A Systematic Review and Meta-Analysis of the Association Between Poor Oral Health and Severe Mental Illness

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Background: Psychiatric patients have increased comorbid physical illness. There is less information, however, on dental disease, especially tooth decay, despite life-style risk factors or psychotropic-induced dry mouth in this population. Importantly, poor oral health can predispose people to chronic physical disease leading to avoidable admissions to hospital for medical causes. **Methods:** Using MEDLINE, PsycInfo, EMBASE, and article bibliographies, we undertook a systematic search for studies from the last 25 years regarding the oral health of people with severe mental illness (SMI). Results were compared with the general population. The two outcomes were total tooth loss (edentulism) and dental decay measured through the following standardized measures: the mean number of decayed, missing, and filled teeth or surfaces. **Results:** We identified 25 studies that had sufficient data for a random-effects meta-analysis. These covered 5076 psychiatric patients and 39,545 controls, the latter from either the same study or community surveys. People with SMI had 2.8 the odds of having lost all their teeth compared with the general community (95% confidence interval [CI] = 1.7–4.6). They also had significantly higher decayed, missing, and filled teeth (mean difference = 5.0, 95% CI = 2.5–7.4) and surfaces scores (mean difference = 14.6, 95% CI = 4.1–25.1). **Conclusion:** The increased focus on the physical health of people with SMI should encompass oral health. Possible interventions could include oral health assessment conducted using standard checklists that can be completed by non–dental personnel, help with oral hygiene, management of iatrogenic dry mouth, and early dental referral.

Key words: severe mental illness, schizophrenia, oral health, dental disease, edentulism, dental decay, caries.

SMI = severe mental illness; **DMFT** = decayed, missing, and filled teeth; **DMFS** = decayed, missing, and filled surfaces.

INTRODUCTION

It is well known that individuals with severe mental illness (SMI) have high rates of physical ill-health including diabetes, cardiovascular disease, chronic lung disease, and cancer (1). This, in turn, is associated with increased mortality from preventable physical disease so that people with schizophrenia die 15 to 20 years earlier than the general population. Historically, there has been less attention to the issue of oral health, although it is also an important part of physical health (2) and linked to systemic diseases such as coronary heart disease, stroke, diabetes, and respiratory disease (3–12). Dental disease can also affect eating, speech, and other social and psychological areas of life (2).

People with SMI are susceptible to oral diseases for a number of reasons. These include amotivation, poor oral hygiene, dental phobia, dental costs, difficulty in accessing health care facilities, and the side effects of psychiatric drugs such as dry mouth (xerostomia) (13–15).

The two most common diseases that affect oral health are dental caries (tooth decay) and periodontal (gum) diseases. The end-stage of both untreated dental caries and periodontal disease is tooth loss, which can involve the whole dentition (edentulism) (16). In an earlier meta-analysis, we reported significantly higher levels of edentulism in patients with SMIs such as dementia, schizophrenia, bipolar affective disorder, and other affective disorders (17). By contrast, the effect on other measures of oral health, such as dental decay, was inconclusive (18). This was possibly because of the low number of studies that could be incorporated into meta-analyses, thereby highlighting the limited data available on this dentally disadvantaged population at the time of publication (17). However, in the past 4 years, there have been a number of new studies examining the links between mental illness and dental disease.

We therefore undertook a further systematic review and meta-analysis, focusing on both edentulism and dental caries to provide a more current and complete picture of the dental status of the people with SMI over the last 25 years.

METHOD

We followed recommendations for the reporting of Meta-analysis Of Observational Studies in Epidemiology, including background, search strategy, methods, results, discussion, and conclusions (19).

Oral Health Outcomes

The two outcomes of this study were edentulism and dental caries. The former is usually expressed as a dichotomous variable, the latter as the number of decayed, missing, and filled teeth or surfaces (DMFT or DMFS). Both the DMFT and DMFS are continuous variables that cumulate over lifetime, reflecting the individual's overall experience of dental caries (20). This is because both dental decay and its treatment leave permanent marks, either through the presence of fillings or through the loss of affected teeth by extraction. The total number of teeth (T) and surfaces (S) that are decayed (D), missing because of disease (M) or filled (F), are measures referred to as the DMFT and DMFS, respectively. In both, an increase in score means greater cumulative dental decay. The mean DMFT and DMFS scores vary widely by country from DMFT scores of under five in parts of India (21,22) to 12.8 in the most recent community survey in a Western country, Australia (20). DMFS scores are higher than DMFT scores because these count damage to each surface of each tooth rather than counting the tooth as a single unit. For example, all anterior teeth have four surfaces and posterior teeth five surfaces. In interpreting both, it is useful to recall that humans have 32 permanent teeth. The maximum possible DMFT would therefore be 32, whereas the maximum DMFS would be 148.

Inclusion and Exclusion Criteria

We included studies with a focus on SMI, meaning a primary diagnosis of dementia, schizophrenia, bipolar affective disorder, and other affective disorders.

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We included studies using clinical diagnoses or diagnostic criteria. We excluded studies of eating disorder and of posttraumatic stress disorder in veterans, as these are very different patient groups. We also excluded studies of people with primary alcohol or substance use disorders, and learning disability, for the same reason. Finally, our focus was on edentulism and, where possible, DMFT and DMFS scores. We excluded studies of less severe dental outcomes such as poor oral hygiene.

Search Strategy

We searched MEDLINE, PsycInfo, and EMBASE for articles from January 1988 until November 2013 using the following text, MeSH, or Emtree terms as appropriate: Mental Disorders, Dementia, Psychotic Disorders, Depression, Depressive Disorders, Bipolar Disorders, Mood Disorders, Schizophrenia and Disorders with Psychotic Features, Oral Health, Dental Health Survey, Dental Care, Dental Health Services, Edentulous Mouth, Edentulous Jaw, Dental Caries, Toothloss and Tooth Wear. Other descriptive words associated with the above MeSH terms were also used as key terms. We searched for further publications by scrutinizing the reference lists of initial studies identified and other relevant review articles. We made attempts to contact selected authors and experts. Two reviewers (H.B. and S.K.) independently assessed abstracts and extracted and checked the data for accuracy. R.L. and N.W.J. provided content expertise, especially in relation to oral and dental health issues.

For inclusion in the meta-analysis, studies had to have data on suitable controls, collected either by the 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). This is because oral health varies between populations, by both age and over time: for example, oral health has improved considerably over the last 20 years in most Western industrialized countries (23–25). 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.

Study Quality

We assessed the quality of included studies using the Newcastle-Ottawa Scale (26). This assesses the quality of nonrandomized 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

We used Review Manager Version 5.0, a statistical software package for analyzing a Cochrane Collaboration systematic review, for our analysis. We calculated odds ratios (ORs) for edentulism, given that the studies we included were cross-sectional design. We calculated the mean differences for continuous data as studies used the same scale for each outcome (e.g., DMFT and DMFS).

We assessed heterogeneity by using the I^2 statistic. This provides an estimate of the percentage of variability due to heterogeneity rather than chance alone. An I^2 estimate of greater than or equal to 50% indicates possible heterogeneity. Scores of 75% to 100% indicate considerable heterogeneity (27). The I^2 statistic is calculated using the χ^2 statistic (Q) and its degrees of freedom. It has several advantages over the Q statistic alone in that it does not depend on the number of studies in the meta-analysis and so has greater power to detect heterogeneity where the number of studies is relatively low (28). The I^2 statistic can also be interpreted similarly irrespective of whether outcome data are dichotomous or continuous.

We used a random-effects model throughout b we found significant heterogeneity in most of our analyses. A random-effects model assumes that variations in the effect among different studies are due to differences in samples or paradigms and have a normal distribution, that is, that heterogeneity exists. In addition, we investigated heterogeneity through a sensitivity analysis of the effect of omitting each study in turn. Other sensitivity analyses included investigating the effect of only including studies that had internal controls, or those from developing countries where dental decay has historically been less prevalent or less severe (21,22).

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. We used Win Pepi version 11.34 (29). The fail-safe N statistic is the number of nonsignificant studies that would be necessary to reduce the OR 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

More than 48,500 citations resulted from the electronic search. Of these, 48,345 were excluded because they were not related to the aim of this meta-analysis. The abstracts of the remaining 155 potentially relevant articles were read, and a further 75 were excluded because they had a different primary focus. We were unable to obtain the article for one of the retrieved abstracts. All remaining articles were accessed, and after scrutinizing them in detail, another 39 were excluded because they were not prevalence studies or used nonrelevant dental outcomes. A further 14 had to be excluded because there were no appropriate internal or external controls. One further article reported on different aspects of the same database. This left 25 studies that could be included in the meta-analysis (Fig. 1). These consisted of 14 full-length articles included in the earlier review plus a further 11 studies identified in the updated search.

Table 1 gives details of these 25 articles (2,14,15,21,30–50). Thirteen were from Europe. The remainder were from India ($n = 2$), Taiwan ($n = 2$), Australia ($n = 4$), Israel ($n = 1$), Hong Kong ($n = 1$), Ethiopia ($n = 1$), and the United States ($n = 1$). The most common diagnosis was psychosis, usually schizophrenia. Other diagnoses (in descending order) included dementia, bipolar affective disorder, mood disorder, anxiety, and personality disorder. Ages ranged from 18 to 96 years.

Study quality was not optimal. Only eight studies defined psychiatric caseness using diagnostic criteria such as the Diagnostic and Statistical Manual or International Classification of Diseases, and this was by clinical assessment, not a standardized psychiatric interview (Table 1). In terms of group comparability, only 6 of the 25 studies had internal controls that enabled matching on a range of sociodemographic characteristics such as sex, education, and socioeconomic status (Table 1). In terms of assessing outcome, ascertainment of dental status in all the studies was by trained dental examiners using some, or all, of the decayed, missing, and filled classification. However, only two studies made specific mention of assessor calibration, or whether standardized epidemiological criteria were used (47,49). In addition, complete uniformity of ascertainment was only possible for those studies with internal controls ($n = 6$). No study commented on whether the dental assessor was blind to psychiatric status.

Data for meta-analyses were available for 5076 psychiatric patients and 39,545 controls. Of these psychiatric cases, 2833 (56.7%) were male and 2193 (43.3%) were female. Six studies had data on control groups collected by the authors themselves with similar characteristics to the psychiatric cases other than the presence of psychological morbidity (Table 1) (21,41,42,44, 48,50). There were 764 cases and 817 controls in these studies (total $n = 1581$). For the other 19, comparison data from community surveys were available for a similar age group and within 10 years of the study (Table 2; $n = 41,881$) (22–25,51–62). In

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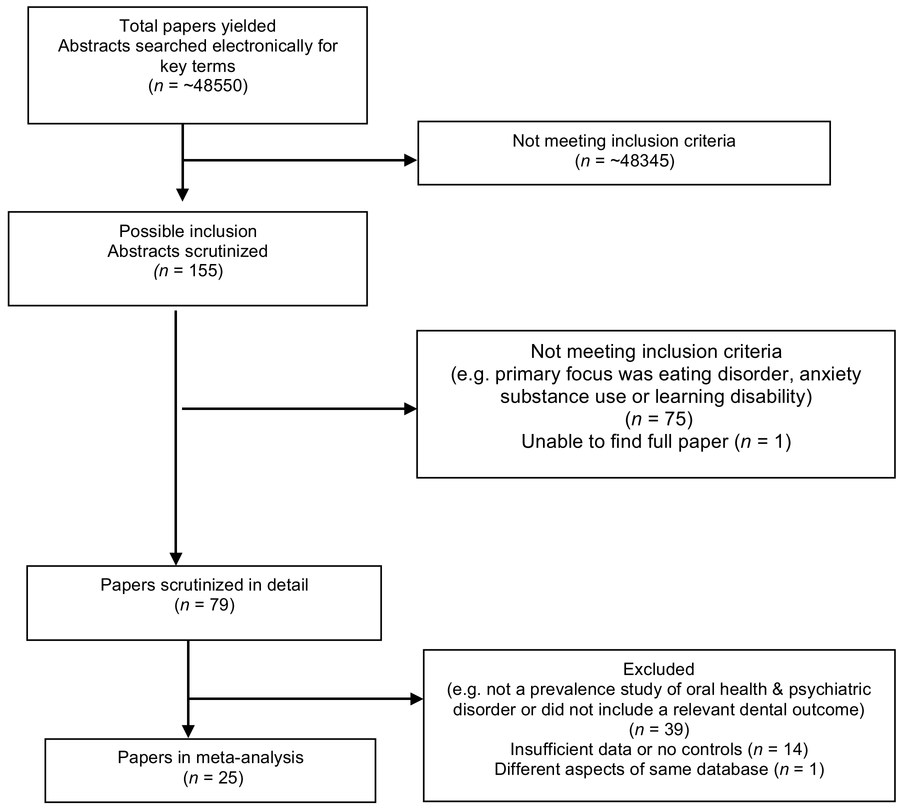

Figure 1. Number of articles yielded by search strategy.

some studies, controls were available for some outcomes in Table 1 but not others. Data on sex were only available for 37,872 controls, but where available, 50.3% were male (*n* = 19,024; Table 2). Men therefore predominated in the data derived from both the studies and the community surveys, albeit to differing degrees.

Edentulism

We were able to include 16 studies in the meta-analysis, although in the case of one study (30), comparison data were only available for those older than 35 years (Fig. 2). We used the same community controls for two studies and so divided the number by two for each comparison (40,47,61).

Data on the proportion of edentulous patients varied from 3.3% in the Indian groups sampled to around 65% in studies from Great Britain and from Denmark (Table 1). Psychiatric patients had 2.8 the odds of having lost all their teeth (95% confidence interval [CI] = 1.7–4.6) compared with controls (Fig. 2). Restricting studies to those of inpatient or residential care (*n* = 8), a marker of psychiatric symptom severity, gave similar results (OR = 3.54, 95% CI = 1.7–7.3) (2,14,30,32,36–38,45). The same applied when we only included those studies that reported on internal controls (OR = 2.4, 95% CI = 1.4–4.1), or used diagnostic criteria to define the psychiatric cases (OR = 3.1, 95% CI = 1.4–6.8; Table 1). Restricting the analysis to the one study from a developing country (inpatients in India) made little difference to the results (37).

Dental Caries

DMFT values ranged from 30.0 in Britain (38) to 0.92 in India (37). Average DMFT scores in countries with more Western life-styles—Europe, Australia, the United States, and Israel—were generally higher than 20 (Table 1). By contrast, scores from India were lower than 6 (Table 1). DMFS scores showed a similar pattern, with the highest score from Italy (88.6) (63) and the lowest (2.5) from India (37). The extent of tooth decay was generally greater for people requiring inpatient care as well as for those with chronic and more severe psychiatric symptoms (Table 1).

We were only able to include 16 studies in our meta-analysis. Two studies from Taiwan (45) (43) used the same control group (56). We therefore divided the number of controls by two for each comparison (Fig. 2). Psychiatric patients had significantly higher DMFS and DMFT scores (Fig. 3). They also had significantly more decayed surfaces, decayed teeth, and missing teeth, but not filled teeth (Fig. 3).

We were only able to undertake sensitivity analyses for DMFS and DMFT scores. Restricting studies to those of inpatients (*n* = 9) made no difference to the results for DMFS (mean difference = 20.4, 95% CI = 14.9–25.9) or DMFT (mean difference = 5.6, 95% CI = 2.5–8.8) (15,21,30,33,37,42,43,45,48). Only including those studies that used psychiatric diagnostic criteria (Table 1) also had no effect on the DMFS scores and little on the DMFT index (mean difference = 6.6, 95% CI = 4.5–8.7).

There were insufficient studies to undertake any further sensitivity analyses for outcomes as measured by DMFS, but it was possible for the DMFT results. Only including those studies that reported on internal controls made little difference (mean difference = 4.1, 95% CI = 0.3–7.9). However, when analyses were limited to the three studies from developing countries (India and

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TABLE 1. Studies Included in the Review

Study	Year	Country	Setting	*N*	Mean Age/ Range, y	Primary Psychiatric Diagnosis (Most Common Main Categories)	Edentulousness (%)	DMFT/S	Mean Score
Stiefel et al. (50)	1990	USA	Outpatients	37 psychiatric	33	78% schizophrenia[b]	—	DMFS	31.9
				29 controls	30	14% Bipolar disorder			27.4
Hede (31)	1992	Denmark	Outpatients	84	52	51% schizophrenia[b]	27	—	—
						25% pother psychosis			
						10% bipolar disorder			
Vigild (32)	1993	Denmark	Inpatients	407	75	—	63	DMFT	26.1
Hede (30)[a]	1995	Denmark	Inpatients	278	18–78	34% schizophrenia[b]	9	DMFS	70.5
						11% affective psychosis			
						14% reactive psychosis			
						16% personality disorder			
Velasco et al. (33)	1997	Spain	Inpatients	565	58	62% schizophrenia	14	DMFT	24.9
						4% dementia			
						5% affective disorders			
Chalmers et al. (34)	1998	Australia	Outpatients	138	46	73% schizophrenia	10	—	—
						17% affective disorder			
Mirza et al. (2)	2001	UK (London)	Inpatients	29	39	—	7	—	—
Lewis et al. (14)	2001	UK (South Wales)	Inpatients	326	71	25% schizophrenia	63	DMFT	19.1
						47% dementia			
						20% depression			
Rekha et al. (21)	2002	India	Inpatients	326 psychiatric	34	—	—	DMFT	6.1
				156 controls	34	—			3.2
Ramon et al. (15)[a]	2003	Israel	Inpatients >2 y	431	54	64% schizophrenia	33	DMFT	26.7
					18–96	12% organic			
						5% affective disorders			
McCreadie et al. (35)[a]	2004	UK	Outpatients	428	43	100% schizophrenia[b]	16	—	—
Tang et al. (36)	2004	Hong Kong	Inpatients	91	45	80% schizophrenia	7	Decayed	5.5
					18–65	10% organic/learning disability		Missing	9.5
						6% depression			
Kumar et al. (37)	2006	India	Inpatients	180	37	—	3	DMFS	2.5
					15–80			DMFT	0.9
Adam et al. (38)	2006	UK (Cheshire)	Inpatients—mild	54	85	100% dementia	70	DMFT	30.0
			Moderate/Severe	81	81		63		29.0
Burchell et al. (39)	2006	Australia	Outpatients	493	—	—	7	Decayed	2.8
								Missing	7.0

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Purandare et al. (40)	2010	UK (Manchester)	Outpatients and day hospital	103	78.7	38% depression[b]	42.7	—	—
					66–96	34% dementia			
						15% psychosis			
Syrjälä et al. (41)	2010	Finland	Community	76 psychiatric	84.8	64% Alzheimers[a,b]	63.3	Decayed	1.3[c]
					82.2	21% vascular dementia	68.8		
					85.3	14% other dementia	72.7		
				278 controls	81.4	—	44.6		
Jovanovic et al. (42)	2010	Serbia	Inpatients	186 psychiatric	46	57% schizophrenia[b]	19.9	DMFT	24.4
				186 controls	20–59	24% other psychotic disorder			
						—	0.0		16.1
Teng et al. (43)	2011	Taiwan	Inpatients	200	41	61% schizophrenia	—	DMFT	14.92
						15% bipolar disorder			
						12% major depressive disorder			
Arnaiz et al. (44)	2011	Spain	Outpatients	66 psychiatric	40	100% schizophrenia[b]	—	DMFT	13.51
				66 controls		—			7.80
Chu et al. (45)	2012	Taiwan	Inpatients	1103	50.8	100% schizophrenia	5	DMFT	13.9
Kebede et al. (46)	2012	Ethiopia	Outpatients	240	29.9	66% depression	—	DMFT	1.9
						18% schizophrenia			
						16% other (e.g., anxiety, bipolar, dementia, etc)			
Patel and Gamboa (47)	2012	UK (London)	Outpatients	89	18+	—	7.9	Decayed	1.8
Philip (48)	2012	Australia	Institutionalized	84 psychiatric	85	100% dementia	21[c]	DMFT	25.9
				102 controls		—			26.1
Lalloo et al. (49)	2013	Australia	Outpatients	50	41	76% schizophrenia and nonaffective psychosis	8	DMFT	17.7
						18% schizoaffective disorder			
						2% bipolar affective disorder			

DMFT/S = decayed, missing, and filled teeth or surfaces.
[a] Subset used in meta-analyses for which controls were available.
[b] International Classification of Diseases or Diagnostic and Statistical Manual criteria.
[c] Results for overall sample.

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TABLE 2. Description of Control Samples Derived from Community Surveys

Author	Year	Country	Study Name	*N*	Mean Age/ Range, y	Male, %
Kirkegaard et al. (51)	1986	Denmark	—	261	—	—
Alvarez-Arenal et al. (52)	1996	Spain	—	261	35–74	45
Kelly et al. (25)	2000	Northern England	Adult Dental Health Survey	219	>65	42
Kelly et al. (25)	2000	Wales	Adult Dental Health Survey	188	>65	44
Kelly et al. (25)	2000	Southern England	Adult Dental Health Survey	302	35–44	49
Kelly et al. (25)	2000	Scotland	Adult Dental Health Survey	1204	>16	45
Palmqvist et al. (53)	2000	Denmark	—	455	55–69	50
Sgan-Cohen et al. (54)	2000	Israel	—	7139	21	54
Oral Health Education Unit (55)	2001	Hong Kong	—	375	35–44	—
Mandal et al. (22)	2001	India	—	121		—
Petersen et al. (24)	2004	Denmark	Danish National Health and Morbidity Survey	5759	25–44	49
Petersen et al. (24)	2004	Denmark	Danish National Health and Morbidity Survey	8592	>45	49
Yang (56)	2006	Taiwan	The Investigation on oral health of the adult and elderly in Taiwan,	2660	18+	50
Vered et al. (57)	2008	Ethiopia/Israel	Ethiopian immigrants on arrival to Israel	365	18+	47
Krustrup and Petersen (58)	2007	Denmark	—	762	35–44	45
				353	65–74	52
AIHW Dental Statistics and Research Unit (23)[a]	2008	Victoria	National Survey of Adult Oral Health	2667 interviewed 1181 examined	>15	50
AIHW Dental Statistics and Research Unit (59)	2008	New South Wales	National Survey of Adult Oral Health	3630 interviewed 1099 examined	>15	50
AIHW Dental Statistics and Research Unit (60)	2008	Queensland	National Survey of Adult Oral Health	2052 interviewed 824 examined	>15	50
Office for National Statistics (61)	2011	North West England	Adult Dental Health Survey	600	>16	42
Patil et al. (62)	2012	India	—	664	18–67	73

[a] Australian Institute of Health and Welfare.

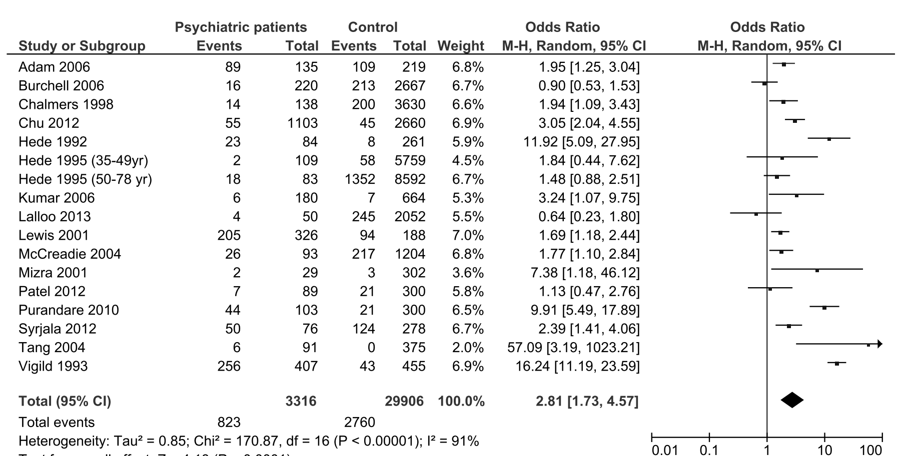

Figure 2. Edentulism. M-H = Mantel-Haenszel; CI = confidence interval.

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Study or Subgroup	Psychiatric patients Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
3.1.1 Decayed surfaces								
Hede 1995 (35-49yr)	3.1	11.6	109	0.9	0.1	762	43.4%	2.20 [0.02, 4.38]
Hede 1995 (65-78yr)	5.9	8.3	23	1.5	0.3	353	18.6%	4.40 [1.01, 7.79]
Stiefel 1990	6.4	6.67	37	2.07	2.53	29	38.0%	4.33 [1.99, 6.67]
Subtotal (95% CI)			**169**			**1144**	**100.0%**	**3.42 [1.93, 4.91]**
Heterogeneity: Tau² = 0.09; Chi² = 2.11, df = 2 (P = 0.35); I² = 5%								
Test for overall effect: Z = 4.51 (P < 0.00001)								
3.1.2 DMFS								
Hede 1995 (35-49yr)	68.3	33.3	109	46.6	0.7	762	38.8%	21.70 [15.45, 27.95]
Hede 1995 (65-78yr)	120.2	27.8	23	104.1	1.7	353	29.5%	16.10 [4.74, 27.46]
Stiefel 1990	31.9	22	37	27.4	20	29	31.7%	4.50 [-5.66, 14.66]
Subtotal (95% CI)			**169**			**1144**	**100.0%**	**14.60 [4.05, 25.14]**
Heterogeneity: Tau² = 64.52; Chi² = 8.00, df = 2 (P = 0.02); I² = 75%								
Test for overall effect: Z = 2.71 (P = 0.007)								
3.1.3 Decayed teeth								
Arnaiz 2011	4.39	3.99	66	0.72	1.23	66	12.5%	3.67 [2.66, 4.68]
Jovanovic 2010	3.4	2.4	186	1.6	1	186	13.3%	1.80 [1.43, 2.17]
Patel 2012	1.8	4.09	89	0.9	2.28	600	12.7%	0.90 [0.03, 1.77]
Philip 2012	3	3.9	84	2.9	3	102	12.5%	0.10 [-0.92, 1.12]
Ramon 2003 (18-34)	9.16	5.2	54	2.55	3.12	7139	11.8%	6.61 [5.22, 8.00]
Syrjala 2012 (AD only)	3.6	4.4	49	1	1.6	278	12.1%	2.60 [1.35, 3.85]
Tang 2004	5.5	6.1	91	0.7	3.12	375	12.0%	4.80 [3.51, 6.09]
Velasco 1997	7.95	6.86	565	2.9	2.9	261	13.0%	5.05 [4.38, 5.72]
Subtotal (95% CI)			**1184**			**9007**	**100.0%**	**3.16 [1.76, 4.55]**
Heterogeneity: Tau² = 3.77; Chi² = 154.92, df = 7 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 4.44 (P < 0.00001)								
3.1.4 Missing teeth								
Arnaiz 2011	5.66	7.13	66	1.5	2.03	66	14.1%	4.16 [2.37, 5.95]
Jovanovic 2010	19	8.2	186	9.9	1	186	14.4%	9.10 [7.91, 10.29]
Philip 2012	25.9	4.5	84	26.1	4.2	102	14.4%	-0.20 [-1.46, 1.06]
Ramon 2003 (18-34)	5.42	6.25	54	0.25	0.69	7139	14.2%	5.17 [3.50, 6.84]
Stiefel 1990	0.57	1.3	37	0.55	1.53	29	14.6%	0.02 [-0.68, 0.72]
Tang 2004	9.5	8.9	91	3.9	0.69	375	14.1%	5.60 [3.77, 7.43]
Velasco 1997	17.02	10.32	565	7.5	6.8	261	14.4%	9.52 [8.33, 10.71]
Subtotal (95% CI)			**1083**			**8158**	**100.0%**	**4.76 [1.31, 8.21]**
Heterogeneity: Tau² = 21.11; Chi² = 322.87, df = 6 (P < 0.00001); I² = 98%								
Test for overall effect: Z = 2.71 (P = 0.007)								
3.1.5 Filled teeth								
Jovanovic 2010	2	2.1	186	4.6	2.4	186	52.8%	-2.60 [-3.06, -2.14]
Philip 2012	5.3	5	84	5	4.8	102	47.2%	0.30 [-1.12, 1.72]
Subtotal (95% CI)			**270**			**288**	**100.0%**	**-1.23 [-4.07, 1.61]**
Heterogeneity: Tau² = 3.92; Chi² = 14.55, df = 1 (P = 0.0001); I² = 93%								
Test for overall effect: Z = 0.85 (P = 0.40)								
3.1.6 DMFT								
Arnaiz 2011	13.51	7.27	66	7.8	4.41	66	8.8%	5.71 [3.66, 7.76]
Chu 2012	13.94	8.84	1103	8.31	7.09	1330	9.3%	5.63 [4.98, 6.28]
Jovanovic 2010	24.4	5.1	186	16.1	1	186	9.3%	8.30 [7.55, 9.05]
Kebede 2012	1.94	2.12	240	2.43	3.87	365	9.3%	-0.49 [-0.97, -0.01]
Kumar 2006	0.92	1.8	180	0.4	0.92	121	9.3%	0.52 [0.21, 0.83]
Lalloo 2013	17.7	2.81	50	13.1	17.03	824	9.1%	4.60 [3.20, 6.00]
Philip 2012	17.4	7.3	84	18	7.1	102	8.7%	-0.60 [-2.68, 1.48]
Ramon 2003 (18-34)	17.5	8.2	54	8.49	4.95	7139	8.7%	9.01 [6.82, 11.20]
Rekha 2002	6.1	6.87	326	3.2	3.49	156	9.2%	2.90 [1.97, 3.83]
Teng 2011	14.9	8.88	200	8.31	7.09	1330	9.1%	6.59 [5.30, 7.88]
Velasco 1997	24.99	7.71	565	12.5	7.1	261	9.2%	12.49 [11.42, 13.56]
Subtotal (95% CI)			**3054**			**11880**	**100.0%**	**4.96 [2.53, 7.39]**
Heterogeneity: Tau² = 16.42; Chi² = 1062.29, df = 10 (P < 0.00001); I² = 99%								
Test for overall effect: Z = 4.00 (P < 0.0001)								

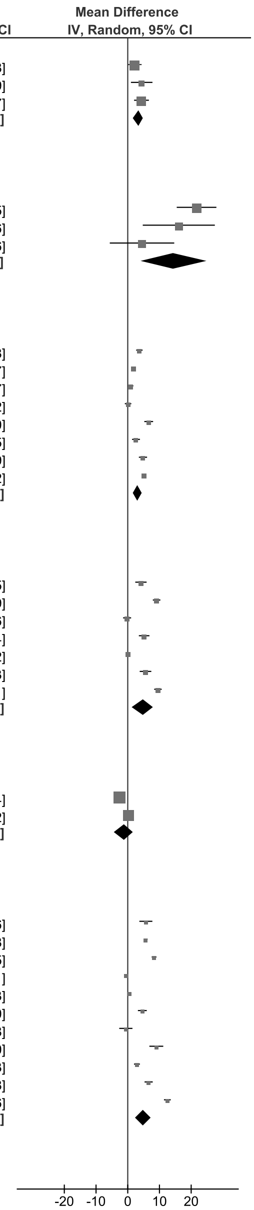

Figure 3. Dental caries (tooth decay). DMFS = decayed, missing, and filled surfaces; DMFT = decayed, missing, and filled teeth; SD = standard deviation; CI = confidence interval; IV = inverse variance.

Ethiopia), there was no longer an association between psychiatric status and DMFT scores (mean difference = 0.9, 95% CI = −0.4 to 2.2).

Publication Bias

We were only able to test for publication bias for the outcomes of edentulism and DMFT scores because there were insufficient studies for the other outcomes. For edentulism, the fail-safe *N* of additional "null" studies needed to reduce the overall OR to 1.1 was 170. The regression test for funnel-plot asymmetry gave a *p* value of .92. For the DMFT score, the fail-safe *N* of additional null studies needed to reduce the overall effect size to 0.1 was 74, whereas the regression test for funnel-plot asymmetry gave a *p* value of .73. These results suggest that the findings for edentulism and decay were reasonably robust against publication bias.

DISCUSSION

Although the oral health of the general population has improved in much of the world, psychiatric patients remain at a disadvantage in a wide range of countries. This update revealed a further 11 studies, thereby doubling the number of psychiatric cases, and more clearly established the association of SMI with both edentulism and measures of dental caries such as decayed and missing teeth. The association was generally less marked in studies from developing countries, especially those of outpatients, possibly because of the low prevalence of dental caries overall. The present study has a further advantage over the earlier

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systematic review in that it followed Meta-analysis of Observational Studies in Epidemiology guidelines for the meta-analysis of observational studies, including the assessment of study quality using the Newcastle-Ottawa Scale (19,26).

Aside from cosmetic considerations, dental disease is an important source of systemic medical morbidity. The oral cavity is the site of many infectious and inflammatory diseases, which have recently been associated with systemic diseases such as diabetes, cardiovascular disease, and bacterial pneumonia (11,12,64) Some of the associations may be due to the fact that dental disease and many of these conditions share the same risk factors. For instance, tobacco smoking, stress, and aging are common risk factors for both dental and systemic disease. However, there are also the direct effects of poor oral hygiene leading to heavy bacterial colonization of dentition with a shift to a more cariogenic and periodontopathic ecology of the resultant biofilm (11,12, 64,65). The consequent anatomic closeness of these microflora to the blood stream can facilitate bacteremia, as well as the systemic spread of bacterial products and immune complexes. In turn, this can lead to chronic inflammation at distant sites including the liver, pancreas, and arteries, initiating or exacerbating underlying diseases such as arteriosclerosis or diabetes. In the case of coronary heart disease and stroke, chronic inflammation, infection, and possible autoimmunity have all been implicated in the pathogenesis of arteriosclerosis (12).

Poor oral health also contributes to avoidable admissions to general hospital. These are admissions for physical conditions, which, with appropriate primary care, should not become serious enough to require inpatient treatment (66). They include diabetes, cardiovascular disorders, and respiratory diseases. Avoidable admissions can be divided into acute and chronic conditions. Dental conditions are the commonest cause of acute avoidable admissions accounting for 20% of the total number, and the rate in psychiatric patients is even higher than that in the general population (67).

Limitations

There are a number of limitations to the present study. There was considerable variation in outcome measures and how these were reported. Most studies had no comparison groups. However, we were able to find suitable community controls for many of these. Although we were able to include up to 25 studies for the meta-analysis of edentulism and DMFT scores, we had fewer studies for the other outcomes.

Study quality was not optimal. For instance, most studies did not use diagnostic criteria to establish psychiatric caseness. However, sensitivity analyses of the effect of only using those studies that used International Classification of Diseases or Diagnostic and Statistical Manual criteria made no difference to the results.

Most 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 or education level. In addition, there were differences in the sex distribution between psychiatric cases and controls from the general population. However, although a potential source of bias, it is important to note that the prevalence of edentulism and tooth decay is generally similar in males and females (25,58), and that where differences have been reported, females have worse dental disease than males (23,58–60). Any effect on our results would therefore have been to underestimate the difference between psychiatric cases and controls, given that there were 8% more males in the psychiatric sample than those in the community. In addition, the results were unchanged when we only included those studies that had internal controls from comparable settings and with similar sociodemographic characteristics to the psychiatric cases. Depending on the study, these included age, sex, education, and socioeconomic status.

We also cannot exclude the possibility that internal or community controls would have included people with other psychiatric diagnoses such as anxiety, substance use, and eating disorders, some of which are known to be associated with increased oral pathology (68). However, any consequent bias would be in the direction of reducing the difference between psychiatric cases and controls and thus to an underestimate of the association between the psychiatric conditions of interest and dental disease. There were other limitations in study quality that we could not attempt to address using sensitivity analyses. These included the calibration, standardization, and blinding of dental assessments.

Many of our results also showed heterogeneity. We explored this further through sensitivity analyses of the effect of omitting each study in turn, but this made no difference to the results (27). Accordingly, we used a random-effects model throughout to incorporate heterogeneity into our analyses (27). However, although we have tried to minimize the effects of heterogeneity, our results should still be treated with caution.

Explanations

Explanations for these findings include poor oral hygiene resulting in periodontal problems as well as dental decay, reduced access to dental care due to reduced motivation and awareness of the psychiatric patients (69), and reduced protective factors like saliva as a side effect of psychotropic medication like antipsychotics, antidepressants, and mood stabilizers (49). As with other aspects of physical ill-health, alcohol, substance use, tobacco, and diet, including the consumption of carbonated drinks, also contribute to poor oral health (13–15).

People with SMI may also have priorities other than their oral health, or lack privacy for oral hygiene due to poor housing or homelessness. These issues are compounded by difficulties with access to dental care, either because of cost or because of fear of pain and dental phobia. Even in countries with universal health care, dental treatment is not always comprehensively covered (17). We were not able to fully explore the relative contributions of psychiatric status and socioeconomic factors to oral health, given not all of the studies took into account sociodemographic characteristics.

Implications

Further systematic reviews and meta-analyses are indicated to explore the association between oral health and other

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psychiatric illnesses not covered in the present study such as anxiety and substance use disorders.

Research could also help determine the effectiveness of screening for oral health problems as part of a comprehensive assessment of people with SMI. For instance, there could be an evaluation of the following on admission to hospital: a) the recording of factors known to cause oral ill-health such as psychotropic medication, tobacco, or substance use; b) a simple examination of the mouth; and c) the supply of tooth brushes and denture baths including instruction in their use (70).

For dental practitioners, people with SMI need to be recognized as a dentally disadvantaged group and, where possible, efforts made to remove barriers to care. This might be facilitated by greater exposure to "special needs" dentistry during their training.

For patients in the community, research could determine the value of case managers providing advice on life-style and oral hygiene, as well as ensuring regular dental check-ups. For example, Queensland's strategy to improve the physical health of people with SMI (Activate: Mind & Body) includes both the promotion of oral hygiene and regular care from a dentist (71). Given that dental conditions are the commonest reason for acute avoidable admissions, improved dental care for people with SMI could result in considerable cost savings (65,67).

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