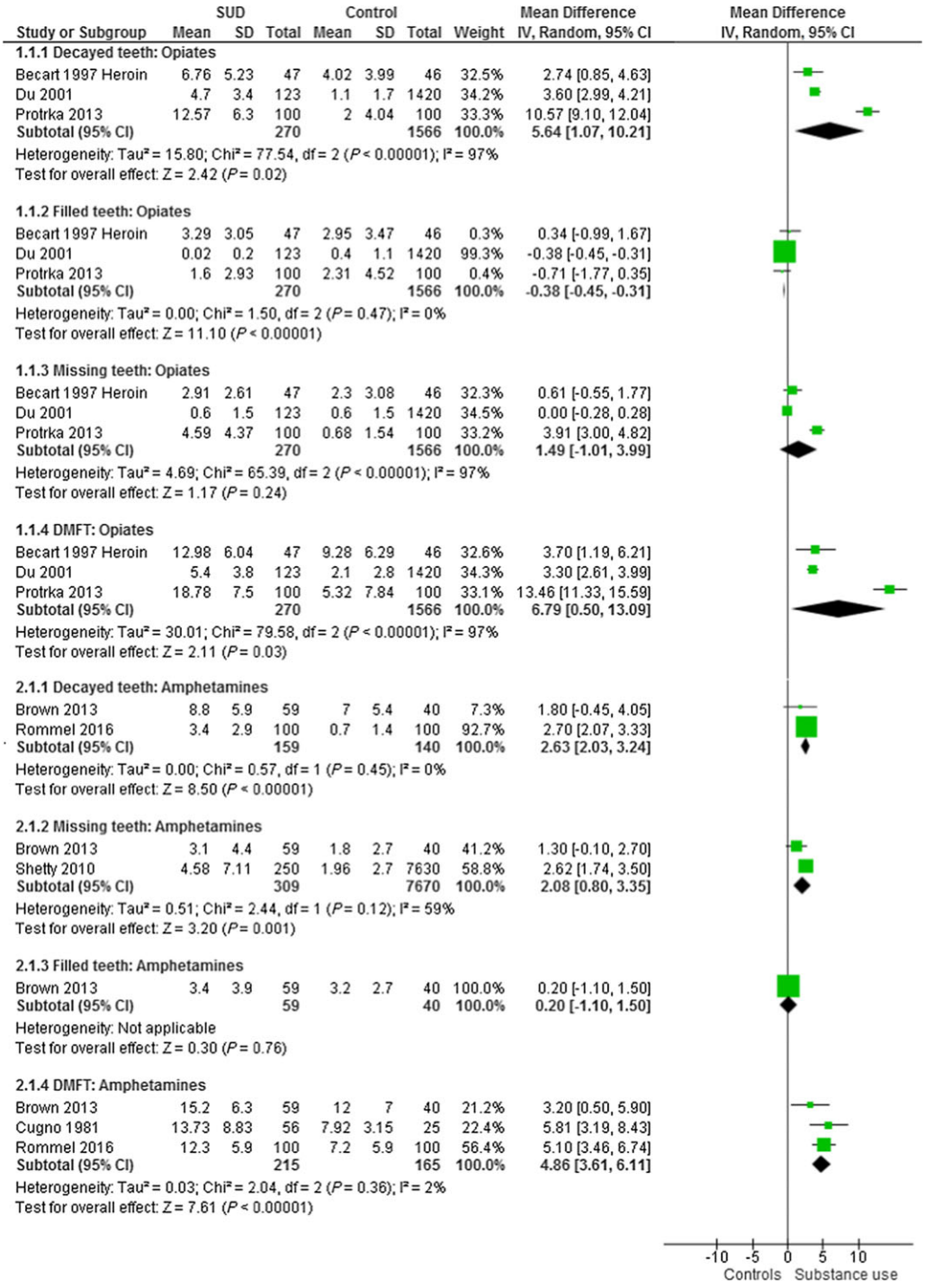

Figure 2 Dental decay in opiate and amphetamine users [Colour figure can be viewed at wileyonlinelibrary.com]

demographic factors and/or alcohol and tobacco use. Two studies of methamphetamine were included [12,32], and users had significantly more missing teeth (OR =2.4; 95% CI = 2.15–2.70; $P < 0.00001$). In terms of other decay experience, oral use of methamphetamine was associated with increased DMFT scores on multivariate analyses in one study [44], while in another use was associated only with increased numbers of decayed teeth in non-Caucasians [12]. In a third study, opiate use was an independent predictor of dental decay [16]. The results of a study of mixed drug users gave more equivocal results (OR = 2.03; 95% CI = 0.98–4.23; $P = 0.056$) [37].

In term of periodontal disease, we were able to combine the results of five studies that adjusted for smoking and/or socio-demographic factors [37,38,42,43,46] (Supporting information, Fig. S1). In this case, substance use remained associated independently with periodontal disease

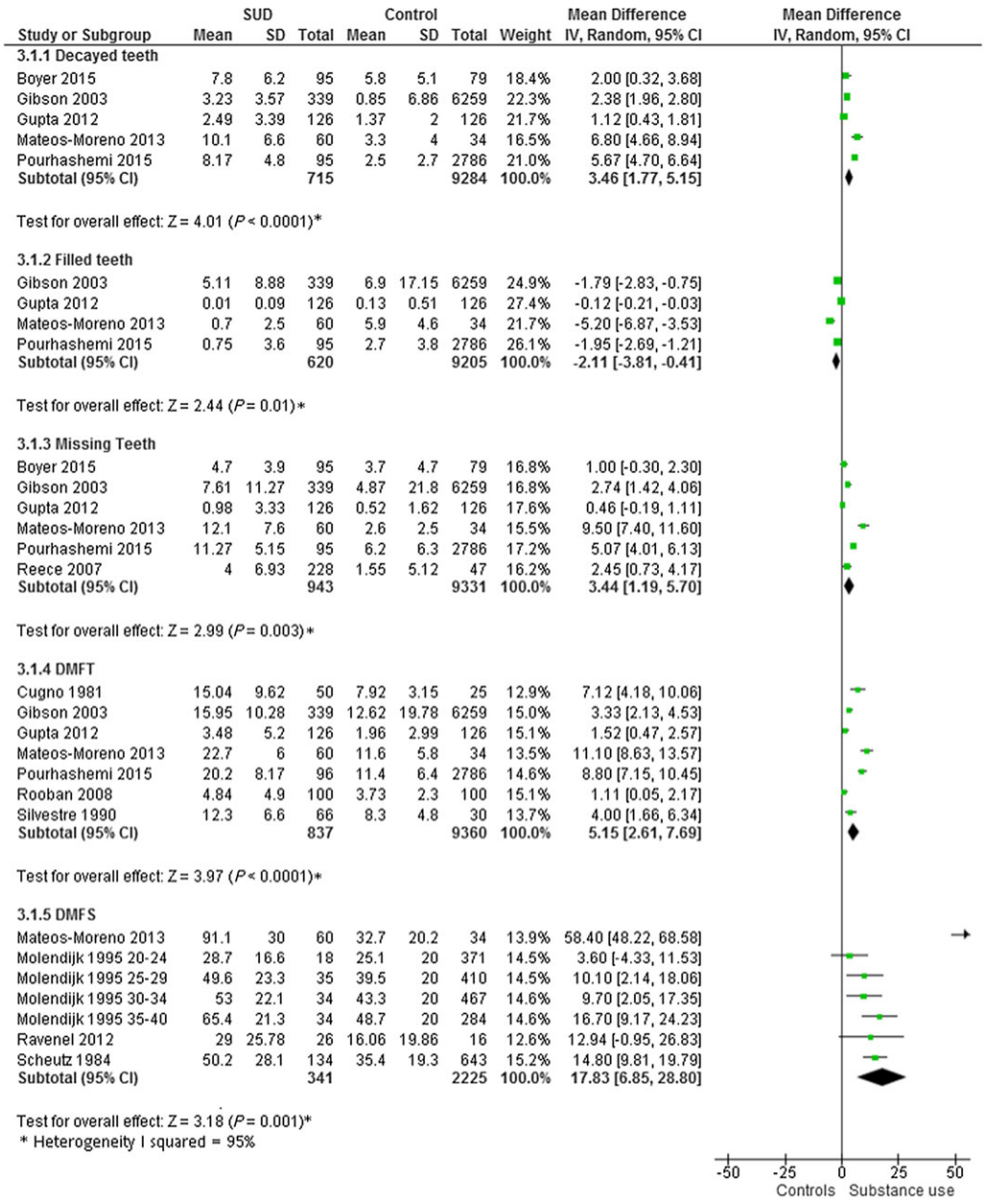

Figure 3 Dental decay in mixed substance users [Colour figure can be viewed at wileyonlinelibrary.com]

(OR = 1.76; 95% CI = 1.47–2.21). In contrast to the main results for periodontal disease, there was no evidence of heterogeneity (*I*-square = 9%) (Supporting information, Fig. S1).

Finally, sensitivity analyses of the effect of omitting each study in turn made little difference to the results, except for two studies. Omission of an outlier study [41] in the comparison of all measures of decay in opiate use reduced the *I*-square value to 0% without changing the effect associated with opiates (e.g. the result for DMFT was MD = 3.33, 95% CI = 2.67–3.99, $P < 0.001$). Similarly, in the case of DMFS scores in mixed substance users (Fig. 2), the omission of another outlier study [14] reduced the *I*-square value to a non-significant value of 30% without effecting the outcome (MD = 11.59, 95% CI = 7.74–15.45, $P < 0.001$).

Publication bias

We were unable to test for publication bias, as there were insufficient studies for any of the outcomes.

DISCUSSION

The use of drugs is increasing by approximately 3 million new users each year [1]. While the global use of amphetamine, cocaine and ecstasy are estimated to have

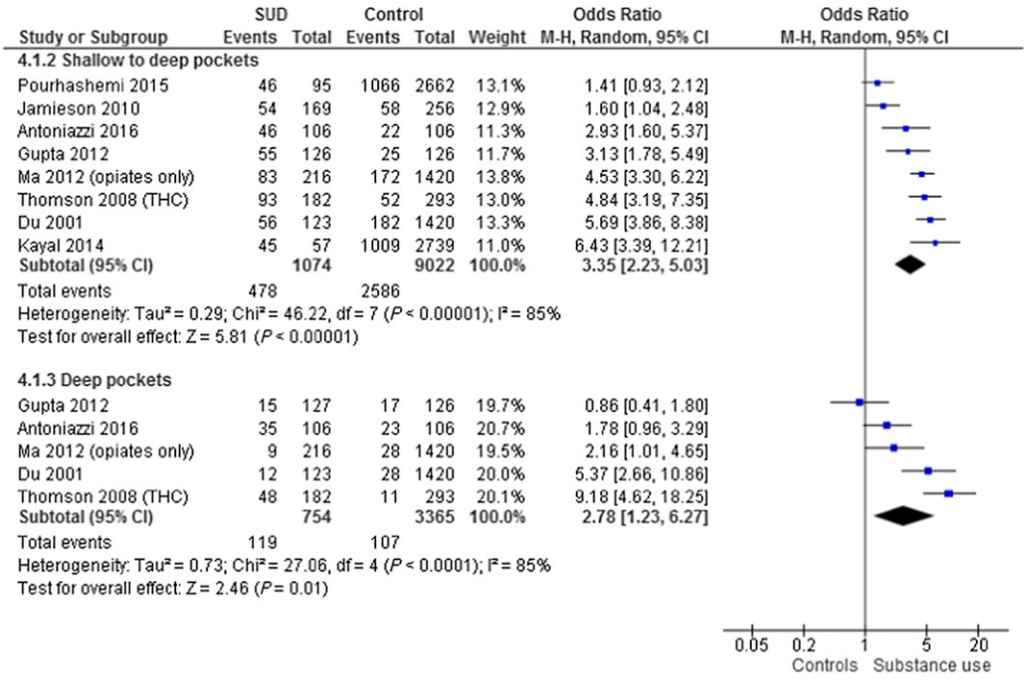

Figure 4 Periodontitis [Colour figure can be viewed at wileyonlinelibrary.com]

decreased in the past decade, the use of opioids and cannabis is continually rising [1].

This meta-analysis has highlighted the increased dental diseases in substance users compared to non-users. Substance users suffer from greater dental decay experience and are more likely to have periodontitis. Interestingly, users had greater number of decayed teeth, but they also had a fewer number of restorations, suggesting reduced access to dental services.

Most of the studies included a wide range of substance use disorders. Studies that considered only one were restricted to methamphetamines and opiates. Although 'methamphetamine mouth' has been the focus of attention, we did not find that users of this substance had worse dental outcomes than controls when compared to other substances on the limited number of available studies. This echoes findings from a study that compared people who used methamphetamine directly to other substance users and highlights the importance of comparisons with controls [50]. Although excessive tooth wear is accepted as one of the sequelae of substance use, we only found three studies that assessed this outcome and all were of amphetamine-like drugs.

Our findings mirror those of increased dental decay in people with severe mental illness and affective disorders when compared to the general population. They are also consistent with greater periodontal disease in people with alcohol use disorders. Oral health has significant consequences on quality of life. Apart from localized effects on function and self-esteem of conditions such as 'meth-mouth', there are systemic implications, such as an association between dental disease and ageing, as well as chronic such as coronary heart disease, stroke, diabetes and respiratory disease [51,52]. This is partly through common risk factors such as tobacco or alcohol, but also because of intermittent bacteraemia, chronic inflammation and secondary proinflammatory cytokines and immune complexes that lead to an inflammatory response in distal organs [52].

Limitations

There are a number of limitations to the present study. There was considerable variation in the outcomes measured and how they were reported. Some studies had no comparison groups. However, we were able to find suitable community controls for three of these. Although care was taken to find community controls from the same country (where possible from same state), same age group, similar gender distribution and similar publication date, comparisons between community controls and users should be interpreted with great caution. Similarly, while we were able to include a total of 16 studies in this review, only nine could be used for DMFT, nine for DT and fewer for all other dental outcomes.

Study quality was not optimal. Most studies [12,15,31,32,35,36,42–49] did not describe the duration of substance use and one study [31] failed to report the actual substances that were used. Most studies relied on self-reported substance use (via completing surveys or divulging the information during interviews). While some studies referred to their subjects as 'addicts' or 'substance

dependants' none revealed how this diagnosis was made. Similarly, none attempted to compare the difference in dental status of substance users and those dependants on substances. Some studies also did not have internal controls and, although we took into account age and secular trends in oral health when selecting external controls, we were unable to take into account other factors such as economic status, education level or access to dental care. Similarly, in most studies there were gender differences between the control and SU group. However, a sensitivity analysis of including only studies with a similar gender mix in both cases and controls did not alter the results. Furthermore, there was a lack of blinding of dental examiners to the substance use history of the patients in all of the studies. Although the use of radiographs allows for better detection of dental caries, radiographic assessment was used in only two of the 28 studies [12,31]. In addition, there were considerable variations in how periodontitis was defined and reported, reflecting lack of consensus diagnosis definition and reporting.

Many of the studies did not consider the effects of potential confounders such as alcohol and tobacco use or socio-demographic differences between users and non-users, and our main meta-analyses were unadjusted for these factors. However, some studies established that there was no difference between cases and controls in terms of alcohol use, and several used statistical methods to adjust for a range of life-style and socio-demographic variables. Furthermore, in sensitivity analyses restricted to results adjusted for socio-demographic factors and/or alcohol and tobacco use, substance use remained an independent predictor of worse dental health. This was confirmed in results from other studies where it was not possible to combine adjusted data in a meta-analysis. A smaller proportion of studies considered differences between cases and controls in brushing, flossing or previous dental care, and only two adjusted for these in multivariate analyses. We acknowledge that it is difficult to account for the effect of influences on dental health that may affect disproportionately people with substance use disorders such as dento-alveloar trauma from accidents or assaults.

Lastly, some of our results showed heterogeneity. This was primarily for studies of opiate or mixed drug use. Those restricted to amphetamines did not show significant heterogeneity. We tried to minimize the effects of heterogeneity in several ways. First, we explored heterogeneity through sensitivity analyses of the effect of omitting each study in turn. The removal of two outlier studies [14,41] meant that heterogeneity was no longer present in our analyses of dental decay. In addition, results were no longer heterogeneous when analyses of were restricted to studies that adjusted periodontal outcomes for smoking and/or socio-demographic factors. Finally, we used a random-effects model to incorporate heterogeneity into our analyses.

Implications

For non-dental practitioners

Clinicians who provide care for individuals with substance use disorders should screen for oral diseases and arrange for such patients to receive dental care. A simple way for non-dental practitioners to screen for dental diseases is to enquire about the presence of either oral pain or loosening of teeth, as well to as inspect the oral cavity for brown or black dental discoloration. In addition, physicians should consider the use of sugar-free preparations when prescribing methadone. They should warn patients of the associated craving for sweet foods and the xerostomic effects of psychotrophic medication, which combine to cause further dental disease. Finally, further research is indicated into the prevalence and extent of dental wear among this cohort, given the low numbers of studies we found for this outcome.

For dental practitioners

More than a third of dentists do not enquire about substance use among new patients, even though more than three-quarters believe that their practice includes patients who are engaged in substance misuse [7]. Lack of experience with this sensitive topic may be one barrier to screening for substance abuse [7]. This is an important issue to address, as dentists may be the first clinicians to suspect substance use when they see clinical signs of advanced dental or periodontal disease that are inconsistent with the age of the patient. Substance use should therefore be part of a standard history in the same way that patients are asked about allergies, medications, smoking and alcohol consumption. Consideration should also be given to issues around treatment and consent when patients are intoxicated, as well as the reduced efficacy of opioid analgesics in these patients. On a related issue, dentists should also be aware that they may be the target of opioid-seeking behaviour [7,53]. Finally, our findings suggest the need for a prison dental service, as people with substance use may find themselves in the criminal justice system.

For researchers

Given the limitations of the existing literature, more studies are indicated that include controls from similar settings and adjust for potential confounders such as differences between groups in terms of socio-demographic variables, life-style and duration of substance use. Ideally, oral health assessments should be made by trained dental personnel blinded to the presence of a substance use diagnosis and confirmed by radiography. Similarly, care should be taken to ensure when selecting indexes to measure dental and periodontal diseases.

CONCLUSION

People with substance abuse disorders have increased rates of both dental caries and periodontal disease. These problems should receive greater attention, and there are simple steps that both dental and non-dental personnel can take to improve this population's oral health.

Declaration of interests

None.

Acknowledgements

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1 Adjusted periodontal disease in SUD patients.
Figure S2 Sample of search terms used for Medline.