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The impact of hospitalisation on oral health. A systematic review.

Running title: Hospitalisation and oral health

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Clinical relevance

Scientific rationale for study: Poor oral health is recognised as a potential risk factor for hospital acquired infections. Therefore a systematic review of the evidence for the effect of hospitalisation on oral health is needed.

Principal findings: The evidence suggests that oral health deteriorates during hospitalisation. However, few studies have investigated this question and the strength of evidence is limited.

Practical implications: Oral care during hospitalisation needs to be strengthened together with further research investigating oral health changes in different settings and factors that facilitate the provision of care.

ABSTRACT

Background: Poor oral health of hospitalised patients is associated with an increased risk of hospital acquired infections and reduced life quality

Objectives: To systematically review the evidence on oral health changes during hospitalisation.

Data sources: Cochrane library, Medline, OldMedline, Embase and CINAHL without language restrictions.

Study eligibility criteria: Observational longitudinal studies.

Data appraisal and synthesis methods: Two independent reviewers screened studies for inclusion, assessed risk of bias and extracted data. Risk of bias was assessed with the Ottawa Newcastle assessment scale. A narrative synthesis was conducted.

Results: Five studies before and after studies were included. The data suggest a deterioration in oral health following hospitalisation with an increase in dental plaque accumulation and gingival inflammation and a deterioration in mucosal health.

Limitations: Whilst before and after studies are at a general risk of bias, other specific study characteristics of were judged to be of low risk of bias. However, methodological issues such as unvalidated outcome measures and lack of assessor training limit the strength of the evidence.

Conclusion: Hospitalisation is associated with a deterioration in oral health, particularly in intubated patients.

INTRODUCTION

Maintenance of oral health is important for hospitalised patients. Oral health affects quality of life (Llewellyn & Warnakulasuriya 2003, Yu et al. 2008) and personal dignity and this impact appears to be more severe in medically compromised or hospitalised patients (Duke et al. 2005, Ingram et al. 2005, Locker et al. 2002, McMillan et al. 2005, Mulligan et al. 2008). Not surprisingly, poor oral health or dysfunction can also have a negative effect on nutritional status (Chai et al. 2006, Gil-Montoya et al. 2008, Rauen et al. 2006), whilst improvement of dental status raises levels of nutritional markers (Wostmann et al. 2008).

Poor oral health and oral hygiene can also contribute to an increased incidence of hospital acquired infections, particularly respiratory diseases (Azarpazhooh & Leake 2006, Shaw 2005). Furthermore, interventions that maintain or improve oral health can reduce the incidence of ventilator associated pneumonia (Chan et al. 2007). Similarly, benefits from effective oral hygiene have also been documented for pneumonia in non ambulatory (Scannapieco 2006) or elderly patients (Sjogren et al. 2008). Therefore, oral health requires management during in-patient care. Therefore, oral health requires management during in-patient care.

Although oral health can be maintained during hospitalisation with proper training of the caregivers (Peltola et al. 2007), there are difficulties in the provision of adequate oral care in hospitals and institutional facilities. Barriers to effective oral care reported by caregivers include the low priority of oral care (Grap et al. 200, Landstrom et al. 2009), fear of causing pain or injury to the patients (Jablonski et al. 2009), the perception that oral care does not provide significant benefits (Binkley et al. 2004, Jones et al. 2004), patients' resistive behaviours (Jablonski, Munro, Grap et al. 2009), inadequate nurse staffing (Grap et al. 2003) and lack of supplies (Jablonski, Munro, Grap et al. 2009). To encourage provision of

1
2
3 effective oral care, guidelines have been published with recommended protocols for
4
5 hospitalised patients (Department of Health 2003, Department of Health 2007, Fiske et al.
6
7 2000, NICE 2008, Tablan et al. 2004). However, the adherence to oral health protocols is
8
9 reported to be low (Grap et al. 2003, Rello et al. 2007).
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11

12
13 Whilst oral health status during hospitalisation is clearly an important public health
14
15 issue, no systematic review has been conducted to critically evaluate the research data on
16
17 this topic. The aim of this systematic review was therefore to address the focussed question,
18
19 what is the effect of hospitalisation on oral health?
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21

22 23 24 25 26 **METHODS**

27
28 We considered as eligible longitudinal prospective observational studies in people of all ages
29
30 being hospitalised, that assessed changes of the following outcomes: tooth loss, any
31
32 measures of periodontal health, dental caries and stomatological diseases. Intervention
33
34 studies, cross sectional studies, case reports and reviews were excluded. Studies reporting
35
36 specifically on patients with psychiatric disorders or on patients receiving treatment with
37
38 frequently observed oral complications (e.g. chemo- or radiotherapy) were excluded.
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43 44 45 **Search strategy (Appendix)**

46
47 The literature search for relevant articles was performed using Ovid MEDLINE and Ovid
48
49 OLDMEDLINE (dating from January 1950 to January 2010), Cumulative Index to Nursing and
50
51 Allied Health Literature (CINAHL) (dating from 1982 to January 2010), Cochrane Library (up
52
53 to 2010) and EMBASE (dating from 1981 to January 2010). We designed a sensitive search
54
55 strategy as we anticipated that coding for relevant search terms was not well developed.
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57
58
59 The bibliographies of all potentially relevant studies and review articles were also searched.
60

1
2
3 Handsearching was performed in the following journals; *Community Dentistry and Oral*
4
5
6 *Epidemiology, Gerodontology, Journal of Disability and Oral Health and Special Care in*
7
8 *Dentistry*. No language restrictions were applied on the search. When necessary we
9
10 corresponded with the first authors of studies to elicit further information. One reviewer
11
12 (ET) scanned the titles and abstracts of the studies identified by the search. When a study
13
14 seemed to meet the eligibility criteria or information was insufficient to exclude, full text
15
16 articles were obtained.
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20 21 22 23 **Data extraction**

24
25
26 Two reviewers (ET, EA) independently screened all full text articles. They also extracted data
27
28 from the included studies in specially designed forms. Disagreements that could not be
29
30 resolved were arbitrated by a third author (IN). Training of reviewers for screening, study
31
32 eligibility and quality assessment was performed by an experienced systematic review
33
34 methodologist (IN). The calibration of the examiners was made on five randomly selected
35
36 studies included for full paper screening.
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43 44 **Quality assessment**

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46 Studies were assessed by the two reviewers (ET, EA) using the Newcastle-Ottawa scale for
47
48 cohort studies (Wells et al. 2008). Since we did not find studies with a non-exposed
49
50 comparison group we omitted the comparability section of the scale. In addition, we
51
52 assessed whether a power calculation was reported for each study and if so, the magnitude
53
54 of a change that the study was powered to detect. Separately, we assessed the quality of
55
56 the outcome assessment in terms of validity of the measure of oral health and
57
58 conduct/reporting of assessor training in the measure.
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Data synthesis

Pooling of data was based on the study design, population characteristics, types of oral hygiene measures used in the hospital units, setting characteristics of the studies and outcomes measured. We anticipated substantial heterogeneity between studies and planned a narrative synthesis of data.

RESULTS

A total of 9689 potentially relevant review records were found. 9652 were excluded on the basis of their titles or abstracts and the full papers of 37 studies were retrieved. Five papers were finally included (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006, Prendergast et al. 2009). (Fig 1) Inter-examiner agreement for eligibility of included papers was 100%. The most common reasons for exclusion were no reported oral health outcomes or study design (e.g. intervention, cross sectional or retrospective).

Quality assessment

Agreement between reviewers on each aspect of the Newcastle-Ottawa scale was 100%. In all studies the representativeness of the cohort was found to be adequate and the demonstration of outcomes of interest was made at baseline. Adequacy of follow up was judged to be good in all studies, considering the healthcare setting, despite the drop outs encountered. This was based on the fact that the reasons for drop out were either death or discharge from the hospital unit (Franklin et al. 2000, Munro et al. 2006, Prendergast et al. 2009). The assessment of outcome was judged to be adequate for all studies in terms of the Newcastle-Ottawa criteria and the follow up period was long enough for the assessment of

1
2
3 dental plaque and gingival health changes. This period was arbitrarily defined as a minimum
4
5 of three to five days (Eilers et al. 1988, Fitch et al. 1999) although too brief to detect either
6
7 dental caries incidence or changes in periodontitis. The validity of the outcome measures
8
9 was more problematic including the use of subjective indices based on visual analogue scale
10
11 measurements (Munro et al. 2006), assessments of gingival health with tools designed for
12
13 population epidemiology (Dennesen et al. 2003) and use of partial recordings with indices
14
15 not designed for this purpose (Fourrier et al. 1998). In addition, examiner training was
16
17 reported in only one study (Prendergast et al. 2009).
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26 **Population characteristics**

27
28 Four studies were located in ICU units (Fourrier et al. 1998, Franklin et al. 2000, Munro et al.
29
30 2006, Prendergast et al. 2009) and one investigated a mixed population of patients in ICU
31
32 and a cardiosurgical ward (Dennesen et al. 2003). The population in three studies was
33
34 intubated (Fourrier et al. 1998, Munro et al. 2006, Prendergast et al. 2009), while in two, the
35
36 population was both intubated and not intubated (Dennesen et al. 2003, Franklin et al.
37
38 2000). One study investigated children only (Franklin et al. 2000), while the remainder
39
40 reported on adult populations. The duration of the hospitalisation ranged from five to
41
42 twenty days.
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51 **Oral care regime**

52
53 There was marked variability in oral care protocols including sterile cloth drenched with
54
55 0.9% saline (Dennesen et al. 2003), rinsing with sterile water (Fourrier et al. 1998),
56
57 foamsticks moistened with water (Franklin et al. 2000) and foam swabs or child
58
59 toothbrushes with toothpaste, sterile water or normal saline (Prendergast et al. 2009). In
60

1
2
3 one study, there were no details of the oral hygiene measures applied (Munro et al. 2006).
4
5
6 Frequency of oral care provision ranged between two to six times per day.
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8
9

10 **Study setting**

11
12 Two studies were based in the USA (Munro et al. 2006, Prendergast et al. 2009), one in the
13
14 UK (Franklin et al. 2000), one in France (Fourrier et al. 1998) and one in the Netherlands
15
16 (Dennesen et al. 2003).
17
18
19

20 **Power calculation**

21
22 Power calculation was reported in only one study (Franklin et al. 2000). The sample size was
23
24 estimated to identify a difference of 10 plaque covered surfaces significant at 5% with a
25
26 power of 90% using a standard deviation of 15.0 for plaque on all tooth surfaces.
27
28
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34 **Dental plaque accumulation**

35
36 Four out of the five included studies reported on the changes of dental plaque accumulation
37
38 during hospitalisation period (Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006,
39
40 Prendergast et al. 2009). Each study used a different measure. In one study no differences
41
42 were observed during the observational period (Prendergast et al. 2009). Three studies
43
44 reported increasing levels of plaque accumulation during hospitalisation (Fourrier et al.
45
46 1998, Franklin et al. 2000, Munro et al. 2006), which was statistically significant in two
47
48 (Fourrier et al. 1998, Franklin et al. 2000). The proportion of sites with abundant dental
49
50 plaque (scores more than 2) increased from 23% at baseline to 93% at day 10 (Fourrier et al.
51
52 1998) and the other study showed mean difference of 3.3% in the O'Leary index ($p=0.001$)
53
54 (Franklin et al. 2000).
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Gingival inflammation

Three studies reported on the levels of gingival inflammation during hospitalisation using different indices (Dennesen et al. 2003, Franklin et al. 2000, Prendergast et al. 2009). Two of the studies found statistically significant increases in the severity of gingival inflammation. (OAG median value changes from 1 at baseline to 2 at day 14 (Prendergast et al. 2009) and mean difference of the sites presenting gingival inflammation of 1.4 ($p=0,006$) (Franklin et al. 2000)) One study reported 'no statistically significant changes' although no data were presented (Dennesen et al. 2003).

Periodontal disease

One study reported on the severity of periodontal disease using an index of assessment of treatment needs, but found no statistically significant change (Dennesen et al. 2003). However, this index was designed for epidemiology and is insensitive to small changes over short durations of time (Holmgren 1994).

Caries incidence

Two studies assessed the incidence of dental caries in hospitalised patients and reported no statistically significant changes following hospitalisation (Franklin et al. 2000, Munro et al. 2006).

Stomatological disease

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3 Two studies evaluated the incidence of stomatological diseases (Dennesen et al. 2003,
4
5 Prendergast et al. 2009). Both studies found a statistically significant increased incidence of
6
7 mucositis intubated patients but with not in non-intubated patients (Dennesen et al. 2003).
8
9

10 11 12 13 **DISCUSSION**

14 15 16 Statement of principal findings

17
18 The five included studies suggest that oral health deteriorates following hospitalisation.

19
20 Most studies were set in intensive care units including both intubated and non-intubated
21
22 patients. Dental plaque accumulation and gingival and mucosal inflammation were the main
23
24 oral health aspects affected in the examined populations and the findings were more
25
26 evident in studies reporting on intubated patients (Dennesen et al. 2003, Franklin et al.
27
28 2000).
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36 37 Strengths and weaknesses of the review

38
39 We conducted a sensitive search including multiple electronic databases without language
40
41 restriction and supplemented by handsearching. However, we were only able to identify five
42
43 eligible studies enrolling a total of 271 patients. We were unable to retrieve two papers for
44
45 the full article reading. Their abstracts were unavailable in the databases and no records of
46
47 the journals were found in British Library. Other strengths of the review are that we
48
49 appraised the methodological quality and risk of bias of included studies including the
50
51 validity of the outcome measures in relation to oral health changes.
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59 Since most of the studies were conducted in intensive care units, the results cannot be
60
extrapolated to other hospital settings. Other than intubation, differences with other

1
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3 settings could include level of dependency of patients for oral care, ease of provision of oral
4
5 care and availability of staff to provide such care.
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10 The quality of the evidence included in the review was affected by a number of
11
12 methodological issues. Firstly, there was marked heterogeneity in the oral care routines
13
14 and in addition, adherence to oral care was not reported in the majority of studies.
15
16 Secondly, a wide variety of indices for assessing of oral health were employed and their
17
18 validity was not clear. Validity issues included the use of subjective indices based on visual
19
20 analogue scale measurements (Munro et al. 2006), assessments of gingival health with
21
22 epidemiological tools (Dennessen et al. 2003) and use of partial recordings with indices not
23
24 designed for this purpose (Fourrier et al. 1998). Furthermore, examiner training in this
25
26 testing setting was reported in only one study (Prendergast et al. 2009). Study design also
27
28 limits the strength of the conclusions. All studies were uncontrolled and changes in
29
30 outcomes may simply relate to shifts in examiner characteristics over time. Including an
31
32 appropriate 'unexposed' comparison group is challenging and its validity as a control would
33
34 be questionable. Therefore, this needs to be accepted as a limitation to the evidence.
35
36 Calibration of an examiner to a gold-standard with re-testing throughout the study might
37
38 have helped counter any drift. The duration of follow-up was limited (to a maximum of 20
39
40 days) due to the nature of the hospitalisation. Although this period was adequate for the
41
42 detection of changes in some oral health outcomes such as dental plaque accumulation
43
44 (Theilade et al. 1966) and gingival inflammation (Loe et al. 1965), longer observational
45
46 periods are required for the detection of a change in periodontitis (Goodson et al. 1982) or
47
48 dental caries occurrence (Pitts and Stamm 2004). Finally, power calculations were reported
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50 in only one study (Franklin et al. 2000), thus hindering the interpretation of findings.
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5 Strengths and weaknesses in relation to other reviews
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8 We have not found other systematic reviews addressing this research question. However, a
9
10 clinical effectiveness review was published in 1999 investigating oral care practices by
11
12 nurses (Bowsher et al. 1999). The published report is limited in details of methodology
13
14 making comparison difficult. However, the findings, even though published more than a
15
16 decade ago, appear to hold true 'This review confirms that current practice largely ignores
17
18 the research evidence and is inadequate for ensuring optimum care. There is a clear need to
19
20 develop and evaluate oral care protocols for hospitalised patients and to support nurses in
21
22 their implementation.'
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30 Meaning of the review, possible explanations and implications for clinicians and policy
31
32 makers.
33

34
35 This review suggests that hospitalisation is associated with a deterioration in oral health and
36
37 this could have profound implications for health and wellbeing. On the basis of current
38
39 evidence, a deterioration in oral health would be expected to increase the risk of hospital
40
41 acquired infections, increase care costs and have negative impact on health related quality
42
43 of life.
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50 We were not able to conclude whether this impact results from a low priority of oral care
51
52 provision, the implementation of improper oral care regimes, from hospitalisation per se or
53
54 from a combination of factors. Guidelines for the provision of oral care in hospital settings
55
56 have been published (Department of Health 2003, Department of Health 2007, Fiske, et al.
57
58 2000, NICE 2008, Tablan et al. 2004) although they provide limited detail for carers.
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4 Additional protocols/guidelines are therefore needed and should be based on the best
5
6 available evidence with sufficient detail to guide carers and patients. Such development
7
8 should include the breadth of relevant stakeholders such as nursing, medical and dental
9
10 professionals as well as patients and address the different settings in which will need to be
11
12 provided such as units with fully dependent patients and those where patients are able to
13
14 carry out oral hygiene themselves. More challenging will be implementation (Rello et al.
15
16 2007) and this will need to be planned together with evaluation of success prior to
17
18 introduction.
19
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26 In terms of interventions, chemical plaque control was the regime of choice in three out of
27
28 five included studies (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000).
29
30 Although the clinical application of chemicals such as antiseptics seems straightforward,
31
32 their effect against established dental plaque is marginal due to its organisation as a biofilm
33
34 in which bacteria are considerably less sensitive to antimicrobial treatments than free-living
35
36 planktonic bacteria (Pratten et al. 1998). This is corroborated by a systematic review of
37
38 chlorhexidine for prevention of ventilator-associated pneumonia (VAP) which reported no
39
40 effect on VAP incidence (Pineda et al. 2006). Therefore, mechanical removal or disruption of
41
42 dental plaque will be needed such as can be achieved through toothbrushing.
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50 Suggestions for further research

51
52 More robust evidence is needed to understand the impact of hospitalisation on oral health.
53
54 In particular, we recommend studies conducted in a wider range of hospital settings
55
56 including outside of critical care units. There are many outcomes measures that are
57
58 validated in oral health research and these should be selected for hospital-based studies.
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60

1
2
3 Furthermore, training of examiners should be provided together and outcomes of training
4
5 (such as agreement levels) reported. Where feasible, longer observational periods could be
6
7 employed to investigate other oral health outcomes such as dental caries and periodontitis.
8
9

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28
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38
39 study. All authors contributed to the study protocol, interpretation of results and
40
41 manuscript. ET conducted the search and initial screening. ET and EA conducted the full-text
42
43 screening and data abstraction. ET wrote the first draft of the manuscript.
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For Peer Review

Figure 1: Flowchart of inclusion of studies

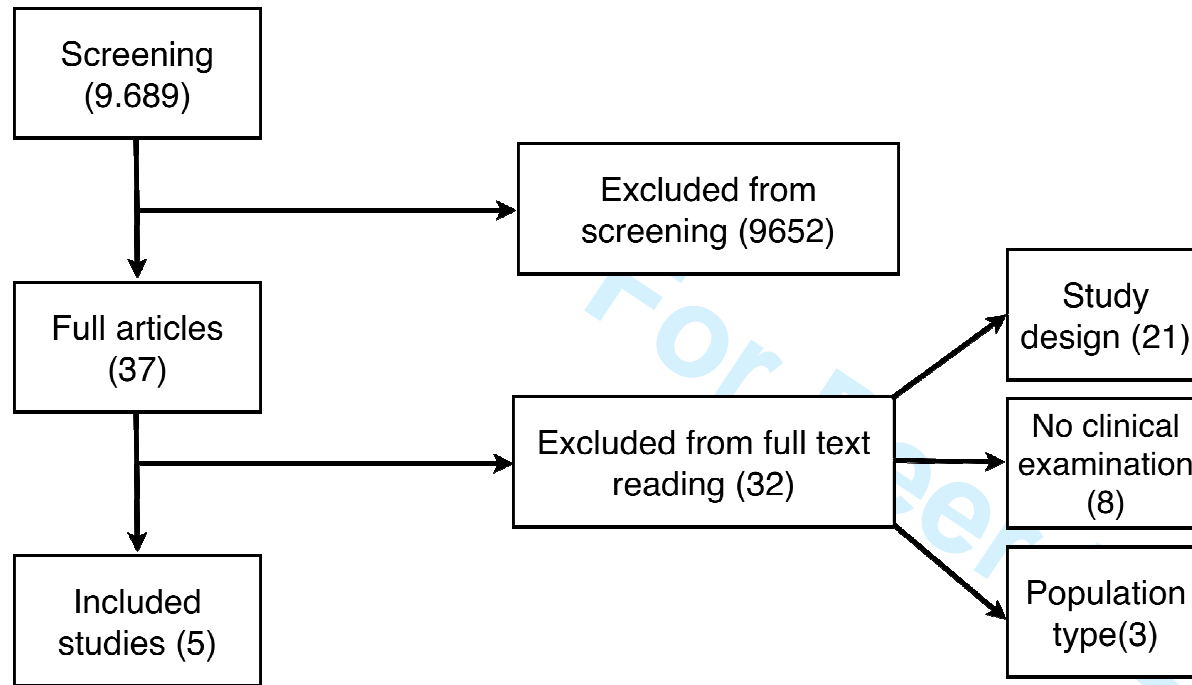


Table 1: Included study characteristics

<i>Authors</i> <i>(Type of study)</i>	<i>Participants:</i> <i>1. Recruited</i> <i>2. Age mean (range)</i> <i>3. Drop-outs</i> <i>4. Dependency/intubated</i> <i>5. Duration of hospitalisation (observation period)</i>	<i>Type of oral care provided:</i> <i>1. Personnel</i> <i>2. Oral care regime</i> <i>3. Frequency</i> <i>4. Duration</i> <i>5. Adherence assessed</i>	<i>1. Hospital department</i> <i>2. Country</i>	<i>1. Type of oral care changes assessed (index used)</i> <i>2. Assessor</i> <i>3. Examiner training</i> <i>4. Blinding</i>	<i>Quality assessment scoring</i>
Prendergast et al. 2009 ⁴⁸ (Cohort study)	1. 45 patients 2. 49.16 years (18-85) 3. D0: 45 patients D1: 31 patients D10: 13 patients 4. Fully dependent (intubated) 5. 15.1 days (1-37) (12.8 days (1-31))	1. Nurse 2. Foam swabs or child toothbrush, toothpaste, sterile water or normal saline and lip lubricant. 3. Every 4-6 hours 4. 5-10 minutes 5. Yes (nurses' notes)	1. Neuroscience ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, dental health (OAG index) 2. Nurses (3) 3. Yes 4. Yes	5/5
Munro et al. 2006 ⁴⁷ (Cohort study)	1. 66 patients 2. 55 years (25-93) 3. D0: 66 patients D4: 37 patients D7: 21 patients 4. Fully dependent (intubated) 5. Not reported (4-7 days)	1. Not reported 2. Not reported 3. 2.58 times per day (0-7 range) 4. Not reported 5. Not reported	1. Respiratory ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, gingival bleeding, purulence, candidiasis, calculus, caries, stain (Oral health assessment tool) 2. Not reported 3. Not reported 4. Not reported	5/5
Dennesen et al. 2003 ⁴⁶ (Cohort study)	1. ICU: 24 patients CS: 20 patients 2. ICU: 58 years (SD 18.6) CS: 61 years (41-77) 3. Not reported 4. ICU: intubated CS: intubated for less than 12 hours 5. ICU: 20.4 days (SD 7.5) (14 days) CS: Not reported	1. ICU: Not reported CS: Not reported 2. ICU: Sterile cloth drenched with NaCl 0.9% CS: Not reported 3. ICU: Not reported CS: Not reported 4. ICU: 2/day CS: Not reported 5. Not reported	1. ICU and Cardiosurgery Ward 2. Netherlands	1. Periodontal disease (CPITN) and Oral mucositis (Quantitative scale of oral mucositis) 2. Dental hygienists (2) 3. Not reported 4. Not reported	5/5

<i>Authors</i> <i>(Type of study)</i>	<i>Participants:</i> <i>1. Recruited</i> <i>2. Age mean (range)</i> <i>3. Drop-outs</i> <i>4. Dependency/intubated</i> <i>5. Duration of hospitalisation (observation period)</i>	<i>Type of oral care provided:</i> <i>1. Personnel</i> <i>2. Oral care regime</i> <i>3. Frequency</i> <i>4. Duration</i> <i>5. Adherence assessed</i>	<i>1. Hospital department</i> <i>2. Country</i>	<i>1. Type of oral care changes assessed (index used)</i> <i>2. Assessor</i> <i>3. Examiner training</i> <i>4. Blinding</i>	<i>Quality assessment scoring</i>
Franklin et al. 2000 ⁴⁵ (Cohort study)	1. 59 children 2. 4.8 (1-16) 3. 5 children 4. 12 children orally intubated. The rest nasally intubated or not intubated 5. 7.4 days (SD 6.2)	1. Nurses 2. Foam sticks moistened with water. Antiseptics and antifungals were used at the discretion of the nurses. 3. Every 4-6 hours 4. Not reported 5. Not reported	1. Pediatric ICU 2. UK	1. Caries, missing, filled teeth (DMF index), dental plaque accumulation (O' Leary index), gingival inflammation (binary assessment), spontaneous gingival bleeding (binary assessment) 2. Author 3. Not reported 4. Not reported	5/5
Fourrier et al. 1998 ⁴⁴ (Cohort study)	1. 57 patients 2. 49 years (18-83) 3. 29 patients 4. 44 patients intubated (77%) 5. 14 days (2-82) (15 patients for 5 days and 13 patients for 10 days)	1. Not reported 2. Not reported 3. Not reported 4. Not reported 5. Not reported	1. ICU 2. France	1. Dental plaque accumulation (Plaque index from one tooth) 2. Not reported 3. Not reported 4. Not reported	5/5

Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community Periodontal Index for Treatment Needs // "DMFT index": Decayed, missed and filled teeth index //

Table 2: Reported results from included studies

Authors	Number of patients and duration of observation period	Dental plaque (index)	Gingival health (index)	Periodontal health (index)	Caries (index)	Stomatological disease incidence (index)	Other outcome measures
Prendergast et al. 2009 ⁴⁸	D0: 45 patients D4: 31 patients D7: 19 patients D10: 11 patients Mean period: 12.8 days (SD 7.5)	Median values OAG: 1st-3rd quartile D0: 2 (2-2) D4: 2 (2-3) D7: 2 (2-3) D14: 2 (2-3)	Median values OAG: 1st-3rd quartile D0: 1 (1-1) D4: 2 (1-2)* D7: 1 (1-2) D14: 2 (2-3)* * statistically significant from baseline	Not reported	Not reported	Median values OAG: 1st-3rd quartile D0: 1 (1-2) D4: 2 (1-2)* D7: 1 (2-2)* D14: 2 (1-2)	Total score in median values OAG⁴⁶: 1st-3rd quartile D0: 12 (11-14) D4: 14 (13-15)* D7: 15 (12-17)* D10: 16 (14-17)* * statistically significant from baseline
Munro et al. 2006 ⁴⁷	D0: 66 patients D4: 37 patients D7: 21 patients	Oral health assessment tool D0: 21.27 (SD 23.66) D4: 22.72 (SD 20.47) D7: 24.32 (SD 29.01)	No data presented	No data presented	No data presented	No data presented	Oral health assessment tool^{21, 53}
Dennesen et al. 2003 ⁴⁶	ICU: 24 patients for 20.4 days (SD 7.5) CS: 20 patients for 15 days	Not reported	CPITN No data presented "No changes" reported	CPITN No data presented "No changes" reported	Not reported	Median mucositis index ICU: D0: 2 (SD 3.2) D21: 19 (SD 5.9) CS: No mucositis found	% subjects n ICU: D0: 79% D7: 25% D14: 12% D21: 0% Quantitative scale of oral mucositis⁵⁴ 0-39 (health: 0) D0: 2±3.2 D21: 19±5.9
Franklin et al. 2000 ⁴⁵	54 children for 7,5 days (SD 6.2)	O'Leary plaque index D0: 22.5% (SD 17.7) Discharge: 25.8% (SD 18.5) Mean difference: 3.3% 95% CI: 1-4.53 p: 0.001	Presence of gingival inflammation (yes/no) D0: 4.1 sites Discharge: 5.5 sites Mean difference: 1.4 sites 95% CI: 0.4-2.3 p: 0.006 Spontaneous gingival bleeding D0: 0.1 sites (SD 0.5) Discharge: 0.2 sites (SD 1.1) No statistically significant differences	Not reported	DMFT index D0: Primary teeth: 1.0 (SD 2.2) Permanent teeth: 1.2 (SD 1.9) Discharge: "No changes" reported	Not reported	
Fourrier et al. 1998 ⁴⁴	Group 1: 15 patients for 5 days Group 2: 13 patients for 10 days	Plaque index (one tooth) Group 1: D0: 1.1 (SD 0.7) D5: 1.6 (SD 0.7) Group 2: D0: 1.0 (SD 0.7) D5: 1.6 (SD 0.6)* D10: 2.0 (SD 0.4)** *statistically significant different (p< 0.05) ** statistically significant different (p<0.001)	Not reported	Not reported	Not reported	Not reported	

1 Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community
2 Periodontal Index for Treatment Needs // "DMFT index": Decayed, missed and filled teeth index //

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For Peer Review

APPENDICES

Search strategy for Ovid Medline

1. exp Hospitalization/
2. Hospital*.mp.
3. exp Intensive Care Units/
4. Intensive care unit*.mp.
5. Intensive care ward*.mp.
6. ICU.mp.
7. Dental deposit*.mp.
8. Dental plaque.mp.
9. Dental calculus.mp.
10. Plaque accumulation.mp.
11. Plaque score.mp.
12. exp Dental Health Surveys/
13. Periodontal index.mp.
14. Gingival index.mp.
15. DMF index.mp.
16. exp Oral Hygiene/
17. Oral hygiene.mp.
18. Oral clean*.mp.
19. exp candidiasis, oral/ or exp mucositis/ exp oral hemorrhage/ or exp periodontal diseases/ or exp stomatitis/
20. Periodont*.mp.
21. Periodontal attachment loss.mp.
22. Periodontal pocket*.mp.

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23. Gingival pocket*.mp.
 24. Probing depth*.mp
 25. Bleeding on probing.mp.
 26. Gingival hemorrhage.mp.
 27. Gingival hemorrhage.mp.
 28. Gingival haemorrhage.mp.
 29. Oral mucositis.mp.
 30. Stomatitis.mp.
 31. tooth diseases/ or exp dental deposits/ or exp dental calculus/ or exp dental plaque/ or exp smear layer/ or exp
tooth demineralization/ or exp dental caries/
 32. Dental caries.mp.
 33. Tooth decay.mp.
 34. Tooth demineralisation.mp.
 35. Tooth demineralization.mp.
 36. Tooth decalcification.mp.
 37. Tooth extraction.mp.
 38. Tooth loss.mp.
 39. exp Oral Health/
 40. Oral health.mp.
 41. or/1-6
 42. or/7-40
 43. 41 and 42

Search strategy for EMBASE

1. exp hospital patient/
2. exp hospitalization/
3. hospital*.mp.
4. exp intensive care/ or exp intensive care unit/
5. intensive care unit*.mp.

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- 2 6. Intensive care ward*.mp.
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- 4 7. ICU.mp.
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- 6 8. exp tooth calculus/
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- 8 9. exp tooth plaque/
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- 10 10. exp mouth hygiene/
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- 14 12. periodontal disease/
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- 16 13. exp periodontitis/
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- 18 14. exp thrush/
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- 20 15. exp stomatitis/
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- 22 16. exp dental caries/
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- 24 17. exp tooth extraction/
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- 26 18. dental deposit*.mp.
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- 28 19. dental calculus.mp
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- 30 20. dental plaque.mp.
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- 44 27. periodont*.mp.
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- 46 28. gingiv*.mp.
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- 52 31. tooth demineralization.mp.
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- 54 32. tooth decalcification.mp.
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- 58 34. tooth extraction.mp.
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36. DMF index.mp

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37. plaque score.mp.
 38. or/1-7
 39. or/8-37
 40. 38 and 39

Search strategy for CINAHL

1. (MH "Hospitalization+")
2. TX hospital*
3. (MH "Intensive Care Units+")
4. TX intensive care unit*
5. TX intensive care ward*
6. TX ICU
7. (MH "Tooth Diseases+")
8. (MH "Mouth Diseases+")
9. (MH "Oral Hygiene+")
10. (MH "Oral Health")
11. TX dental deposit*
12. TX dental calculus
13. TX plaque accumulation
14. TX periodont*
15. TX gingiv*
16. TX stomatitis
17. TX oral candid*
18. TX oral mucositis
19. TX dental caries
20. TX tooth decay
21. TX tooth demineralization
22. TX tooth decalcification
23. TX tooth decalcification
24. TX tooth loss

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25. TX tooth extraction
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31. TX DMF index
32. TX oral clean*
33. TX oral hygiene
34. TX oral health
35. or/1-6
36. or/7-33
37. 35 and 36

For Peer Review

Modified quality assessment scale for cohort studies (based on Newcastle-Ottawa scale)

(Note: A study can be awarded a maximum of one star for each numbered item with the selection and outcome categories.)

Selection

1) Representativeness of the cohort:

- a) truly representative of the average hospitalised patients in the community (*)
- b) somewhat representative of the average hospitalised patients in the community (*)
- c) selected group of users eg nurses, volunteers
- d) no description of the derivation of the cohort

2) Ascertainment of exposure:

- a) secure record (eg surgical records) (*)
- b) structured interview (*)
- c) written self report
- d) no description

4) Demonstration that outcome of interest at baseline:

- a) yes (*)
- b) no

Outcome

1) Assessment of outcome:

- a) independent blind assessment (*)
- b) record linkage (*)
- c) self report
- d) no description

2) Was follow-up long enough for outcomes to occur:

- a) yes (3-5 days for plaque and gingival changes)(*)
- b) no

3) Adequacy of follow up of cohorts:

- a) complete follow up - all subjects accounted for (*)
- b) subjects lost to follow up unlikely to introduce bias - small number lost (subjects lost due to death or discharge from the hospital or unit) (*)
- c) no description of those lost or loss due to other reasons than death or discharge from the hospital/unit.
- d) no statement

The impact of hospitalisation on oral health. A systematic review.

Running title: Hospitalisation and oral health

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Keywords: Oral health, oral hygiene, hospitalization, hospital acquired infections

Word count:

Funding and conflict of interest

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Clinical relevance

Scientific rationale for study: Poor oral health is recognised as a potential risk factor for hospital acquired infections. Therefore a systematic review of the evidence for the effect of hospitalisation on oral health is needed.

Principal findings: The evidence suggests that oral health deteriorates during hospitalisation. However, few studies have investigated this question and the strength of evidence is limited.

Practical implications: Oral care during hospitalisation needs to be strengthened together with further research investigating oral health changes in different settings and factors that facilitate the provision of care.

ABSTRACT

Background: Poor oral health of hospitalised patients is associated with an increased risk of hospital acquired infections and reduced life quality

Objectives: To systematically review the evidence on oral health changes during hospitalisation.

Data sources: Cochrane library, Medline, OldMedline, Embase and CINAHL without language restrictions.

Study eligibility criteria: Observational longitudinal studies that measured the effect of hospitalisation on oral health.

Data appraisal and synthesis methods: Two independent reviewers screened studies for inclusion, assessed risk of bias and extracted data. Risk of bias was assessed with the Ottawa Newcastle assessment scale. Pooling of data was based on the study design, population characteristics, types of oral hygiene measures used in the hospital units, characteristics of the settings of the studies and outcomes measured. A narrative synthesis was conducted.

Results: Five studies were included. The data show a deterioration in oral health following hospitalisation with an increase in dental plaque accumulation and gingival inflammation and a deterioration in mucosal health.

Limitations: Risk of bias was judged to be low although methodological issues such as unvalidated outcome measures and lack of assessor training limit the strength of the evidence.

Conclusion: Hospitalisation is associated with a deterioration in oral health, particularly in intubated patients

Word count: 199

INTRODUCTION

Maintenance of oral health is important for hospitalised patients. Oral health affects quality of life (Llewellyn & Warnakulasuriya 2003, Yu et al. 2008) and personal dignity and this impact appears to be more severe in medically compromised or hospitalised patients (Duke et al. 2005, Ingram et al. 2005, Locker et al. 2002, McMillan et al. 2005, Mulligan et al. 2008). Not surprisingly, poor oral health or dysfunction can also have a negative effect on nutritional status (Chai et al. 2006, Gil-Montoya et al. 2008, Rauen et al. 2006), whilst improvement of dental status raises levels of nutritional markers (Wostmann et al. 2008).

Poor oral health and oral hygiene can also contribute to an increased incidence of hospital acquired infections, particularly respiratory diseases (Azarpazhooh & Leake 2006, Shaw 2005). Furthermore, interventions that maintain or improve oral health can reduce the incidence of ventilator associated pneumonia (Chan et al. 2007). Similarly, benefits from effective oral hygiene have also been documented for pneumonia in non ambulatory (Scannapieco 2006) or elderly patients (Sjogren et al. 2008). Therefore, oral health requires management during in-patient care. Therefore, oral health requires management during in-patient care.

Although oral health can be maintained during hospitalisation with proper training of the caregivers (Peltola et al. 2007), there are difficulties in the provision of adequate oral care in hospitals and institutional facilities. Barriers to effective oral care reported by caregivers include the low priority of oral care (Grap et al. 200, Landstrom et al. 2009), fear of causing pain or injury to the patients (Jablonski et al. 2009), the perception that oral care does not provide significant benefits (Binkley et al. 2004, Jones et al. 2004), patients' resistive behaviours (Jablonski, Munro, Grap et al. 2009), inadequate nurse staffing (Grap et al. 2003) and lack of supplies (Jablonski, Munro, Grap et al. 2009). To encourage provision of

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3 effective oral care, guidelines have been published with recommended protocols for
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5 hospitalised patients (Department of Health 2003, Department of Health 2007, Fiske et al.
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7 2000, NICE 2008, Tablan et al. 2004). However, the adherence to oral health protocols, is
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9 reported to be low (Grap et al. 2003, Rello et al. 2007).
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13 Whilst oral health status during hospitalisation is clearly an important public health
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15 issue, no systematic review has been conducted to critically evaluate the research data on
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17 this topic. The aim of this systematic review was therefore to address the focussed question,
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19 what is the effect of hospitalisation on oral health?
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22 23 24 25 26 **METHODS**

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28 We considered as eligible longitudinal prospective observational studies in people of all ages
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30 being hospitalised, that assessed changes of the following outcomes; tooth loss, any
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32 measures of periodontal health, dental caries and stomatological disease. Intervention
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34 studies, cross sectional studies, case reports and reviews were excluded. Studies reporting
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36 specifically on patients with psychiatric disorders or on patients receiving treatment with
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38 frequently observed oral complications (e.g. chemo- or radiotherapy) were excluded.
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46 **Search strategy**

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48 The literature search for relevant articles was performed using Ovid MEDLINE and Ovid
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50 OLDMEDLINE (dating from January 1950 to January 2010), Cumulative Index to Nursing and
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52 Allied Health Literature (CINAHL) (dating from 1982 to January 2010), Cochrane Library (up
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54 to 2010) and EMBASE (dating from 1981 to January 2010). We designed a sensitive search
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56 strategy as we anticipated that coding for relevant search terms was not well developed.
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60 The bibliographies of all potentially relevant studies and review articles were also searched.

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3 Handsearching was performed in the following journals; *Community Dentistry and Oral*
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6 *Epidemiology, Gerodontology, Journal of Disability and Oral Health and Special Care in*
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8 *Dentistry*. No language restrictions were applied on the search. When necessary we
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10 corresponded with the first authors of studies to elicit further information. One reviewer
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12 (ET) scanned the titles and abstracts of the studies identified by the search. When a study
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14 seemed to meet the eligibility criteria or information was insufficient to exclude, full text
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16 articles were obtained.
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20 21 22 23 **Data extraction**

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26 Two reviewers (ET, EPA) independently screened all full text articles. They also extracted
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28 data from the included studies in specially designed forms. Disagreements that could not be
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30 resolved were arbitrated by a third author (IN). Training of reviewers for screening, study
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32 eligibility and quality assessment was performed by an experienced systematic review
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34 methodologist (IN). The calibration of the examiners was made on five randomly selected
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36 studies included for full paper screening.
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43 44 **Quality assessment**

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46 Studies were assessed by the two reviewers (ET, EPA) using the Newcastle-Ottawa scale for
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48 cohort studies (Wells et al. 2008). Since we did not find studies with a non-exposed
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50 comparison group we omitted the comparability section of the scale. In addition, we
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52 assessed whether a power calculation was reported for each study and if so, the magnitude
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54 of a change that the study was powered to detect. Separately, we assessed the quality of
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56 the outcome assessment in terms of validity of the measure of oral health and
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58 conduct/reporting of assessor training in the measure.
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Data synthesis

Pooling of data was based on the study design, population characteristics, types of oral hygiene measures used in the hospital units, setting characteristics of the studies and outcomes measured. We anticipated substantial heterogeneity between studies and planned a narrative synthesis of data.

RESULTS

A total of 9689 potentially relevant review records were found. 9652 were excluded on the basis of their titles or abstracts and the full papers of 37 studies were retrieved. Five papers were finally included (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006, Prendergast et al. 2009). (Fig 1) Inter-examiner agreement for eligibility of included papers was 100%. The most common reasons for exclusion were no reported oral health outcomes or study design (e.g. intervention, cross sectional or retrospective).

Quality assessment

Agreement between reviewers on each aspect of the Newcastle-Ottawa scale was 100%. In all studies the representativeness of the cohort was found to be adequate and the demonstration of outcomes of interest was made at baseline. Adequacy of follow up was judged to be good in all studies, considering the healthcare setting, despite the drop outs encountered. This was based on the fact that the reasons for drop out were either death or discharge from the hospital unit (Franklin et al. 2000, Munro et al. 2006, Prendergast et al. 2009). The assessment of outcome was judged to be adequate for all studies in terms of the Newcastle-Ottawa criteria and the follow up period was long enough for the assessment of

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3 dental plaque and gingival health changes. This period was arbitrarily defined as a minimum
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5 of three to five days (Eilers et al. 1988, Fitch et al. 1999) although too brief to detect either
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7 dental caries incidence or changes in periodontitis. The validity of the outcome measures
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9 was more problematic including the use of subjective indices based on visual analogue scale
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11 measurements (Munro et al. 2006), assessments of gingival health with tools designed for
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13 population epidemiology (Dennesen et al. 2003) and use of partial recordings with indices
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15 not designed for this purpose (Fourrier et al. 1998). In addition, examiner training was
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17 reported in only one study (Prendergast et al. 2009).
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26 **Population characteristics**

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28 Four studies were located in ICU units (Fourrier et al. 1998, Franklin et al. 2000, Munro et al.
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30 2006, Prendergast et al. 2009) and one investigated a mixed population of patients in ICU
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32 and a cardiosurgical ward (Dennesen et al. 2003). The population in three studies was
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34 intubated (Fourrier et al. 1998, Munro et al. 2006, Prendergast et al. 2009), while in two, the
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36 population was both intubated and not intubated (Dennesen et al. 2003, Franklin et al.
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38 2000). One study investigated children only (Franklin et al. 2000), while the remainder
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40 reported on adult populations. The duration of the hospitalisation ranged from five to
41
42 twenty days.
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51 **Oral care regime**

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53 There was marked variability in oral care protocols including sterile cloth drenched with
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55 0.9% saline (Dennesen et al. 2003), rinsing with sterile water (Fourrier et al. 1998),
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57 foamsticks moistened with water (Franklin et al. 2000) and foam swabs or child
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59 toothbrushes with toothpaste, sterile water or normal saline (Prendergast et al. 2009). In
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3 one study, there were no details of the oral hygiene measures applied (Munro et al. 2006).
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6 Frequency of oral care provision ranged between two to six times per day.
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10 **Study setting**

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12 Two studies were based in the USA (Munro et al. 2006, Prendergast et al. 2009), one in the
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14 UK (Franklin et al. 2000), one in France (Fourrier et al. 1998) and one in the Netherlands
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16 (Dennessen et al. 2003).
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20 **Power calculation**

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22 Power calculation was reported in only one study (Franklin et al. 2000). The sample size was
23
24 estimated to identify a difference of 10 plaque covered surfaces significant at 5% with a
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26 power of 90% using a standard deviation of 15.0 for plaque on all tooth surfaces.
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34 **Dental plaque accumulation**

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36 Four out of the five included studies reported on the changes of dental plaque accumulation
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38 during hospitalisation period (Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006,
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40 Prendergast et al. 2009). Each study used a different measure. In one study no differences
41
42 were observed during the observational period (Prendergast et al. 2009). Three studies
43
44 reported increasing levels of plaque accumulation during hospitalisation (Fourrier et al.
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46 1998, Franklin et al. 2000, Munro et al. 2006), which was statistically significant in two
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48 (Fourrier et al. 1998, Franklin et al. 2000). The proportion of sites with abundant dental
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50 plaque (scores more than 2) increased from 23% at baseline to 93% at day 10 (Fourrier et al.
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52 1998) and the other study showed mean difference of 3.3% in the O'Leary index ($p=0.001$)
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54 (Franklin et al. 2000).
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Gingival inflammation

Three studies reported on the levels of gingival inflammation during hospitalisation using different indices (Dennesen et al. 2003, Franklin et al. 2000, Prendergast et al. 2009). Two of the studies found statistically significant increases in the severity of gingival inflammation. (OAG median value changes from 1 at baseline to 2 at day 14 (Prendergast et al. 2009) and mean difference of the sites presenting gingival inflammation of 1.4 (p=0,006) (Franklin et al. 2000)) One study reported 'no statistically significant changes' although no data were presented (Dennesen et al. 2003).

Periodontal disease

One study reported on the severity of periodontal disease using an index of assessment of treatment needs, but found no statistically significant change (Dennesen et al. 2003). However, this index was designed for epidemiology and is insensitive to small changes over short durations of time (Holmgren 1994).

Caries incidence

Two studies assessed the incidence of dental caries in hospitalised patients and reported no statistically significant changes following hospitalisation (Franklin et al. 2000, Munro et al. 2006).

Stomatological disease

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3 Two studies evaluated the incidence of stomatological diseases (Dennessen et al. 2003,
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5 Prendergast et al. 2009). Both studies found a statistically significant increased incidence of
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7 mucositis intubated patients but with not in non-intubated patients (Dennessen et al. 2003).
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10 11 12 13 **DISCUSSION**

14 15 16 Statement of principal findings

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18 The five included studies suggest that oral health deteriorates following hospitalisation.

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20 Most studies were set in intensive care units including both intubated and non-intubated
21
22 patients. Dental plaque accumulation and gingival and mucosal inflammation were the main
23
24 oral health aspects affected in the examined populations and the findings were more
25
26 evident in studies reporting on intubated patients (Dennessen et al. 2003, Franklin et al.
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28 2000).
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36 37 Strengths and weaknesses of the review

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39 We conducted a sensitive search including multiple electronic databases without language
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41 restriction and supplemented by handsearching. However, we were only able to identify five
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43 eligible studies enrolling a total of 271 patients. We were unable to retrieve two papers for
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45 the full article reading. Their abstracts were unavailable in the databases and the no records
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47 of the journals were found in British Library. Other strengths of the review are that we
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49 appraised the methodological quality and risk of bias of included studies including the
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51 validity of the outcome measures in relation to oral health changes.
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59 Since most of the studies were conducted in intensive care units, the results cannot be
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extrapolated to other hospital settings. Other than intubation, differences with other

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3 settings could include level of dependency of patients for oral care, ease of provision of oral
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5 care and availability of staff to provide such care.
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10 The quality of the evidence included in the review was affected by a number of
11
12 methodological issues. Firstly, there was marked heterogeneity in the oral care routines
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14 and in addition, adherence to oral care was not reported in the majority of studies.
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16 Secondly, a wide variety of indices for assessing of oral health were employed and their
17
18 validity was not clear. Validity issues included the use of subjective indices based on visual
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20 analogue scale measurements (Munro et al. 2006), assessments of gingival health with
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22 epidemiological tools (Dennessen et al. 2003) and use of partial recordings with indices not
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24 designed for this purpose (Fourrier et al. 1998). Furthermore, examiner training in this
25
26 testing setting was reported in only one study (Prendergast et al. 2009). The duration of
27
28 follow-up was limited (to a maximum of 20 days) due to the nature of the hospitalisation.
29
30 Although this period was adequate for the detection of changes in some oral health
31
32 outcomes such as dental plaque accumulation (Theilade et al. 1966) and gingival
33
34 inflammation (Loe et al. 1965), longer observational periods are required for the detection
35
36 of a change in periodontitis (Goodson et al. 1982) or dental caries occurrence (Pitts and
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38 Stamm 2004). Finally, power calculations were reported in only one study (Franklin et al.
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40 2000), thus hindering the interpretation of findings.
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52 Strengths and weaknesses in relation to other reviews
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55 We have not found other systematic reviews addressing this research question. However, a
56
57 clinical effectiveness review was published in 1999 investigating oral care practices by
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59 nurses (Bowsher et al. 1999). The published report is limited in details of methodology
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3 making comparison difficult. However, the findings, even though published more than a
4
5 decade ago, appear to hold true 'This review confirms that current practice largely ignores
6
7 the research evidence and is inadequate for ensuring optimum care. There is a clear need to
8
9 develop and evaluate oral care protocols for hospitalised patients and to support nurses in
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11 their implementation.'
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18 Meaning of the review, possible explanations and implications for clinicians and policy
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20 makers.
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23 This review suggests that hospitalisation is associated with a deterioration in oral health and
24
25 this could have profound implications for health and wellbeing. On the basis of current
26
27 evidence, a deterioration in oral health would be expected to increase the risk of hospital
28
29 acquired infections, increase care costs and have negative impact on health related quality
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31 of life.
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38 We were not able to conclude whether this impact results from a low priority of oral care
39
40 provision, the implementation of improper oral care regimes, from hospitalisation per se or
41
42 from a combination of factors. Guidelines for the provision of oral care in hospital settings
43
44 have been published (Department of Health 2003, Department of Health 2007, Fiske, et al.
45
46 2000, NICE 2008, Tablan et al. 2004) although they provide limited detail for carers.
47
48 Additional protocols/guidelines are therefore needed and should be based on the best
49
50 available evidence with sufficient detail to guide carers and patients. Such development
51
52 should include the breadth of relevant stakeholders such as nursing, medical and dental
53
54 professionals as well as patients and address the different settings in which will need to be
55
56 provided such as units with fully dependent patients and those where patients are able to
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1
2
3 carry out oral hygiene themselves. More challenging will be implementation (Rello et al.
4
5
6 2007) and this will need to be planned together with evaluation of success prior to
7
8 introduction.
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11
12 In terms of interventions, chemical plaque control was the regime of choice in three out of
13
14 five included studies (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000).
15
16 Although the clinical application of chemicals such as antiseptics seems straightforward,
17
18 their effect against established dental plaque is marginal due to its organisation as a biofilm
19
20 in which bacteria are considerably less sensitive to antimicrobial treatments than free-living
21
22 planktonic bacteria (Pratten et al. 1998). This is corroborated by a systematic review of
23
24 chlorhexidine for VAP prevention which reported no effect on VAP incidence (Pineda et al.
25
26 2006). Therefore, mechanical removal or disruption of dental plaque will be needed such as
27
28 can be achieved through toothbrushing.
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37 Suggestions for further research

38
39 More robust evidence is needed to understand the impact of hospitalisation on oral health.
40
41 In particular, we recommend studies conducted in a wider range of hospital settings
42
43 including outside of critical care units. There are many outcomes measures that are
44
45 validated in oral health research and these should be selected for hospital-based studies.
46
47 Furthermore, training of examiners should be provided together and outcomes of training
48
49 (such as agreement levels) reported. Where feasible, longer observational periods could be
50
51 employed to investigate other oral health outcomes such as dental caries and periodontitis.
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2
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10
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1
2 **Contibutorship**
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4

5
6 IGN conceived the study. All authors contributed to the study protocol, interpretation of results
7
8 and manuscript. ET conducted the search and initial screening. ET and EA conducted the full-text
9
10 screening and data abstraction. ET wrote the first draft of the manuscript.
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14 IGN is guarantor:
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For Peer Review

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Figure 1: Flowchart of inclusion of studies

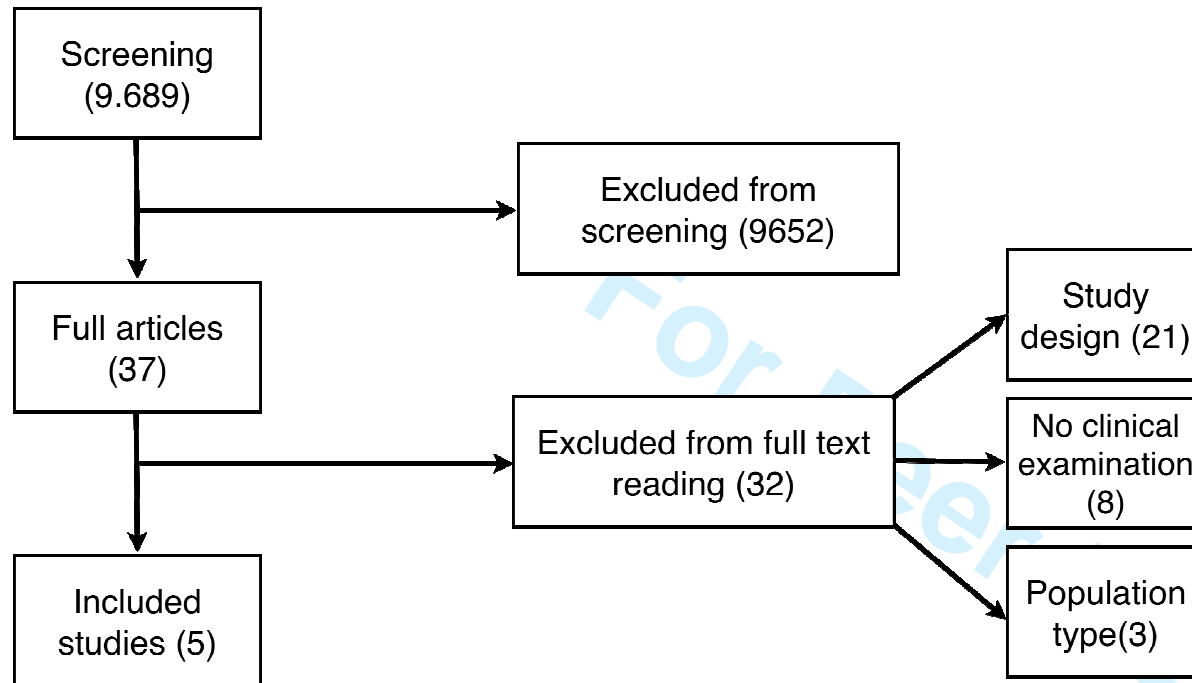


Table 1: Included study characteristics

<i>Authors</i>	<i>Participants:</i>	<i>Type of oral care provided:</i>	<i>1. Hospital department 2. Country</i>	<i>1. Type of oral care changes assessed (index used) 2. Assessor 3. Examiner training 4. Blinding</i>	<i>Quality assessment scoring</i>
<i>(Type of study)</i>	<i>1. Recruited 2. Age mean (range) 3. Drop-outs 4. Dependency/intubated 5. Duration of hospitalisation (observation period)</i>	<i>1. Personnel 2. Oral care regime 3. Frequency 4. Duration 5. Adherence assessed</i>			
Prendergast et al. 2009 ⁴⁸ (Cohort study)	1. 45 patients 2. 49.16 years (18-85) 3. D0: 45 patients D1: 31 patients D10: 13 patients 4. Fully dependent (intubated) 5. 15.1 days (1-37) (12.8 days (1-31))	1. Nurse 2. Foam swabs or child toothbrush, toothpaste, sterile water or normal saline and lip lubricant. 3. Every 4-6 hours 4. 5-10 minutes 5. Yes (nurses' notes)	1. Neuroscience ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, dental health (OAG index) 2. Nurses (3) 3. Yes 4. Yes	5/5
Munro et al. 2006 ⁴⁷ (Cohort study)	1. 66 patients 2. 55 years (25-93) 3. D0: 66 patients D4: 37 patients D7: 21 patients 4. Fully dependent (intubated) 5. Not reported (4-7 days)	1. Not reported 2. Not reported 3. 2.58 times per day (0-7 range) 4. Not reported 5. Not reported	1. Respiratory ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, gingival bleeding, purulence, candidiasis, calculus, caries, stain (Oral health assessment tool) 2. Not reported 3. Not reported 4. Not reported	5/5
Dennesen et al. 2003 ⁴⁶ (Cohort study)	1. ICU: 24 patients CS: 20 patients 2. ICU: 58 years (SD 18.6) CS: 61 years (41-77) 3. Not reported 4. ICU: intubated CS: intubated for less than 12 hours 5. ICU: 20.4 days (SD 7.5) (14 days) CS: Not reported	1. ICU: Not reported CS: Not reported 2. ICU: Sterile cloth drenched with NaCl 0.9% CS: Not reported 3. ICU: Not reported CS: Not reported 4. ICU: 2/day CS: Not reported 5. Not reported	1. ICU and Cardiosurgery Ward 2. Netherlands	1. Periodontal disease (CPITN) and Oral mucositis (Quantitative scale of oral mucositis) 2. Dental hygienists (2) 3. Not reported 4. Not reported	5/5

<i>Authors</i> <i>(Type of study)</i>	<i>Participants:</i> <i>1. Recruited</i> <i>2. Age mean (range)</i> <i>3. Drop-outs</i> <i>4. Dependency/intubated</i> <i>5. Duration of hospitalisation (observation period)</i>	<i>Type of oral care provided:</i> <i>1. Personnel</i> <i>2. Oral care regime</i> <i>3. Frequency</i> <i>4. Duration</i> <i>5. Adherence assessed</i>	<i>1. Hospital department</i> <i>2. Country</i>	<i>1. Type of oral care changes assessed (index used)</i> <i>2. Assessor</i> <i>3. Examiner training</i> <i>4. Blinding</i>	<i>Quality assessment scoring</i>
Franklin et al. 2000 ⁴⁵ (Cohort study)	1. 59 children 2. 4.8 (1-16) 3. 5 children 4. 12 children orally intubated. The rest nasally intubated or not intubated 5. 7.4 days (SD 6.2)	1. Nurses 2. Foam sticks moistened with water. Antiseptics and antifungals were used at the discretion of the nurses. 3. Every 4-6 hours 4. Not reported 5. Not reported	1. Pediatric ICU 2. UK	1. Caries, missing, filled teeth (DMF index), dental plaque accumulation (O' Leary index), gingival inflammation (binary assessment), spontaneous gingival bleeding (binary assessment) 2. Author 3. Not reported 4. Not reported	5/5
Fourrier et al. 1998 ⁴⁴ (Cohort study)	1. 57 patients 2. 49 years (18-83) 3. 29 patients 4. 44 patients intubated (77%) 5. 14 days (2-82) (15 patients for 5 days and 13 patients for 10 days)	1. Not reported 2. Not reported 3. Not reported 4. Not reported 5. Not reported	1. ICU 2. France	1. Dental plaque accumulation (Plaque index from one tooth) 2. Not reported 3. Not reported 4. Not reported	5/5

Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community Periodontal Index for Treatment Needs // "DMFT index": Decayed, missed and filled teeth index //

Table 2: Reported results from included studies

Authors	Number of patients and duration of observation period	Dental plaque (index)	Gingival health (index)	Periodontal health (index)	Caries (index)	Stomatological disease incidence (index)	Other outcome measures
Prendergast et al. 2009 ⁴⁸	D0: 45 patients D4: 31 patients D7: 19 patients D10: 11 patients Mean period: 12.8 days (SD 7.5)	Median values OAG: 1st-3rd quartile D0: 2 (2-2) D4: 2 (2-3) D7: 2 (2-3) D14: 2 (2-3)	Median values OAG: 1st-3rd quartile D0: 1 (1-1) D4: 2 (1-2)* D7: 1 (1-2) D14: 2 (2-3)* * statistically significant from baseline	Not reported	Not reported	Median values OAG: 1st-3rd quartile D0: 1 (1-2) D4: 2 (1-2)* D7: 1 (2-2)* D14: 2 (1-2)	Total score in median values OAG⁴⁶: 1st-3rd quartile D0: 12 (11-14) D4: 14 (13-15)* D7: 15 (12-17)* D10: 16 (14-17)* * statistically significant from baseline
Munro et al. 2006 ⁴⁷	D0: 66 patients D4: 37 patients D7: 21 patients	Oral health assessment tool D0: 21.27 (SD 23.66) D4: 22.72 (SD 20.47) D7: 24.32 (SD 29.01)	No data presented	No data presented	No data presented	No data presented	Oral health assessment tool^{21, 53}
Dennesen et al. 2003 ⁴⁶	ICU: 24 patients for 20.4 days (SD 7.5) CS: 20 patients for 15 days	Not reported	CPITN No data presented "No changes" reported	CPITN No data presented "No changes" reported	Not reported	Median mucositis index ICU: D0: 2 (SD 3.2) D21: 19 (SD 5.9) CS: No mucositis found	% subjects n ICU: D0: 79% D7: 25% D14: 12% D21: 0% Quantitative scale of oral mucositis⁵⁴ 0-39 (health: 0) D0: 2±3.2 D21: 19±5.9
Franklin et al. 2000 ⁴⁵	54 children for 7,5 days (SD 6.2)	O'Leary plaque index D0: 22.5% (SD 17.7) Discharge: 25.8% (SD 18.5) Mean difference: 3.3% 95% CI: 1-4.53 p: 0.001	Presence of gingival inflammation (yes/no) D0: 4.1 sites Discharge: 5.5 sites Mean difference: 1.4 sites 95% CI: 0.4-2.3 p: 0.006 Spontaneous gingival bleeding D0: 0.1 sites (SD 0.5) Discharge: 0.2 sites (SD 1.1) No statistically significant differences	Not reported	DMFT index D0: Primary teeth: 1.0 (SD 2.2) Permanent teeth: 1.2 (SD 1.9) Discharge: "No changes" reported	Not reported	
Fourrier et al. 1998 ⁴⁴	Group 1: 15 patients for 5 days Group 2: 13 patients for 10 days	Plaque index (one tooth) Group 1: D0: 1.1 (SD 0.7) D5: 1.6 (SD 0.7) Group 2: D0: 1.0 (SD 0.7) D5: 1.6 (SD 0.6)* D10: 2.0 (SD 0.4)** *statistically significant different (p< 0.05) ** statistically significant different (p<0.001)	Not reported	Not reported	Not reported	Not reported	

1 Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community
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APPENDICES

Search strategy for Ovid Medline

1. exp Hospitalization/
2. Hospital*.mp.
3. exp Intensive Care Units/
4. Intensive care unit*.mp.
5. Intensive care ward*.mp.
6. ICU.mp.
7. Dental deposit*.mp.
8. Dental plaque.mp.
9. Dental calculus.mp.
10. Plaque accumulation.mp.
11. Plaque score.mp.
12. exp Dental Health Surveys/
13. Periodontal index.mp.
14. Gingival index.mp.
15. DMF index.mp.
16. exp Oral Hygiene/
17. Oral hygiene.mp.
18. Oral clean*.mp.
19. exp candidiasis, oral/ or exp mucositis/ exp oral hemorrhage/ or exp periodontal diseases/ or exp stomatitis/
20. Periodont*.mp.
21. Periodontal attachment loss.mp.
22. Periodontal pocket*.mp.

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23. Gingival pocket*.mp.
 24. Probing depth*.mp
 25. Bleeding on probing.mp.
 26. Gingival hemorrhage.mp.
 27. Gingival hemorrhage.mp.
 28. Gingival haemorrhage.mp.
 29. Oral mucositis.mp.
 30. Stomatitis.mp.
 31. tooth diseases/ or exp dental deposits/ or exp dental calculus/ or exp dental plaque/ or exp smear layer/ or exp
tooth demineralization/ or exp dental caries/
 32. Dental caries.mp.
 33. Tooth decay.mp.
 34. Tooth demineralisation.mp.
 35. Tooth demineralization.mp.
 36. Tooth decalcification.mp.
 37. Tooth extraction.mp.
 38. Tooth loss.mp.
 39. exp Oral Health/
 40. Oral health.mp.
 41. or/1-6
 42. or/7-40
 43. 41 and 42

Search strategy for EMBASE

1. exp hospital patient/
2. exp hospitalization/
3. hospital*.mp.
4. exp intensive care/ or exp intensive care unit/
5. intensive care unit*.mp.

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- 2 6. Intensive care ward*.mp.
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- 6 8. exp tooth calculus/
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- 8 9. exp tooth plaque/
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- 12 11. exp mouth disease/
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- 14 12. periodontal disease/
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- 16 13. exp periodontitis/
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- 18 14. exp thrush/
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- 20 15. exp stomatitis/
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- 22 16. exp dental caries/
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- 24 17. exp tooth extraction/
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- 26 18. dental deposit*.mp.
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- 28 19. dental calculus.mp
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- 30 20. dental plaque.mp.
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- 32 21. plaque accumulation.mp.
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- 34 22. oral hygiene.mp.
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- 36 23. oral clean*.mp.
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- 38 24. oral candidiasis.mp.
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- 42 26. stomatitis.mp.
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- 44 27. periodont*.mp.
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- 52 31. tooth demineralization.mp.
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- 54 32. tooth decalcification.mp.
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- 56 33. tooth loss.mp.
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- 60 35. oral health.mp
36. DMF index.mp

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37. plaque score.mp.
 38. or/1-7
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Search strategy for CINAHL

1. (MH "Hospitalization+")
2. TX hospital*
3. (MH "Intensive Care Units+")
4. TX intensive care unit*
5. TX intensive care ward*
6. TX ICU
7. (MH "Tooth Diseases+")
8. (MH "Mouth Diseases+")
9. (MH "Oral Hygiene+")
10. (MH "Oral Health")
11. TX dental deposit*
12. TX dental calculus
13. TX plaque accumulation
14. TX periodont*
15. TX gingiv*
16. TX stomatitis
17. TX oral candid*
18. TX oral mucositis
19. TX dental caries
20. TX tooth decay
21. TX tooth demineralization
22. TX tooth decalcification
23. TX tooth decalcification
24. TX tooth loss

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25. TX tooth extraction
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29. TX gingival haemorrhage
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31. TX DMF index
32. TX oral clean*
33. TX oral hygiene
34. TX oral health
35. or/1-6
36. or/7-33
37. 35 and 36

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Modified quality assessment scale for cohort studies (based on Newcastle-Ottawa scale)

(Note: A study can be awarded a maximum of one star for each numbered item with the selection and outcome categories.)

Selection

1) Representativeness of the cohort:

- a) truly representative of the average hospitalised patients in the community (*)
- b) somewhat representative of the average hospitalised patients in the community (*)
- c) selected group of users eg nurses, volunteers
- d) no description of the derivation of the cohort

2) Ascertainment of exposure:

- a) secure record (eg surgical records) (*)
- b) structured interview (*)
- c) written self report
- d) no description

4) Demonstration that outcome of interest at baseline:

- a) yes (*)
- b) no

Outcome

1) Assessment of outcome:

- a) independent blind assessment (*)
- b) record linkage (*)
- c) self report
- d) no description

2) Was follow-up long enough for outcomes to occur:

- a) yes (3-5 days for plaque and gingival changes)(*)
- b) no

3) Adequacy of follow up of cohorts:

- a) complete follow up - all subjects accounted for (*)
- b) subjects lost to follow up unlikely to introduce bias - small number lost (subjects lost due to death or discharge from the hospital or unit) (*)
- c) no description of those lost or loss due to other reasons than death or discharge from the hospital/unit.
- d) no statement

1
2 **The impact of hospitalisation on oral health. A systematic review.**
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4 **Running title: Hospitalisation and oral health**
5

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37 Keywords: Oral health, oral hygiene, hospitalization, hospital acquired infections
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Clinical relevance

Scientific rationale for study: Poor oral health is recognised as a potential risk factor for hospital acquired infections. Therefore a systematic review of the evidence for the effect of hospitalisation on oral health is needed.

Principal findings: The evidence suggests that oral health deteriorates during hospitalisation. However, few studies have investigated this question and the strength of evidence is limited.

Practical implications: Oral care during hospitalisation needs to be strengthened together with further research investigating oral health changes in different settings and factors that facilitate the provision of care.

ABSTRACT

Background: Poor oral health of hospitalised patients is associated with an increased risk of hospital acquired infections and reduced life quality

Objectives: To systematically review the evidence on oral health changes during hospitalisation.

Data sources: Cochrane library, Medline, OldMedline, Embase and CINAHL without language restrictions.

Study eligibility criteria: Observational longitudinal studies.

Data appraisal and synthesis methods: Two independent reviewers screened studies for inclusion, assessed risk of bias and extracted data. Risk of bias was assessed with the Ottawa Newcastle assessment scale. A narrative synthesis was conducted.

Results: Five before and after studies were included. The data suggest a deterioration in oral health following hospitalisation with an increase in dental plaque accumulation and gingival inflammation and a deterioration in mucosal health.

Limitations: Whilst before and after studies are at a general risk of bias, other specific study characteristics were judged to be of low risk of bias. However, methodological issues such as unvalidated outcome measures and lack of assessor training limit the strength of the evidence.

Conclusion: Hospitalisation is associated with a deterioration in oral health, particularly in intubated patients.

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INTRODUCTION

Maintenance of oral health is important for hospitalised patients. Oral health affects quality of life (Llewellyn & Warnakulasuriya 2003, Yu et al. 2008) and personal dignity and this impact appears to be more severe in medically compromised or hospitalised patients (Duke et al. 2005, Ingram et al. 2005, Locker et al. 2002, McMillan et al. 2005, Mulligan et al. 2008). Not surprisingly, poor oral health or dysfunction can also have a negative effect on nutritional status (Chai et al. 2006, Gil-Montoya et al. 2008, Rauen et al. 2006), whilst improvement of dental status raises levels of nutritional markers (Wostmann et al. 2008).

Poor oral health and oral hygiene can also contribute to an increased incidence of hospital acquired infections, particularly respiratory diseases (Azarpazhooh & Leake 2006, Shaw 2005). Furthermore, interventions that maintain or improve oral health can reduce the incidence of ventilator associated pneumonia (Chan et al. 2007). Similarly, benefits from effective oral hygiene have also been documented for pneumonia in non ambulatory (Scannapieco 2006) or elderly patients (Sjogren et al. 2008). Therefore, oral health requires management during in-patient care. Therefore, oral health requires management during in-patient care.

Although oral health can be maintained during hospitalisation with proper training of the caregivers (Peltola et al. 2007), there are difficulties in the provision of adequate oral care in hospitals and institutional facilities. Barriers to effective oral care reported by caregivers include the low priority of oral care (Grap et al. 200, Landstrom et al. 2009), fear of causing pain or injury to the patients (Jablonski et al. 2009), the perception that oral care does not provide significant benefits (Binkley et al. 2004, Jones et al. 2004), patients' resistive behaviours (Jablonski, Munro, Grap et al. 2009), inadequate nurse staffing (Grap et al. 2003) and lack of supplies (Jablonski, Munro, Grap et al. 2009). To encourage provision of

1
2 effective oral care, guidelines have been published with recommended protocols for
3
4 hospitalised patients (Department of Health 2003, Department of Health 2007, Fiske et al.
5
6 2000, NICE 2008, Tablan et al. 2004). However, the adherence to oral health protocols is
7
8 reported to be low (Grap et al. 2003, Rello et al. 2007).
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10
11 Whilst oral health status during hospitalisation is clearly an important public health
12
13 issue, no systematic review has been conducted to critically evaluate the research data on
14
15 this topic. The aim of this systematic review was therefore to address the focussed question,
16
17 what is the effect of hospitalisation on oral health?
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19 20 21 **METHODS**

22
23 We considered as eligible longitudinal prospective observational studies in people of all ages
24
25 being hospitalised, that assessed changes of the following outcomes: tooth loss, any
26
27 measures of periodontal health, dental caries and stomatological diseases. Intervention
28
29 studies, cross sectional studies, case reports and reviews were excluded. Studies reporting
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31 specifically on patients with psychiatric disorders or on patients receiving treatment with
32
33 frequently observed oral complications (e.g. chemo- or radiotherapy) were excluded.
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36 37 38 **Search strategy (Appendix)**

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40 The literature search for relevant articles was performed using Ovid MEDLINE and Ovid
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42 OLDMEDLINE (dating from January 1950 to January 2010), Cumulative Index to Nursing and
43
44 Allied Health Literature (CINAHL) (dating from 1982 to January 2010), Cochrane Library (up
45
46 to 2010) and EMBASE (dating from 1981 to January 2010). We designed a sensitive search
47
48 strategy as we anticipated that coding for relevant search terms was not well developed.
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50 The bibliographies of all potentially relevant studies and review articles were also searched.
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1
2 Handsearching was performed in the following journals; *Community Dentistry and Oral*
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4 *Epidemiology, Gerodontology, Journal of Disability and Oral Health and Special Care in*
5
6 *Dentistry*. No language restrictions were applied on the search. When necessary we
7
8 corresponded with the first authors of studies to elicit further information. One reviewer
9
10 (ET) scanned the titles and abstracts of the studies identified by the search. When a study
11
12 seemed to meet the eligibility criteria or information was insufficient to exclude, full text
13
14 articles were obtained.
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17 18 19 **Data extraction**

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21 Two reviewers (ET, EA) independently screened all full text articles. They also extracted data
22
23 from the included studies in specially designed forms. Disagreements that could not be
24
25 resolved were arbitrated by a third author (IN). Training of reviewers for screening, study
26
27 eligibility and quality assessment was performed by an experienced systematic review
28
29 methodologist (IN). The calibration of the examiners was made on five randomly selected
30
31 studies included for full paper screening.
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34 35 36 **Quality assessment**

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38 Studies were assessed by the two reviewers (ET, EA) using the Newcastle-Ottawa scale for
39
40 cohort studies (Wells et al. 2008). Since we did not find studies with a non-exposed
41
42 comparison group we omitted the comparability section of the scale. In addition, we
43
44 assessed whether a power calculation was reported for each study and if so, the magnitude
45
46 of a change that the study was powered to detect. Separately, we assessed the quality of
47
48 the outcome assessment in terms of validity of the measure of oral health and
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50 conduct/reporting of assessor training in the measure.
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Data synthesis

Pooling of data was based on the study design, population characteristics, types of oral hygiene measures used in the hospital units, setting characteristics of the studies and outcomes measured. We anticipated substantial heterogeneity between studies and planned a narrative synthesis of data.

RESULTS

A total of 9689 potentially relevant review records were found. 9652 were excluded on the basis of their titles or abstracts and the full papers of 37 studies were retrieved. Five papers were finally included (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006, Prendergast et al. 2009). (Fig 1) Inter-examiner agreement for eligibility of included papers was 100%. The most common reasons for exclusion were no reported oral health outcomes or study design (e.g. intervention, cross sectional or retrospective).

Quality assessment

Agreement between reviewers on each aspect of the Newcastle-Ottawa scale was 100%. In all studies the representativeness of the cohort was found to be adequate and the demonstration of outcomes of interest was made at baseline. Adequacy of follow up was judged to be good in all studies, considering the healthcare setting, despite the drop outs encountered. This was based on the fact that the reasons for drop out were either death or discharge from the hospital unit (Franklin et al. 2000, Munro et al. 2006, Prendergast et al 2009). The assessment of outcome was judged to be adequate for all studies in terms of the Newcastle-Ottawa criteria and the follow up period was long enough for the assessment of

1
2 dental plaque and gingival health changes. This period was arbitrarily defined as a minimum
3
4 of three to five days (Eilers et al. 1988, Fitch et al. 1999) although too brief to detect either
5
6 dental caries incidence or changes in periodontitis. The validity of the outcome measures
7
8 was more problematic including the use of subjective indices based on visual analogue scale
9
10 measurements (Munro et al. 2006), assessments of gingival health with tools designed for
11
12 population epidemiology (Dennesen et al. 2003) and use of partial recordings with indices
13
14 not designed for this purpose (Fourrier et al. 1998). In addition, examiner training was
15
16 reported in only one study (Prendergast et al. 2009).
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21 **Population characteristics**

22
23 Four studies were located in ICU units (Fourrier et al. 1998, Franklin et al. 2000, Munro et al.
24
25 2006, Prendergast et al. 2009) and one investigated a mixed population of patients in ICU
26
27 and a cardiosurgical ward (Dennesen et al. 2003). The population in three studies was
28
29 intubated (Fourrier et al. 1998, Munro et al. 2006, Prendergast et al. 2009), while in two, the
30
31 population was both intubated and not intubated (Dennesen et al. 2003, Franklin et al.
32
33 2000). One study investigated children only (Franklin et al. 2000), while the remainder
34
35 reported on adult populations. The duration of the hospitalisation ranged from five to
36
37 twenty days.
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42 **Oral care regime**

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44 There was marked variability in oral care protocols including sterile cloth drenched with
45
46 0.9% saline (Dennesen et al. 2003), rinsing with sterile water (Fourrier et al. 1998),
47
48 foamsticks moistened with water (Franklin et al. 2000) and foam swabs or child
49
50 toothbrushes with toothpaste, sterile water or normal saline (Prendergast et al. 2009). In
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1
2 one study, there were no details of the oral hygiene measures applied (Munro et al. 2006).

3
4 Frequency of oral care provision ranged between two to six times per day.
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8 **Study setting**

9
10 Two studies were based in the USA (Munro et al. 2006, Prendergast et al. 2009), one in the
11 UK (Franklin et al. 2000), one in France (Fourrier et al. 1998) and one in the Netherlands
12 (Dennesen et al. 2003).
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18 **Power calculation**

19
20 Power calculation was reported in only one study (Franklin et al. 2000). The sample size was
21 estimated to identify a difference of 10 plaque covered surfaces significant at 5% with a
22 power of 90% using a standard deviation of 15.0 for plaque on all tooth surfaces.
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28 **Dental plaque accumulation**

29
30 Four out of the five included studies reported on the changes of dental plaque accumulation
31 during hospitalisation period (Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006,
32 Prendergast et al. 2009). Each study used a different measure. In one study no differences
33 were observed during the observational period (Prendergast et al. 2009). Three studies
34 reported increasing levels of plaque accumulation during hospitalisation (Fourrier et al.
35 1998, Franklin et al. 2000, Munro et al. 2006), which was statistically significant in two
36 (Fourrier et al. 1998, Franklin et al. 2000). The proportion of sites with abundant dental
37 plaque (scores more than 2) increased from 23% at baseline to 93% at day 10 (Fourrier et al.
38 1998) and the other study showed mean difference of 3.3% in the O'Leary index ($p=0.001$)
39 (Franklin et al. 2000).
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Gingival inflammation

Three studies reported on the levels of gingival inflammation during hospitalisation using different indices (Dennessen et al. 2003, Franklin et al. 2000, Prendergast et al. 2009). Two of the studies found statistically significant increases in the severity of gingival inflammation. (OAG median value changes from 1 at baseline to 2 at day 14 (Prendergast et al. 2009) and mean difference of the sites presenting gingival inflammation of 1.4 (p=0,006) (Franklin et al. 2000)) One study reported 'no statistically significant changes' although no data were presented (Dennessen et al. 2003).

Periodontal disease

One study reported on the severity of periodontal disease using an index of assessment of treatment needs, but found no statistically significant change (Dennessen et al. 2003). However, this index was designed for epidemiology and is insensitive to small changes over short durations of time (Holmgren 1994).

Caries incidence

Two studies assessed the incidence of dental caries in hospitalised patients and reported no statistically significant changes following hospitalisation (Franklin et al. 2000, Munro et al. 2006).

Stomatological disease

1
2 Two studies evaluated the incidence of stomatological diseases (Dennesen et al. 2003,
3 Prendergast et al. 2009). Both studies found a statistically significant increased incidence of
4 mucositis intubated patients but with not in non-intubated patients (Dennesen et al. 2003).
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10 **DISCUSSION**

11 Statement of principal findings

12
13 The five included studies suggest that oral health deteriorates following hospitalisation.
14
15 Most studies were set in intensive care units including both intubated and non-intubated
16 patients. Dental plaque accumulation and gingival and mucosal inflammation were the main
17 oral health aspects affected in the examined populations and the findings were more
18 evident in studies reporting on intubated patients (Dennesen et al. 2003, Franklin et al.
19 2000).
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30 Strengths and weaknesses of the review

31 We conducted a sensitive search including multiple electronic databases without language
32 restriction and supplemented by handsearching. However, we were only able to identify five
33 eligible studies enrolling a total of 271 patients. We were unable to retrieve two papers for
34 the full article reading. Their abstracts were unavailable in the databases and no records of
35 the journals were found in British Library. Other strengths of the review are that we
36 appraised the methodological quality and risk of bias of included studies including the
37 validity of the outcome measures in relation to oral health changes.
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48 Since most of the studies were conducted in intensive care units, the results cannot be
49 extrapolated to other hospital settings. Other than intubation, differences with other
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1
2 settings could include level of dependency of patients for oral care, ease of provision of oral
3
4 care and availability of staff to provide such care.
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8 The quality of the evidence included in the review was affected by a number of
9
10 methodological issues. Firstly, there was marked heterogeneity in the oral care routines
11
12 and in addition, adherence to oral care was not reported in the majority of studies.
13
14 Secondly, a wide variety of indices for assessing of oral health were employed and their
15
16 validity was not clear. Validity issues included the use of subjective indices based on visual
17
18 analogue scale measurements (Munro et al. 2006), assessments of gingival health with
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20 epidemiological tools (Dennesen et al. 2003) and use of partial recordings with indices not
21
22 designed for this purpose (Fourrier et al. 1998). Furthermore, examiner training in this
23
24 testing setting was reported in only one study (Prendergast et al. 2009). Study design also
25
26 limits the strength of the conclusions. All studies were uncontrolled and changes in
27
28 outcomes may simply relate to shifts in examiner characteristics over time. Including an
29
30 appropriate 'unexposed' comparison group is challenging and its validity as a control would
31
32 be questionable. Therefore, this needs to be accepted as a limitation to the evidence.
33
34 Calibration of an examiner to a gold-standard with re-testing throughout the study might
35
36 have helped counter any drift. The duration of follow-up was limited (to a maximum of 20
37
38 days) due to the nature of the hospitalisation. Although this period was adequate for the
39
40 detection of changes in some oral health outcomes such as dental plaque accumulation
41
42 (Theilade et al. 1966) and gingival inflammation (Loe et al. 1965), longer observational
43
44 periods are required for the detection of a change in periodontitis (Goodson et al. 1982) or
45
46 dental caries occurrence (Pitts and Stamm 2004). Finally, power calculations were reported
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48 in only one study (Franklin et al. 2000), thus hindering the interpretation of findings.
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3 Strengths and weaknesses in relation to other reviews
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5 We have not found other systematic reviews addressing this research question. However, a
6
7 clinical effectiveness review was published in 1999 investigating oral care practices by
8
9 nurses (Bowsher et al. 1999). The published report is limited in details of methodology
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11 making comparison difficult. However, the findings, even though published more than a
12
13 decade ago, appear to hold true 'This review confirms that current practice largely ignores
14
15 the research evidence and is inadequate for ensuring optimum care. There is a clear need to
16
17 develop and evaluate oral care protocols for hospitalised patients and to support nurses in
18
19 their implementation.'
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24 Meaning of the review, possible explanations and implications for clinicians and policy
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26 makers.
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28 This review suggests that hospitalisation is associated with a deterioration in oral health and
29
30 this could have profound implications for health and wellbeing. On the basis of current
31
32 evidence, a deterioration in oral health would be expected to increase the risk of hospital
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34 acquired infections, increase care costs and have negative impact on health related quality
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36 of life.
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41 We were not able to conclude whether this impact results from a low priority of oral care
42
43 provision, the implementation of improper oral care regimes, from hospitalisation per se or
44
45 from a combination of factors. Guidelines for the provision of oral care in hospital settings
46
47 have been published (Department of Health 2003, Department of Health 2007, Fiske, et al.
48
49 2000, NICE 2008, Tablan et al. 2004) although they provide limited detail for carers.
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1
2 Additional protocols/guidelines are therefore needed and should be based on the best
3 available evidence with sufficient detail to guide carers and patients. Such development
4 should include the breadth of relevant stakeholders such as nursing, medical and dental
5 professionals as well as patients and address the different settings in which will need to be
6 provided such as units with fully dependent patients and those where patients are able to
7 carry out oral hygiene themselves. More challenging will be implementation (Rello et al.
8 2007) and this will need to be planned together with evaluation of success prior to
9 introduction.
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21 In terms of interventions, chemical plaque control was the regime of choice in three out of
22 five included studies (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000).
23 Although the clinical application of chemicals such as antiseptics seems straightforward,
24 their effect against established dental plaque is marginal due to its organisation as a biofilm
25 in which bacteria are considerably less sensitive to antimicrobial treatments than free-living
26 planktonic bacteria (Pratten et al. 1998). This is corroborated by a systematic review of
27 chlorhexidine for prevention of ventilator-associated pneumonia (VAP) which reported no
28 effect on VAP incidence (Pineda et al. 2006). Therefore, mechanical removal or disruption of
29 dental plaque will be needed such as can be achieved through toothbrushing.
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41 Suggestions for further research

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43 More robust evidence is needed to understand the impact of hospitalisation on oral health.
44 In particular, we recommend studies conducted in a wider range of hospital settings
45 including outside of critical care units. There are many outcomes measures that are
46 validated in oral health research and these should be selected for hospital-based studies.
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2 Furthermore, training of examiners should be provided together and outcomes of training
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4 (such as agreement levels) reported. Where feasible, longer observational periods could be
5
6 employed to investigate other oral health outcomes such as dental caries and periodontitis.
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32
33 study. All authors contributed to the study protocol, interpretation of results and
34
35 manuscript. ET conducted the search and initial screening. ET and EA conducted the full-text
36
37 screening and data abstraction. ET wrote the first draft of the manuscript.
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7 patients. *Journal of Dentistry*, **36**, 816-821

8
9 Yu, D.S., Lee, D.T., Hong, A.W., Lau, T.Y., & Leung, E.M. (2008) Impact of oral health status on oral
10 health-related quality of life in Chinese hospitalised geriatric patients. *Quality of Life Research*, **17**,
11 397-405

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Figure 1: Flowchart of inclusion of studies

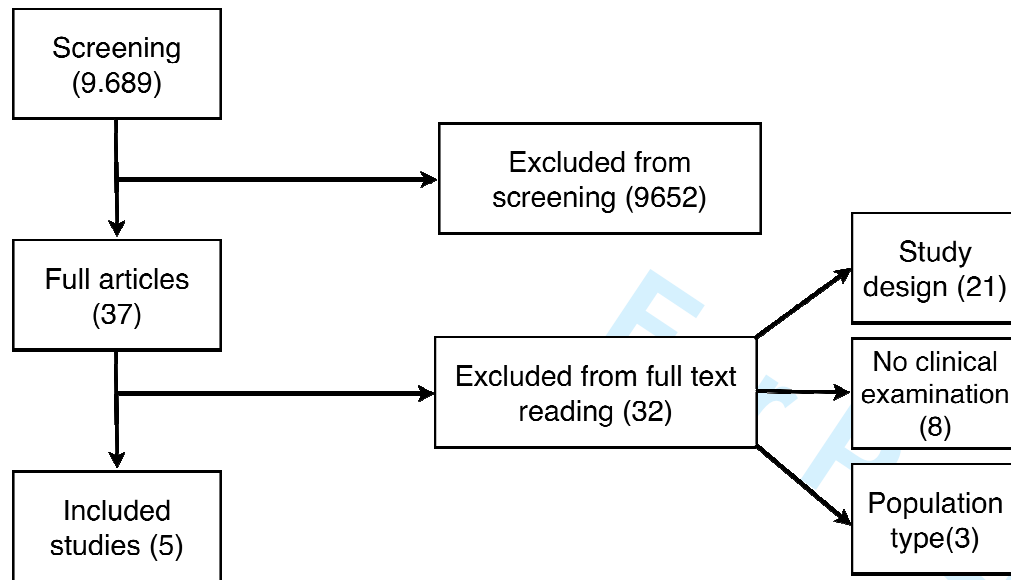


Table 1: Included study characteristics

Authors (Type of study)	Participants: 1. Recruited 2. Age mean (range) 3. Drop-outs 4. Dependency/intubated 5. Duration of hospitalisation (observation period)	Type of oral care provided: 1. Personnel 2. Oral care regime 3. Frequency 4. Duration 5. Adherence assessed	1. Hospital department 2. Country	1. Type of oral care changes assessed (index used) 2. Assessor 3. Examiner training 4. Blinding	Quality assessment scoring
Prendergast et al. 2009 ⁴⁶ (Cohort study)	1. 45 patients 2. 49.16 years (18-85) 3. D0: 45 patients D1: 31 patients D10: 13 patients 4. Fully dependent (intubated) 5. 15.1 days (1-37) (12.8 days (1-31))	1. Nurse 2. Foam swabs or child toothbrush, toothpaste, sterile water or normal saline and lip lubricant. 3. Every 4-6 hours 4. 5-10 minutes 5. Yes (nurses' notes)	1. Neuroscience ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, dental health (OAG index) 2. Nurses (3) 3. Yes 4. Yes	5/5
Munro et al. 2006 ⁴⁷ (Cohort study)	1. 66 patients 2. 55 years (25-93) 3. D0: 66 patients D4: 37 patients D7: 21 patients 4. Fully dependent (intubated) 5. Not reported (4-7 days)	1. Not reported 2. Not reported 3. 2.58 times per day (0-7 range) 4. Not reported 5. Not reported	1. Respiratory ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, gingival bleeding, purulence, candidiasis, calculus, caries, stain (Oral health assessment tool) 2. Not reported 3. Not reported 4. Not reported	5/5
Dennesen et al. 2003 ⁴⁶ (Cohort study)	1. ICU: 24 patients CS: 20 patients 2. ICU: 58 years (SD 18.6) CS: 61 years (41-77) 3. Not reported 4. ICU: intubated CS: intubated for less than 12 hours 5. ICU: 20.4 days (SD 7.5) (14 days) CS: Not reported	1. ICU: Not reported CS: Not reported 2. ICU: Sterile cloth drenched with NaCl 0.9% CS: Not reported 3. ICU: Not reported CS: Not reported 4. ICU: 2/day CS: Not reported 5. Not reported	1. ICU and Cardiosurgery Ward 2. Netherlands	1. Periodontal disease (CPITN) and Oral mucositis (Quantitative scale of oral mucositis) 2. Dental hygienists (2) 3. Not reported 4. Not reported	5/5

<i>Authors</i> <i>(Type of study)</i>	<i>Participants:</i> <i>1. Recruited</i> <i>2. Age mean (range)</i> <i>3. Drop-outs</i> <i>4. Dependency/intubated</i> <i>5. Duration of hospitalisation (observation period)</i>	<i>Type of oral care provided:</i> <i>1. Personnel</i> <i>2. Oral care regime</i> <i>3. Frequency</i> <i>4. Duration</i> <i>5. Adherence assessed</i>	<i>1. Hospital department</i> <i>2. Country</i>	<i>1. Type of oral care changes assessed (index used)</i> <i>2. Assessor</i> <i>3. Examiner training</i> <i>4. Blinding</i>	<i>Quality assessment scoring</i>
Franklin et al. 2000 ⁴⁵ (Cohort study)	1. 59 children 2. 4.8 (1-16) 3. 5 children 4. 12 children orally intubated. The rest nasally intubated or not intubated 5. 7.4 days (SD 6.2)	1. Nurses 2. Foam sticks moistened with water. Antiseptics and antifungals were used at the discretion of the nurses. 3. Every 4-6 hours 4. Not reported 5. Not reported	1. Pediatric ICU 2. UK	1. Caries, missing, filled teeth (DMF index), dental plaque accumulation (O' Leary index), gingival inflammation (binary assessment), spontaneous gingival bleeding (binary assessment) 2. Author 3. Not reported 4. Not reported	5/5
Fourrier et al. 1998 ⁴⁴ (Cohort study)	1. 57 patients 2. 49 years (18-83) 3. 29 patients 4. 44 patients intubated (77%) 5. 14 days (2-82) (15 patients for 5 days and 13 patients for 10 days)	1. Not reported 2. Not reported 3. Not reported 4. Not reported 5. Not reported	1. ICU 2. France	1. Dental plaque accumulation (Plaque index from one tooth) 2. Not reported 3. Not reported 4. Not reported	5/5

Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community Periodontal Index for Treatment Needs // "DMFT index": Decayed, missed and filled teeth index //

Table 2: Reported results from included studies

Authors	Number of patients and duration of observation period	Dental plaque (index)	Gingival health (index)	Periodontal health (index)	Caries (index)	Stomatological disease incidence (index)	Other outcome measures
Prendergast et al. 2009 ⁴⁶	D0: 45 patients D4: 31 patients D7: 19 patients D10: 11 patients Mean period: 12.8 days (SD 7.5)	Median values OAG: 1st-3rd quartile D0: 2 (2-2) D4: 2 (2-3) D7: 2 (2-3) D14: 2 (2-3)	Median values OAG: 1st-3rd quartile D0: 1 (1-1) D4: 2 (1-2)* D7: 1 (1-2) D14: 2 (2-3)* * statistically significant from baseline	Not reported	Not reported	Median values OAG: 1st-3rd quartile D0: 1 (1-2) D4: 2 (1-2)* D7: 1 (2-2)* D14: 2 (1-2)	Total score in median values OAG⁴⁶: 1st-3rd quartile D0: 12 (11-14) D4: 14 (13-15)* D7: 15 (12-17)* D10: 16 (14-17)* * statistically significant from baseline
Munro et al. 2006 ⁴⁷	D0: 66 patients D4: 37 patients D7: 21 patients	Oral health assessment tool D0: 21.27 (SD 23.66) D4: 22.72 (SD 20.47) D7: 24.32 (SD 29.01)	No data presented	No data presented	No data presented	No data presented	Oral health assessment tool⁴⁷
Dennesen et al. 2003 ⁴⁸	ICU: 24 patients for 20.4 days (SD 7.5) CS: 20 patients for 15 days	Not reported	CPITN No data presented "No changes" reported	CPITN No data presented "No changes" reported	Not reported	Median mucositis index ICU: D0: 2 (SD 3.2) D21: 19 (SD 5.9) CS: No mucositis found	% subjects with mucositis⁴⁸ ICU: D0: 79% D7: 25% D14: 12% D21: 0% Quantitative scale of oral mucositis⁴⁸ 0-39 (health: 0) D0: 2±3.2 D21: 19±5.9
Franklin et al. 2000 ⁴⁹	54 children for 7,5 days (SD 6.2)	O'Leary plaque index D0: 22.5% (SD 17.7) Discharge: 25.8% (SD 18.5) Mean difference: 3.3% 95% CI: 1-4.53 p: 0.001	Presence of gingival inflammation (yes/no) D0: 4.1 sites Discharge: 5.5 sites Mean difference: 1.4 sites 95% CI: 0.4-2.3 p: 0.006 Spontaneous gingival bleeding D0: 0.1 sites (SD 0.5) Discharge: 0.2 sites (SD 1.1) No statistically significant differences	Not reported	DMFT index D0: Primary teeth: 1.0 (SD 2.2) Permanent teeth: 1.2 (SD 1.9) Discharge: "No changes" reported	Not reported	
Fourrier et al. 1998 ⁴⁴	Group 1: 15 patients for 5 days Group 2: 13 patients for 10 days	Plaque index (one tooth) Group 1: D0: 1.1 (SD 0.7) D5: 1.6 (SD 0.7) Group 2: D0: 1.0 (SD 0.7) D5: 1.6 (SD 0.6)* D10: 2.0 (SD 0.4)** *statistically significant different (p< 0.05) ** statistically significant different (p<0.001)	Not reported	Not reported	Not reported	Not reported	

Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community Periodontal Index for Treatment Needs // "DMFT index": Decayed, missed and filled teeth index //

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APPENDICES

Search strategy for Ovid Medline

1. exp Hospitalization/
2. Hospital*.mp.
3. exp Intensive Care Units/
4. Intensive care unit*.mp.
5. Intensive care ward*.mp.
6. ICU.mp.
7. Dental deposit*.mp.
8. Dental plaque.mp.
9. Dental calculus.mp.
10. Plaque accumulation.mp.
11. Plaque score.mp.
12. exp Dental Health Surveys/
13. Periodontal index.mp.
14. Gingival index.mp.
15. DMF index.mp.
16. exp Oral Hygiene/
17. Oral hygiene.mp.
18. Oral clean*.mp.
19. exp candidiasis, oral/ or exp mucositis/ exp oral hemorrhage/ or exp periodontal diseases/ or exp stomatitis/
20. Periodont*.mp.
21. Periodontal attachment loss.mp.
22. Periodontal pocket*.mp.

- 1 23. Gingival pocket*.mp.
- 2
- 3 24. Probing depth*.mp
- 4
- 5 25. Bleeding on probing.mp.
- 6
- 7 26. Gingival hemorrhage.mp.
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- 9 27. Gingival hemorrhage.mp.
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- 11 28. Gingival haemorrhage.mp.
- 12
- 13 29. Oral mucositis.mp.
- 14
- 15 30. Stomatitis.mp.
- 16
- 17 31. tooth diseases/ or exp dental deposits/ or exp dental calculus/ or exp dental plaque/ or exp smear layer/ or exp
tooth demineralization/ or exp dental caries/
- 18
- 19 32. Dental caries.mp.
- 20
- 21 33. Tooth decay.mp.
- 22
- 23 34. Tooth demineralisation.mp.
- 24
- 25 35. Tooth demineralization.mp.
- 26
- 27 36. Tooth decalcification.mp.
- 28
- 29 37. Tooth extraction.mp.
- 30
- 31 38. Tooth loss.mp.
- 32
- 33 39. exp Oral Health/
- 34
- 35 40. Oral health.mp.
- 36
- 37 41. or/1-6
- 38
- 39 42. or/7-40
- 40
- 41 43. 41 and 42

42 Search strategy for EMBASE

- 44 1. exp hospital patient/
- 45
- 46 2. exp hospitalization/
- 47
- 48 3. hospital*.mp.
- 49
- 50 4. exp intensive care/ or exp intensive care unit/
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- 52 5. intensive care unit*.mp.
- 53
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- 1 6. Intensive care ward*.mp.
- 2
- 3 7. ICU.mp.
- 4
- 5 8. exp tooth calculus/
- 6
- 7 9. exp tooth plaque/
- 8
- 9 10. exp mouth hygiene/
- 10
- 11 11. exp mouth disease/
- 12
- 13 12. periodontal disease/
- 14
- 15 13. exp periodontitis/
- 16
- 17 14. exp thrush/
- 18
- 19 15. exp stomatitis/
- 20
- 21 16. exp dental caries/
- 22
- 23 17. exp tooth extraction/
- 24
- 25 18. dental deposit*.mp.
- 26
- 27 19. dental calculus.mp
- 28
- 29 20. dental plaque.mp.
- 30
- 31 21. plaque accumulation.mp.
- 32
- 33 22. oral hygiene.mp.
- 34
- 35 23. oral clean*.mp.
- 36
- 37 24. oral candidiasis.mp.
- 38
- 39 25. oral mucositis.mp.
- 40
- 41 26. stomatitis.mp.
- 42
- 43 27. periodont*.mp.
- 44
- 45 28. gingiv*.mp.
- 46
- 47 29. dental caries.mp.
- 48
- 49 30. tooth decay.mp.
- 50
- 51 31. tooth demineralization.mp.
- 52
- 53 32. tooth decalcification.mp.
- 54
- 55 33. tooth loss.mp.
- 56
- 57 34. tooth extraction.mp.
- 58
- 59 35. oral health.mp
- 60 36. DMF index.mp

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- 1 37. plaque score.mp.
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- 3 38. or/1-7
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- 5 39. or/8-37
- 6
- 7 40. 38 and 39
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11 Search strategy for CINAHL

- 13 1. (MH "Hospitalization+")
- 14
- 15 2. TX hospital*
- 16
- 17 3. (MH "Intensive Care Units+")
- 18
- 19 4. TX intensive care unit*
- 20
- 21 5. TX intensive care ward*
- 22
- 23 6. TX ICU
- 24
- 25 7. (MH "Tooth Diseases+")
- 26
- 27 8. (MH "Mouth Diseases+")
- 28
- 29 9. (MH "Oral Hygiene+")
- 30
- 31 10. (MH "Oral Health")
- 32
- 33 11. TX dental deposit*
- 34
- 35 12. TX dental calculus
- 36
- 37 13. TX plaque accumulation
- 38
- 39 14. TX periodont*
- 40
- 41 15. TX gingiv*
- 42
- 43 16. TX stomatitis
- 44
- 45 17. TX oral candid*
- 46
- 47 18. TX oral mucositis
- 48
- 49 19. TX dental caries
- 50
- 51 20. TX tooth decay
- 52
- 53 21. TX tooth demineralization
- 54
- 55 22. TX tooth decalcification
- 56
- 57 23. TX tooth decalcification
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- 59 24. TX tooth loss
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- 1 25. TX tooth extraction
- 2
- 3 26. TX probing depth
- 4
- 5 27. TX bleeding on probing
- 6
- 7 28. TX gingival hemorrhage
- 8
- 9 29. TX gingival haemorrhage
- 10
- 11 30. TX plaque score
- 12
- 13 31. TX DMF index
- 14
- 15 32. TX oral clean*
- 16
- 17 33. TX oral hygiene
- 18
- 19 34. TX oral health
- 20
- 21 35. or/1-6
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- 23 36. or/7-33
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- 25 37. 35 and 36
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Modified quality assessment scale for cohort studies (based on Newcastle-Ottawa scale)

(Note: A study can be awarded a maximum of one star for each numbered item with the selection and outcome categories.)

Selection1) Representativeness of the cohort:

- a) truly representative of the average hospitalised patients in the community (*)
- b) somewhat representative of the average hospitalised patients in the community (*)
- c) selected group of users eg nurses, volunteers
- d) no description of the derivation of the cohort

2) Ascertainment of exposure:

- a) secure record (eg surgical records) (*)
- b) structured interview (*)
- c) written self report
- d) no description

4) Demonstration that outcome of interest at baseline:

- a) yes (*)
- b) no

Outcome1) Assessment of outcome:

- a) independent blind assessment (*)
- b) record linkage (*)
- c) self report
- d) no description

2) Was follow-up long enough for outcomes to occur:

- a) yes (3-5 days for plaque and gingival changes)(*)
- b) no

3) Adequacy of follow up of cohorts:

- a) complete follow up - all subjects accounted for (*)
- b) subjects lost to follow up unlikely to introduce bias - small number lost (subjects lost due to death or discharge from the hospital or unit) (*)
- c) no description of those lost or loss due to other reasons than death or discharge from the hospital/unit.
- d) no statement

The impact of hospitalisation on oral health. A systematic review.

Running title: Hospitalisation and oral health

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Keywords: Oral health, oral hygiene, hospitalization, hospital acquired infections

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Clinical relevance

Scientific rationale for study: Poor oral health is recognised as a potential risk factor for hospital acquired infections. Therefore a systematic review of the evidence for the effect of hospitalisation on oral health is needed.

Principal findings: The evidence suggests that oral health deteriorates during hospitalisation. However, few studies have investigated this question and the strength of evidence is limited.

Practical implications: Oral care during hospitalisation needs to be strengthened together with further research investigating oral health changes in different settings and factors that facilitate the provision of care.

ABSTRACT

Background: Poor oral health of hospitalised patients is associated with an increased risk of hospital acquired infections and reduced life quality

Objectives: To systematically review the evidence on oral health changes during hospitalisation.

Data sources: Cochrane library, Medline, OldMedline, Embase and CINAHL without language restrictions.

Study eligibility criteria: Observational longitudinal studies.

Data appraisal and synthesis methods: Two independent reviewers screened studies for inclusion, assessed risk of bias and extracted data. Risk of bias was assessed with the Ottawa Newcastle assessment scale. A narrative synthesis was conducted.

Results: Five before and after studies were included. The data suggest a deterioration in oral health following hospitalisation with an increase in dental plaque accumulation and gingival inflammation and a deterioration in mucosal health.

Limitations: Whilst before and after studies are at a general risk of bias, other specific study characteristics were judged to be of low risk of bias. However, methodological issues such as unvalidated outcome measures and lack of assessor training limit the strength of the evidence.

Conclusion: Hospitalisation is associated with a deterioration in oral health, particularly in intubated patients.

INTRODUCTION

Maintenance of oral health is important for hospitalised patients. Oral health affects quality of life (Llewellyn & Warnakulasuriya 2003, Yu et al. 2008) and personal dignity and this impact appears to be more severe in medically compromised or hospitalised patients (Duke et al. 2005, Ingram et al. 2005, Locker et al. 2002, McMillan et al. 2005, Mulligan et al. 2008). Not surprisingly, poor oral health or dysfunction can also have a negative effect on nutritional status (Chai et al. 2006, Gil-Montoya et al. 2008, Rauen et al. 2006), whilst improvement of dental status raises levels of nutritional markers (Wostmann et al. 2008).

Poor oral health and oral hygiene can also contribute to an increased incidence of hospital acquired infections, particularly respiratory diseases (Azarpazhooh & Leake 2006, Shaw 2005). Furthermore, interventions that maintain or improve oral health can reduce the incidence of ventilator associated pneumonia (Chan et al. 2007). Similarly, benefits from effective oral hygiene have also been documented for pneumonia in non ambulatory (Scannapieco 2006) or elderly patients (Sjogren et al. 2008). Therefore, oral health requires management during in-patient care. Therefore, oral health requires management during in-patient care.

Although oral health can be maintained during hospitalisation with proper training of the caregivers (Peltola et al. 2007), there are difficulties in the provision of adequate oral care in hospitals and institutional facilities. Barriers to effective oral care reported by caregivers include the low priority of oral care (Grap et al. 200, Landstrom et al. 2009), fear of causing pain or injury to the patients (Jablonski et al. 2009), the perception that oral care does not provide significant benefits (Binkley et al. 2004, Jones et al. 2004), patients' resistive behaviours (Jablonski, Munro, Grap et al. 2009), inadequate nurse staffing (Grap et al. 2003) and lack of supplies (Jablonski, Munro, Grap et al. 2009). To encourage provision of

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3 effective oral care, guidelines have been published with recommended protocols for
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5 hospitalised patients (Department of Health 2003, Department of Health 2007, Fiske et al.
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7 2000, NICE 2008, Tablan et al. 2004). However, the adherence to oral health protocols is
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9 reported to be low (Grap et al. 2003, Rello et al. 2007).
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13 Whilst oral health status during hospitalisation is clearly an important public health
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15 issue, no systematic review has been conducted to critically evaluate the research data on
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17 this topic. The aim of this systematic review was therefore to address the focussed question,
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19 what is the effect of hospitalisation on oral health?
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22 23 24 25 26 **METHODS**

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28 We considered as eligible longitudinal prospective observational studies in people of all ages
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30 being hospitalised, that assessed changes of the following outcomes: tooth loss, any
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32 measures of periodontal health, dental caries and stomatological diseases. Intervention
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34 studies, cross sectional studies, case reports and reviews were excluded. Studies reporting
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36 specifically on patients with psychiatric disorders or on patients receiving treatment with
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38 frequently observed oral complications (e.g. chemo- or radiotherapy) were excluded.
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46 **Search strategy (Appendix)**

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48 The literature search for relevant articles was performed using Ovid MEDLINE and Ovid
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50 OLDMEDLINE (dating from January 1950 to January 2010), Cumulative Index to Nursing and
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52 Allied Health Literature (CINAHL) (dating from 1982 to January 2010), Cochrane Library (up
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54 to 2010) and EMBASE (dating from 1981 to January 2010). We designed a sensitive search
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56 strategy as we anticipated that coding for relevant search terms was not well developed.
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60 The bibliographies of all potentially relevant studies and review articles were also searched.

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3 Handsearching was performed in the following journals; *Community Dentistry and Oral*
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6 *Epidemiology, Gerodontology, Journal of Disability and Oral Health and Special Care in*
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8 *Dentistry*. No language restrictions were applied on the search. When necessary we
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10 corresponded with the first authors of studies to elicit further information. One reviewer
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12 (ET) scanned the titles and abstracts of the studies identified by the search. When a study
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14 seemed to meet the eligibility criteria or information was insufficient to exclude, full text
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16 articles were obtained.
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20 21 22 23 **Data extraction**

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26 Two reviewers (ET, EA) independently screened all full text articles. They also extracted data
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28 from the included studies in specially designed forms. Disagreements that could not be
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30 resolved were arbitrated by a third author (IN). Training of reviewers for screening, study
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32 eligibility and quality assessment was performed by an experienced systematic review
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34 methodologist (IN). The calibration of the examiners was made on five randomly selected
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36 studies included for full paper screening.
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43 **Quality assessment**

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46 Studies were assessed by the two reviewers (ET, EA) using the Newcastle-Ottawa scale for
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48 cohort studies (Wells et al. 2008). Since we did not find studies with a non-exposed
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50 comparison group we omitted the comparability section of the scale. In addition, we
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52 assessed whether a power calculation was reported for each study and if so, the magnitude
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54 of a change that the study was powered to detect. Separately, we assessed the quality of
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56 the outcome assessment in terms of validity of the measure of oral health and
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58 conduct/reporting of assessor training in the measure.
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Data synthesis

Pooling of data was based on the study design, population characteristics, types of oral hygiene measures used in the hospital units, setting characteristics of the studies and outcomes measured. We anticipated substantial heterogeneity between studies and planned a narrative synthesis of data.

RESULTS

A total of 9689 potentially relevant review records were found. 9652 were excluded on the basis of their titles or abstracts and the full papers of 37 studies were retrieved. Five papers were finally included (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006, Prendergast et al. 2009). (Fig 1) Inter-examiner agreement for eligibility of included papers was 100%. The most common reasons for exclusion were no reported oral health outcomes or study design (e.g. intervention, cross sectional or retrospective).

Quality assessment

Agreement between reviewers on each aspect of the Newcastle-Ottawa scale was 100%. In all studies the representativeness of the cohort was found to be adequate and the demonstration of outcomes of interest was made at baseline. Adequacy of follow up was judged to be good in all studies, considering the healthcare setting, despite the drop outs encountered. This was based on the fact that the reasons for drop out were either death or discharge from the hospital unit (Franklin et al. 2000, Munro et al. 2006, Prendergast et al. 2009). The assessment of outcome was judged to be adequate for all studies in terms of the Newcastle-Ottawa criteria and the follow up period was long enough for the assessment of

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3 dental plaque and gingival health changes. This period was arbitrarily defined as a minimum
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5 of three to five days (Eilers et al. 1988, Fitch et al. 1999) although too brief to detect either
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7 dental caries incidence or changes in periodontitis. The validity of the outcome measures
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9 was more problematic including the use of subjective indices based on visual analogue scale
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11 measurements (Munro et al. 2006), assessments of gingival health with tools designed for
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13 population epidemiology (Dennesen et al. 2003) and use of partial recordings with indices
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15 not designed for this purpose (Fourrier et al. 1998). In addition, examiner training was
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17 reported in only one study (Prendergast et al. 2009).
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26 **Population characteristics**

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28 Four studies were located in ICU units (Fourrier et al. 1998, Franklin et al. 2000, Munro et al.
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30 2006, Prendergast et al. 2009) and one investigated a mixed population of patients in ICU
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32 and a cardiosurgical ward (Dennesen et al. 2003). The population in three studies was
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34 intubated (Fourrier et al. 1998, Munro et al. 2006, Prendergast et al. 2009), while in two, the
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36 population was both intubated and not intubated (Dennesen et al. 2003, Franklin et al.
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38 2000). One study investigated children only (Franklin et al. 2000), while the remainder
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40 reported on adult populations. The duration of the hospitalisation ranged from five to
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42 twenty days.
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51 **Oral care regime**

52
53 There was marked variability in oral care protocols including sterile cloth drenched with
54
55 0.9% saline (Dennesen et al. 2003), rinsing with sterile water (Fourrier et al. 1998),
56
57 foamsticks moistened with water (Franklin et al. 2000) and foam swabs or child
58
59 toothbrushes with toothpaste, sterile water or normal saline (Prendergast et al. 2009). In
60

1
2
3 one study, there were no details of the oral hygiene measures applied (Munro et al. 2006).
4
5
6 Frequency of oral care provision ranged between two to six times per day.
7
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9

10 **Study setting**

11
12 Two studies were based in the USA (Munro et al. 2006, Prendergast et al. 2009), one in the
13
14 UK (Franklin et al. 2000), one in France (Fourrier et al. 1998) and one in the Netherlands
15
16 (Dennesen et al. 2003).
17
18
19

20 **Power calculation**

21
22 Power calculation was reported in only one study (Franklin et al. 2000). The sample size was
23
24 estimated to identify a difference of 10 plaque covered surfaces significant at 5% with a
25
26 power of 90% using a standard deviation of 15.0 for plaque on all tooth surfaces.
27
28
29
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34 **Dental plaque accumulation**

35
36 Four out of the five included studies reported on the changes of dental plaque accumulation
37
38 during hospitalisation period (Fourrier et al. 1998, Franklin et al. 2000, Munro et al. 2006,
39
40 Prendergast et al. 2009). Each study used a different measure. In one study no differences
41
42 were observed during the observational period (Prendergast et al. 2009). Three studies
43
44 reported increasing levels of plaque accumulation during hospitalisation (Fourrier et al.
45
46 1998, Franklin et al. 2000, Munro et al. 2006), which was statistically significant in two
47
48 (Fourrier et al. 1998, Franklin et al. 2000). The proportion of sites with abundant dental
49
50 plaque (scores more than 2) increased from 23% at baseline to 93% at day 10 (Fourrier et al.
51
52 1998) and the other study showed mean difference of 3.3% in the O'Leary index ($p=0.001$)
53
54 (Franklin et al. 2000).
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Gingival inflammation

Three studies reported on the levels of gingival inflammation during hospitalisation using different indices (Dennesen et al. 2003, Franklin et al. 2000, Prendergast et al. 2009). Two of the studies found statistically significant increases in the severity of gingival inflammation. (OAG median value changes from 1 at baseline to 2 at day 14 (Prendergast et al. 2009) and mean difference of the sites presenting gingival inflammation of 1.4 ($p=0,006$) (Franklin et al. 2000)) One study reported 'no statistically significant changes' although no data were presented (Dennesen et al. 2003).

Periodontal disease

One study reported on the severity of periodontal disease using an index of assessment of treatment needs, but found no statistically significant change (Dennesen et al. 2003). However, this index was designed for epidemiology and is insensitive to small changes over short durations of time (Holmgren 1994).

Caries incidence

Two studies assessed the incidence of dental caries in hospitalised patients and reported no statistically significant changes following hospitalisation (Franklin et al. 2000, Munro et al. 2006).

Stomatological disease

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3 Two studies evaluated the incidence of stomatological diseases (Dennesen et al. 2003,
4
5 Prendergast et al. 2009). Both studies found a statistically significant increased incidence of
6
7 mucositis intubated patients but with not in non-intubated patients (Dennesen et al. 2003).
8
9

10 11 12 13 **DISCUSSION**

14 15 16 Statement of principal findings

17
18 The five included studies suggest that oral health deteriorates following hospitalisation.

19
20 Most studies were set in intensive care units including both intubated and non-intubated
21
22 patients. Dental plaque accumulation and gingival and mucosal inflammation were the main
23
24 oral health aspects affected in the examined populations and the findings were more
25
26 evident in studies reporting on intubated patients (Dennesen et al. 2003, Franklin et al.
27
28 2000).
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36 37 Strengths and weaknesses of the review

38
39 We conducted a sensitive search including multiple electronic databases without language
40
41 restriction and supplemented by handsearching. However, we were only able to identify five
42
43 eligible studies enrolling a total of 271 patients. We were unable to retrieve two papers for
44
45 the full article reading. Their abstracts were unavailable in the databases and no records of
46
47 the journals were found in British Library. Other strengths of the review are that we
48
49 appraised the methodological quality and risk of bias of included studies including the
50
51 validity of the outcome measures in relation to oral health changes.
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59 Since most of the studies were conducted in intensive care units, the results cannot be
60
extrapolated to other hospital settings. Other than intubation, differences with other

1
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3 settings could include level of dependency of patients for oral care, ease of provision of oral
4
5 care and availability of staff to provide such care.
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9
10 The quality of the evidence included in the review was affected by a number of
11
12 methodological issues. Firstly, there was marked heterogeneity in the oral care routines
13
14 and in addition, adherence to oral care was not reported in the majority of studies.
15
16 Secondly, a wide variety of indices for assessing of oral health were employed and their
17
18 validity was not clear. Validity issues included the use of subjective indices based on visual
19
20 analogue scale measurements (Munro et al. 2006), assessments of gingival health with
21
22 epidemiological tools (Dennessen et al. 2003) and use of partial recordings with indices not
23
24 designed for this purpose (Fourrier et al. 1998). Furthermore, examiner training in this
25
26 testing setting was reported in only one study (Prendergast et al. 2009). Study design also
27
28 limits the strength of the conclusions. All studies were uncontrolled and changes in
29
30 outcomes may simply relate to shifts in examiner characteristics over time or due to other
31
32 effects such as changes in general health status. Therefore, this needs to be accepted as a
33
34 limitation to the evidence. Calibration of an examiner to a gold-standard with re-testing
35
36 throughout the study might have helped counter any drift. The duration of follow-up was
37
38 limited (to a maximum of 20 days) due to the nature of the hospitalisation. Although this
39
40 period was adequate for the detection of changes in some oral health outcomes such as
41
42 dental plaque accumulation (Theilade et al. 1966) and gingival inflammation (Loe et al.
43
44 1965), longer observational periods are required for the detection of a change in
45
46 periodontitis (Goodson et al. 1982) or dental caries occurrence (Pitts and Stamm 2004).
47
48 Finally, power calculations were reported in only one study (Franklin et al. 2000), thus
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50 hindering the interpretation of findings.
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5 Strengths and weaknesses in relation to other reviews
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7 We have not found other systematic reviews addressing this research question. However, a
8 clinical effectiveness review was published in 1999 investigating oral care practices by
9 nurses (Bowsher et al. 1999). The published report is limited in details of methodology
10 making comparison difficult. However, the findings, even though published more than a
11 decade ago, appear to hold true 'This review confirms that current practice largely ignores
12 the research evidence and is inadequate for ensuring optimum care. There is a clear need to
13 develop and evaluate oral care protocols for hospitalised patients and to support nurses in
14 their implementation.'
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30 Meaning of the review, possible explanations and implications for clinicians and policy
31 makers.
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34 This review suggests that hospitalisation is associated with a deterioration in oral health and
35 this could have profound implications for health and wellbeing. On the basis of current
36 evidence, a deterioration in oral health would be expected to increase the risk of hospital
37 acquired infections, increase care costs and have negative impact on health related quality
38 of life.
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50 We were not able to conclude whether this impact results from a low priority of oral care
51 provision, the implementation of improper oral care regimes, from hospitalisation per se or
52 from a combination of factors. Guidelines for the provision of oral care in hospital settings
53 have been published (Department of Health 2003, Department of Health 2007, Fiske, et al.
54 2000, NICE 2008, Tablan et al. 2004) although they provide limited detail for carers.
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4 Additional protocols/guidelines are therefore needed and should be based on the best
5
6 available evidence with sufficient detail to guide carers and patients. Such development
7
8 should include the breadth of relevant stakeholders such as nursing, medical and dental
9
10 professionals as well as patients and address the different settings in which will need to be
11
12 provided such as units with fully dependent patients and those where patients are able to
13
14 carry out oral hygiene themselves. More challenging will be implementation (Rello et al.
15
16 2007) and this will need to be planned together with evaluation of success prior to
17
18 introduction.
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26 In terms of interventions, chemical plaque control was the regime of choice in three out of
27
28 five included studies (Dennesen et al. 2003, Fourrier et al. 1998, Franklin et al. 2000).
29
30 Although the clinical application of chemicals such as antiseptics seems straightforward,
31
32 their effect against established dental plaque is marginal due to its organisation as a biofilm
33
34 in which bacteria are considerably less sensitive to antimicrobial treatments than free-living
35
36 planktonic bacteria (Pratten et al. 1998). This is corroborated by a systematic review of
37
38 chlorhexidine for prevention of ventilator-associated pneumonia (VAP) which reported no
39
40 effect on VAP incidence (Pineda et al. 2006). Therefore, mechanical removal or disruption of
41
42 dental plaque will be needed such as can be achieved through toothbrushing.
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50 Suggestions for further research

51
52 More robust evidence is needed to understand the impact of hospitalisation on oral health.
53
54 In particular, we recommend studies conducted in a wider range of hospital settings
55
56 including outside of critical care units. There are many outcomes measures that are
57
58 validated in oral health research and these should be selected for hospital-based studies.
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3 Furthermore, training of examiners should be provided together and outcomes of training
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5 (such as agreement levels) reported. Where feasible, longer observational periods could be
6
7 employed to investigate other oral health outcomes such as dental caries and periodontitis.
8
9

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38
39 study. All authors contributed to the study protocol, interpretation of results and
40
41 manuscript. ET conducted the search and initial screening. ET and EA conducted the full-text
42
43 screening and data abstraction. ET wrote the first draft of the manuscript.
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For Peer Review

Figure 1: Flowchart of inclusion of studies

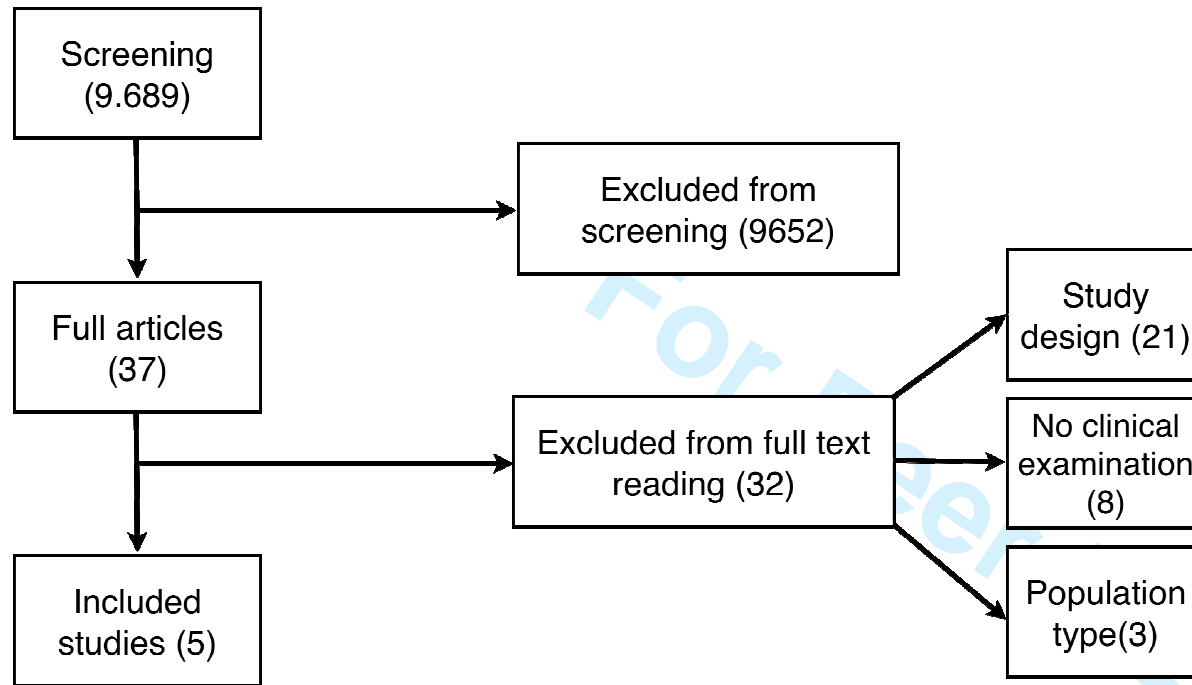


Table 1: Included study characteristics

<i>Authors</i>	<i>Participants:</i>	<i>Type of oral care provided:</i>	<i>1. Hospital department 2. Country</i>	<i>1. Type of oral care changes assessed (index used) 2. Assessor 3. Examiner training 4. Blinding</i>	<i>Quality assessment scoring</i>
<i>(Type of study)</i>	<i>1. Recruited 2. Age mean (range) 3. Drop-outs 4. Dependency/intubated 5. Duration of hospitalisation (observation period)</i>	<i>1. Personnel 2. Oral care regime 3. Frequency 4. Duration 5. Adherence assessed</i>			
Prendergast et al. 2009 ⁴⁸ (Cohort study)	1. 45 patients 2. 49.16 years (18-85) 3. D0: 45 patients D1: 31 patients D10: 13 patients 4. Fully dependent (intubated) 5. 15.1 days (1-37) (12.8 days (1-31))	1. Nurse 2. Foam swabs or child toothbrush, toothpaste, sterile water or normal saline and lip lubricant. 3. Every 4-6 hours 4. 5-10 minutes 5. Yes (nurses' notes)	1. Neuroscience ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, dental health (OAG index) 2. Nurses (3) 3. Yes 4. Yes	5/5
Munro et al. 2006 ⁴⁷ (Cohort study)	1. 66 patients 2. 55 years (25-93) 3. D0: 66 patients D4: 37 patients D7: 21 patients 4. Fully dependent (intubated) 5. Not reported (4-7 days)	1. Not reported 2. Not reported 3. 2.58 times per day (0-7 range) 4. Not reported 5. Not reported	1. Respiratory ICU 2. USA	1. Dental plaque accumulation, gingival inflammation, gingival bleeding, purulence, candidiasis, calculus, caries, stain (Oral health assessment tool) 2. Not reported 3. Not reported 4. Not reported	5/5
Dennesen et al. 2003 ⁴⁶ (Cohort study)	1. ICU: 24 patients CS: 20 patients 2. ICU: 58 years (SD 18.6) CS: 61 years (41-77) 3. Not reported 4. ICU: intubated CS: intubated for less than 12 hours 5. ICU: 20.4 days (SD 7.5) (14 days) CS: Not reported	1. ICU: Not reported CS: Not reported 2. ICU: Sterile cloth drenched with NaCl 0.9% CS: Not reported 3. ICU: Not reported CS: Not reported 4. ICU: 2/day CS: Not reported 5. Not reported	1. ICU and Cardiosurgery Ward 2. Netherlands	1. Periodontal disease (CPITN) and Oral mucositis (Quantitative scale of oral mucositis) 2. Dental hygienists (2) 3. Not reported 4. Not reported	5/5

<i>Authors</i> <i>(Type of study)</i>	<i>Participants:</i> <i>1. Recruited</i> <i>2. Age mean (range)</i> <i>3. Drop-outs</i> <i>4. Dependency/intubated</i> <i>5. Duration of hospitalisation (observation period)</i>	<i>Type of oral care provided:</i> <i>1. Personnel</i> <i>2. Oral care regime</i> <i>3. Frequency</i> <i>4. Duration</i> <i>5. Adherence assessed</i>	<i>1. Hospital department</i> <i>2. Country</i>	<i>1. Type of oral care changes assessed (index used)</i> <i>2. Assessor</i> <i>3. Examiner training</i> <i>4. Blinding</i>	<i>Quality assessment scoring</i>
Franklin et al. 2000 ⁴⁵ (Cohort study)	1. 59 children 2. 4.8 (1-16) 3. 5 children 4. 12 children orally intubated. The rest nasally intubated or not intubated 5. 7.4 days (SD 6.2)	1. Nurses 2. Foam sticks moistened with water. Antiseptics and antifungals were used at the discretion of the nurses. 3. Every 4-6 hours 4. Not reported 5. Not reported	1. Pediatric ICU 2. UK	1. Caries, missing, filled teeth (DMF index), dental plaque accumulation (O' Leary index), gingival inflammation (binary assessment), spontaneous gingival bleeding (binary assessment) 2. Author 3. Not reported 4. Not reported	5/5
Fourrier et al. 1998 ⁴⁴ (Cohort study)	1. 57 patients 2. 49 years (18-83) 3. 29 patients 4. 44 patients intubated (77%) 5. 14 days (2-82) (15 patients for 5 days and 13 patients for 10 days)	1. Not reported 2. Not reported 3. Not reported 4. Not reported 5. Not reported	1. ICU 2. France	1. Dental plaque accumulation (Plaque index from one tooth) 2. Not reported 3. Not reported 4. Not reported	5/5

Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community Periodontal Index for Treatment Needs // "DMFT index": Decayed, missed and filled teeth index //

Table 2: Reported results from included studies

Authors	Number of patients and duration of observation period	Dental plaque (index)	Gingival health (index)	Periodontal health (index)	Caries (index)	Stomatological disease incidence (index)	Other outcome measures
Prendergast et al. 2009 ⁴⁸	D0: 45 patients D4: 31 patients D7: 19 patients D10: 11 patients Mean period: 12.8 days (SD 7.5)	Median values OAG: 1st-3rd quartile D0: 2 (2-2) D4: 2 (2-3) D7: 2 (2-3) D14: 2 (2-3)	Median values OAG: 1st-3rd quartile D0: 1 (1-1) D4: 2 (1-2)* D7: 1 (1-2) D14: 2 (2-3)* * statistically significant from baseline	Not reported	Not reported	Median values OAG: 1st-3rd quartile D0: 1 (1-2) D4: 2 (1-2)* D7: 1 (2-2)* D14: 2 (1-2)	Total score in median values OAG⁴⁶: 1st-3rd quartile D0: 12 (11-14) D4: 14 (13-15)* D7: 15 (12-17)* D10: 16 (14-17)* * statistically significant from baseline
Munro et al. 2006 ⁴⁷	D0: 66 patients D4: 37 patients D7: 21 patients	Oral health assessment tool D0: 21.27 (SD 23.66) D4: 22.72 (SD 20.47) D7: 24.32 (SD 29.01)	No data presented	No data presented	No data presented	No data presented	Oral health assessment tool^{21, 53}
Dennesen et al. 2003 ⁴⁶	ICU: 24 patients for 20.4 days (SD 7.5) CS: 20 patients for 15 days	Not reported	CPITN No data presented "No changes" reported	CPITN No data presented "No changes" reported	Not reported	Median mucositis index ICU: D0: 2 (SD 3.2) D21: 19 (SD 5.9) CS: No mucositis found	% subjects n ICU: D0: 79% D7: 25% D14: 12% D21: 0% Quantitative scale of oral mucositis⁵⁴ 0-39 (health: 0) D0: 2±3.2 D21: 19±5.9
Franklin et al. 2000 ⁴⁵	54 children for 7,5 days (SD 6.2)	O'Leary plaque index D0: 22.5% (SD 17.7) Discharge: 25.8% (SD 18.5) Mean difference: 3.3% 95% CI: 1-4.53 p: 0.001	Presence of gingival inflammation (yes/no) D0: 4.1 sites Discharge: 5.5 sites Mean difference: 1.4 sites 95% CI: 0.4-2.3 p: 0.006 Spontaneous gingival bleeding D0: 0.1 sites (SD 0.5) Discharge: 0.2 sites (SD 1.1) No statistically significant differences	Not reported	DMFT index D0: Primary teeth: 1.0 (SD 2.2) Permanent teeth: 1.2 (SD 1.9) Discharge: "No changes" reported	Not reported	
Fourrier et al. 1998 ⁴⁴	Group 1: 15 patients for 5 days Group 2: 13 patients for 10 days	Plaque index (one tooth) Group 1: D0: 1.1 (SD 0.7) D5: 1.6 (SD 0.7) Group 2: D0: 1.0 (SD 0.7) D5: 1.6 (SD 0.6)* D10: 2.0 (SD 0.4)** *statistically significant different (p< 0.05) ** statistically significant different (p<0.001)	Not reported	Not reported	Not reported	Not reported	

1 Key* "D0, D1, D4, D5, D7, D10": Baseline, Day one, Day four, Day five, Day seven, Day ten // "ICU": Intensive care unit // "CS": Cardiosurgical ward // "OAG": Oral Assessment Guide // "CPITN": Community
2 Periodontal Index for Treatment Needs // "DMFT index": Decayed, missed and filled teeth index //

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For Peer Review

APPENDICES

Search strategy for Ovid Medline

1. exp Hospitalization/
2. Hospital*.mp.
3. exp Intensive Care Units/
4. Intensive care unit*.mp.
5. Intensive care ward*.mp.
6. ICU.mp.
7. Dental deposit*.mp.
8. Dental plaque.mp.
9. Dental calculus.mp.
10. Plaque accumulation.mp.
11. Plaque score.mp.
12. exp Dental Health Surveys/
13. Periodontal index.mp.
14. Gingival index.mp.
15. DMF index.mp.
16. exp Oral Hygiene/
17. Oral hygiene.mp.
18. Oral clean*.mp.
19. exp candidiasis, oral/ or exp mucositis/ exp oral hemorrhage/ or exp periodontal diseases/ or exp stomatitis/
20. Periodont*.mp.
21. Periodontal attachment loss.mp.
22. Periodontal pocket*.mp.

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23. Gingival pocket*.mp.
 24. Probing depth*.mp
 25. Bleeding on probing.mp.
 26. Gingival hemorrhage.mp.
 27. Gingival hemorrhage.mp.
 28. Gingival haemorrhage.mp.
 29. Oral mucositis.mp.
 30. Stomatitis.mp.
 31. tooth diseases/ or exp dental deposits/ or exp dental calculus/ or exp dental plaque/ or exp smear layer/ or exp
tooth demineralization/ or exp dental caries/
 32. Dental caries.mp.
 33. Tooth decay.mp.
 34. Tooth demineralisation.mp.
 35. Tooth demineralization.mp.
 36. Tooth decalcification.mp.
 37. Tooth extraction.mp.
 38. Tooth loss.mp.
 39. exp Oral Health/
 40. Oral health.mp.
 41. or/1-6
 42. or/7-40
 43. 41 and 42

Search strategy for EMBASE

1. exp hospital patient/
2. exp hospitalization/
3. hospital*.mp.
4. exp intensive care/ or exp intensive care unit/
5. intensive care unit*.mp.

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- 14 12. periodontal disease/
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- 16 13. exp periodontitis/
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- 18 14. exp thrush/
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- 20 15. exp stomatitis/
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- 22 16. exp dental caries/
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- 24 17. exp tooth extraction/
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- 26 18. dental deposit*.mp.
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- 28 19. dental calculus.mp
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- 30 20. dental plaque.mp.
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- 32 21. plaque accumulation.mp.
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- 34 22. oral hygiene.mp.
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- 36 23. oral clean*.mp.
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- 38 24. oral candidiasis.mp.
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- 40 25. oral mucositis.mp.
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- 42 26. stomatitis.mp.
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- 44 27. periodont*.mp.
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- 46 28. gingiv*.mp.
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- 48 29. dental caries.mp.
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- 50 30. tooth decay.mp.
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- 52 31. tooth demineralization.mp.
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- 54 32. tooth decalcification.mp.
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- 56 33. tooth loss.mp.
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- 58 34. tooth extraction.mp.
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- 60 35. oral health.mp
36. DMF index.mp

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37. plaque score.mp.
 38. or/1-7
 39. or/8-37
 40. 38 and 39

Search strategy for CINAHL

1. (MH "Hospitalization+")
2. TX hospital*
3. (MH "Intensive Care Units+")
4. TX intensive care unit*
5. TX intensive care ward*
6. TX ICU
7. (MH "Tooth Diseases+")
8. (MH "Mouth Diseases+")
9. (MH "Oral Hygiene+")
10. (MH "Oral Health")
11. TX dental deposit*
12. TX dental calculus
13. TX plaque accumulation
14. TX periodont*
15. TX gingiv*
16. TX stomatitis
17. TX oral candid*
18. TX oral mucositis
19. TX dental caries
20. TX tooth decay
21. TX tooth deminerali?ation
22. TX tooth decalcification
23. TX tooth decalcification
24. TX tooth loss

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25. TX tooth extraction
26. TX probing depth
27. TX bleeding on probing
28. TX gingival hemorrhage
29. TX gingival haemorrhage
30. TX plaque score
31. TX DMF index
32. TX oral clean*
33. TX oral hygiene
34. TX oral health
35. or/1-6
36. or/7-33
37. 35 and 36

For Peer Review

Modified quality assessment scale for cohort studies (based on Newcastle-Ottawa scale)

(Note: A study can be awarded a maximum of one star for each numbered item with the selection and outcome categories.)

Selection

1) Representativeness of the cohort:

- a) truly representative of the average hospitalised patients in the community (*)
- b) somewhat representative of the average hospitalised patients in the community (*)
- c) selected group of users eg nurses, volunteers
- d) no description of the derivation of the cohort

2) Ascertainment of exposure:

- a) secure record (eg surgical records) (*)
- b) structured interview (*)
- c) written self report
- d) no description

4) Demonstration that outcome of interest at baseline:

- a) yes (*)
- b) no

Outcome

1) Assessment of outcome:

- a) independent blind assessment (*)
- b) record linkage (*)
- c) self report
- d) no description

2) Was follow-up long enough for outcomes to occur:

- a) yes (3-5 days for plaque and gingival changes)(*)
- b) no

3) Adequacy of follow up of cohorts:

- a) complete follow up - all subjects accounted for (*)
- b) subjects lost to follow up unlikely to introduce bias - small number lost (subjects lost due to death or discharge from the hospital or unit) (*)
- c) no description of those lost or loss due to other reasons than death or discharge from the hospital/unit.
- d) no statement