

# A systematic review to assess interventions delivered by mobile phones in improving adherence to oral hygiene advice for children and adolescents

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## Key points

The available evidence suggests that interventions delivered by mobile phones may be effective in improving adherence to oral hygiene advice.

Argues there is a need to design mobile phone interventions that are grounded in behaviour change theory to explore this concept further.

Suggests, given the rapid proliferation of apps and other online information targeted at patients, there is a need to assess quality and effectiveness of these resources and navigate patients towards the most appropriate ones.

## Abstract

**Background** Mobile phones are potentially an invaluable tool in addressing the global challenge associated with dental caries as they may elicit behaviour change by incorporating numerous behaviour change techniques (BCTs) to address an individual's capability, opportunity and motivation.

**Methods** The methodology for this review is published on the PROSPERO database (CRD42017078414).

**Results** Two randomised controlled trials were included, both were undertaken with orthodontic patients and both reported significantly reduced plaque scores in the intervention group compared with the control at final follow-up. One study also reported statistically significantly lower gingival bleeding scores and caries in the intervention group at final follow-up. The risk of bias was 'unclear' for both studies and neither study intervention appeared to be based on specific theories of behaviour change. Of 93 BCTs available, only six were utilised across the two trials. The overall strength of evidence for the effectiveness of mobile phones in reducing plaque score was rated as moderate using GRADE, while the effectiveness in reducing bleeding scores was considered to be high.

**Conclusion** There is some evidence that mobile phones are effective in improving adherence to oral hygiene advice in orthodontic patients. The generalisability of this review is limited due to the small number of trials and the unclear risk of bias of included studies.

## Introduction

Dental caries is almost entirely preventable; however, globally it affects 60–90% of school-aged children.<sup>1</sup> In 2013, a national survey (England, Wales and Northern Ireland) reported a 28% prevalence of dental caries among five-year-old children.<sup>2</sup>

The management of extensive decay in young children is often under general anaesthesia and dental caries is now the most common reason for admission to NHS hospitals in England for 5–9-year-olds.<sup>3</sup> Repeat episodes

of dental general anaesthetic are reported to be between 4.2% and 17.0%.<sup>4,5</sup> Furthermore, general anaesthesia carries risks to health and is costly, often necessitating time off school for children and time away from work for their parents. Recent research has shown that children who have received a dental general anaesthetic are over 2.5 times more likely to be dentally anxious in their late teens than those who have not.<sup>6</sup> There are then implications associated with this, in that dental anxiety often leads to avoidance of dental care and allows for dental disease to progress, causing irreversible damage.

The Royal College of Surgeons of England has identified dental caries and dental general anaesthesia as major health care challenges. The need for Public Health England to invest in programmes to improve children's oral health was also at the forefront of recommendations made by the college to the Chief Dental

Officer.<sup>7</sup> Given that diet and oral hygiene are key components in the aetiology of dental caries, approaches to effect a change in diet and oral hygiene-related behaviours are essential to address this global challenge. Traditionally, approaches to improve oral health behaviours have aimed to increase patient knowledge. However, at present, there is weak evidence that improvements in knowledge lead to improved oral health behaviour.<sup>8</sup> Conversely, there is evidence supporting the use of interventions developed using psychological behaviour change models to improve oral health.<sup>8</sup> Although many models of behaviour change exist, a contemporary and widely accepted framework is the Behaviour Change Wheel (BCW). Developed by Michie *et al.*,<sup>9</sup> the BCW is a theoretical framework based on multiple models of behaviour change. The COM-B model forms the core of this and proposes that individuals require capability

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(C), opportunity (O) and motivation (M) to perform or adapt a particular behaviour (B). Available evidence shows that interventions based on behaviour change theory and those with more behaviour change techniques (BCTs) are more effective than those that are not based on theory and with fewer BCTs.<sup>10</sup> Behaviour change techniques are defined as 'the smallest identifiable components that in themselves have the potential to change behaviour'.<sup>11</sup> Ninety-three BCTs have been identified and categorised in the BCT taxonomy V1.<sup>12</sup>

Mobile phones may be invaluable tools in delivering interventions developed using behaviour change theory. This technology allows for several approaches to be utilised simultaneously in order to address an individual's capability, opportunity and motivation in a cost-effective manner. Mobile phones are readily available, with some sources reporting 100% penetration in Western Europe.<sup>13</sup> Moreover, they are very versatile; for example, they can also be utilised to provide personalised treatment information, such as appointment and toothbrushing reminders, at times which are convenient to the patient. A scoping review of the literature revealed that a number of randomised controlled trials assessing the effectiveness of mobile phones in improving adherence to treatment advice had been reported. Notably, evidence is emerging to suggest that apps and mobile phone-based reminders are effective in improving oral health.<sup>14,15</sup>

The aim of this systematic review was therefore to assess the effectiveness of interventions delivered by mobile phones in improving adherence to oral hygiene advice for children and adolescents.

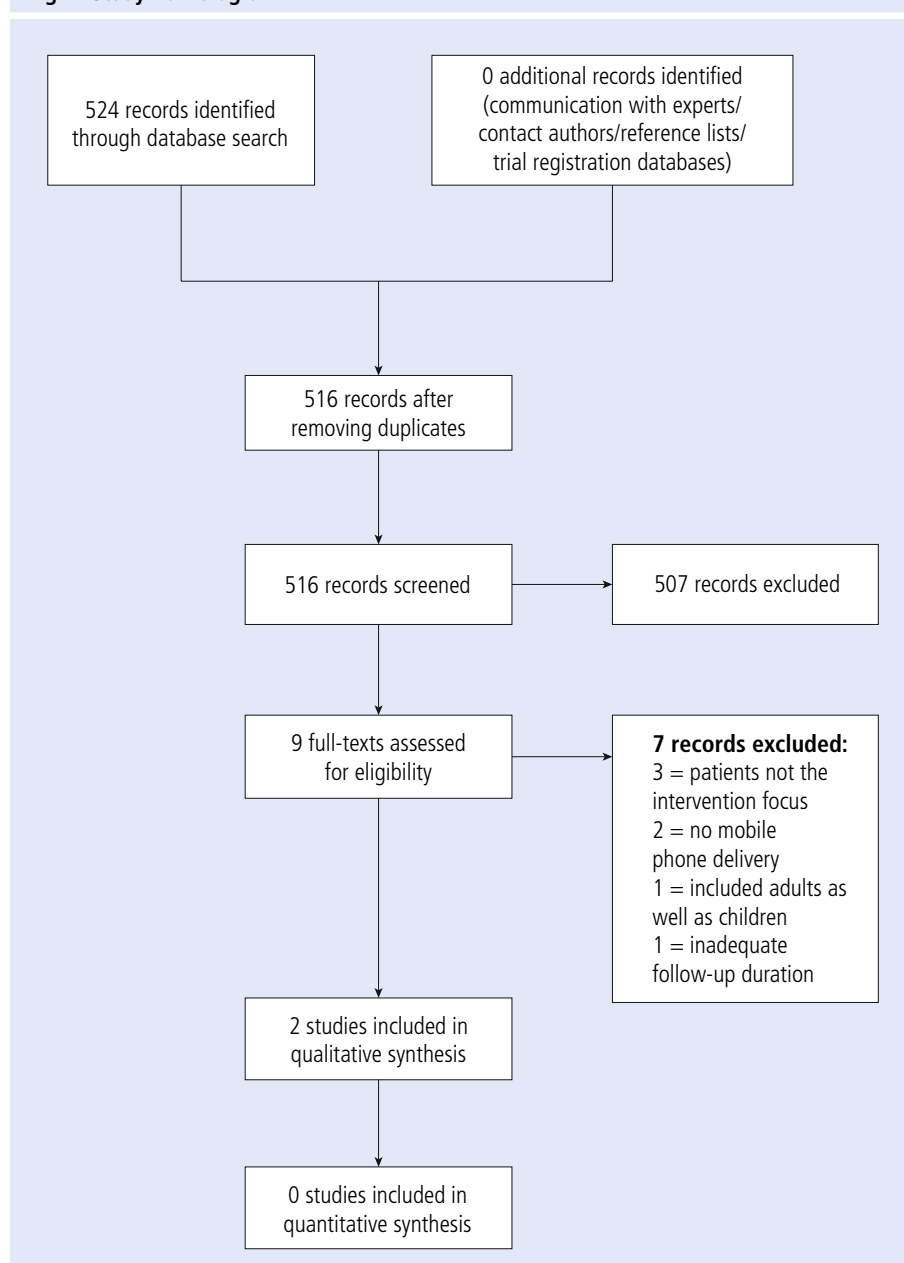
## Objective

A systematic review of randomised controlled trials to determine the effectiveness of interventions delivered by mobile phones versus other interventions not using mobile phones in improving adherence to oral hygiene advice for children and/or adolescents.

## Methods

The methodology for this systematic review including criteria for considering studies eligible for inclusion, the outcomes assessed, settings, information sources, data management, analysis and proposed synthesis was registered online on the PROSPERO database in November 2017: CRD42017078414.

Fig. 1 Study flow diagram



## Protocol changes

The registered protocol initially included 'children aged 10 to 17 years (inclusive)', however, an initial screening of the results highlighted that a number of studies included patients up to the age of 18 years. To maximise the potential studies for inclusion it was decided to amend the inclusion criteria to allow the inclusion of individuals aged 10 to 18 years (inclusive).

## Results

The search of databases (up to 18 January 2018) retrieved 524 titles and abstracts; after removing duplicates, 516 were eligible for screening

(Supplementary online appendix). The titles and abstracts were screened independently by MOS and SJC and categorised as: 'include', 'exclude' or 'uncertain'. A weighted kappa score demonstrated the overall level of agreement to be 'good' ( $K = 0.664$ ). There was 100% agreement for the records for 'inclusion', the full texts of these studies and those studies categorised as 'uncertain' were obtained for further assessment. After assessing nine full texts, two studies were eligible for inclusion and seven were excluded.

No additional studies were identified on the ClinicalTrials.gov or the World Health Organisation International Clinical Trials Registry Platform, the reference list screening

Table 1 Characteristics of included studies

	Study 1: Bowen <i>et al.</i> <sup>16</sup>	Study 2: Zotti <i>et al.</i> <sup>17</sup>
<b>Methods</b>	<p>Study design: a randomised, controlled, parallel-group trial</p> <p>Sample size calculation: 'The power analysis showed that our sample size was sufficient enough to achieve a power of 80% and maintain a type I alpha risk of .05'.</p> <p>Setting: Seton Hill University Centre for Orthodontics, Greensburg, Pennsylvania, USA</p> <p>Number of centres: one</p> <p>Operators: not stated</p> <p>Recruitment period: June 2013–June 2014</p> <p>Maximum follow-up: three months</p> <p>Funding source: none stated</p> <p>Declarations of interest: none stated</p>	<p>Study design: a randomised, controlled, parallel-group</p> <p>Sample size calculation: 'An a priori sample size (n) calculation, with the periodontal indices as the main outcomes, was performed, fixing a power of 90%. <math>\alpha</math> of 5% (<math>Z_{\alpha/2}</math>–5 1.96.'</p> <p>*Setting: School of Dentistry, University of Brescia, Italy</p> <p>*Number of centres: one</p> <p>*Operators: not stated</p> <p>Recruitment period: not stated</p> <p>Maximum follow-up: 12 months</p> <p>Funding source: none stated</p> <p>Declarations of interest: none stated</p>
<b>Participants</b>	<p><b>Inclusion criteria</b></p> <p>10–18 years</p> <p>Access to a cellular phone</p> <p>Orthodontic treatment with a fixed maxillary appliance</p> <p>At least 6 months of treatment (remaining)</p> <p><b>Exclusion criteria</b></p> <p>Not specified</p> <p>Gender: 29 females, 21 males</p> <p>Mean age: 15.1 years. Intervention group = 15.5 years. Control group: 14.6 years</p> <p>Age range: not stated</p> <p>*Number randomised: intervention group: 25; control group: 25.</p> <p>*Number analysed: intervention group: 19; control group: 21</p> <p>*Lost to follow-up/dropouts: ten (reasons not given)</p>	<p><b>Inclusion criteria</b></p> <p>Adolescent patients</p> <p>Scheduled to start orthodontic multi-bracket treatment</p> <p>Own a smartphone</p> <p>Able to be online daily</p> <p><b>Exclusion criteria</b></p> <p>The presence of a significant medical history</p> <p>A restrictive dietary regimen</p> <p>Difficulties in reading or speaking the national language</p> <p>Gender: 46 females, 34 males</p> <p>Mean age: intervention group = 14.1 years; control group: 13.6 years</p> <p>Age range: not stated</p> <p>Number randomised: intervention group: 40; control group: 40</p> <p>Number analysed: intervention group: 40; control group: 40</p> <p>Lost to follow-up/dropouts: zero</p>
<b>Interventions</b>	<p>Both groups watched an audio-visual presentation on how to brush correctly with a conventional toothbrush (the Bass technique).</p> <p>Intervention group: received automated text messages two to three times a week for four weeks (totalling 12 texts) as a reminder and encouragement to practise good oral hygiene</p>	<p>Both groups received standardised oral hygiene instructions along with toothpaste, toothbrush, mouthwash, interproximal brush, dental floss, and plaque-disclosing tablets.</p> <p>Intervention group:</p> <p>Smartphone-specific video tutorials</p> <p>Individuals given access to a chat room ('Brush Game'). All participants were instructed to share selfies of their teeth weekly, before and after using the plaque-disclosing tablets</p> <p>Participants were allowed to share information, pictures, and movies regarding oral hygiene and orthodontic treatment</p> <p>Each Saturday, the moderator visually assessed the patients' photographs and level of participation in the chat room and then published a ranking of the five best participants of the week</p>
<b>Outcomes</b>	<p><b>Primary outcome measures</b></p> <p>Plaque score: disclosed using Trace Disclosing Solution. Followed by photographs and plaque analysis of four maxillary and four mandibular teeth using planimetry.</p> <p><b>Secondary outcome measures</b></p> <p>None reported</p> <p><b>Adverse outcomes</b></p> <p>No adverse events reported</p>	<p><b>Primary outcome measures</b></p> <p>Unclear</p> <p>The following outcome measures were reported:</p> <p>Plaque index: scored by evaluating the presence of plaque at four surfaces (mesial, buccal, distal, and lingual) of tooth 1.6, 1.2, 2.4, 3.6, 3.2, and 4.4, assigning a score from zero to three for each surface, and calculating the mean overall value</p> <p>Gingival index: scored by evaluating the presence of inflammation on the same teeth as for PI and assigning a score from zero to three, as described</p> <p>Caries: buccal white spot presence on each bonded tooth, scored after five seconds of air drying and assigned a score from zero to three, and extent visually and radiographically evaluated and recorded</p> <p><b>Adverse outcomes</b></p> <p>No adverse events reported</p>
<b>Notes</b>	<p>*In the materials and methods the authors state 'the text message group was composed of 15 girls and 10 boys... while the control group included 14 girls and 11 boys.' However, in the results section, the following was stated 'twenty subjects were randomly assigned to the text message or control group. Forty subjects completed all study measurements, as two subjects from the control group and three subjects from the text group did not complete T2 measurements.'</p> <p>This led to some confusion regarding the number of patients randomised, analysed and lost to follow-up. The author was contacted by email to clarify this and to obtain further information relating to study settings and operators. To date no response has been received.</p>	<p>*The information relating to these sections was not clear from the manuscript, the contact author was contacted by email and kindly clarified these points.</p>

of included studies, communication with experts in the field or communication with contact authors. Figure 1 presents a flow diagram for the review. The searches were updated on 18 December 2018, and no additional studies were identified.

### Included studies

Two studies were included in this review.<sup>16,17</sup> One study explored the use of text messages<sup>16</sup> and the other explored the use of an 'app'.<sup>17</sup> Both of these studies exclusively recruited orthodontic treatment patients. Table 1 presents characteristics of the included studies and summarises details of the design, methods, participants, interventions, comparisons and outcome measures.

### Characteristics of the trial settings and investigators

The Bowen *et al.* trial<sup>16</sup> was conducted in the Seton Hill University Centre for Orthodontics, USA, but the providers of care were not stated. The corresponding author was contacted by email to obtain clarification, but no response has been received to date.

The setting and care providers were not stated in the Zotti *et al.* paper.<sup>17</sup> However, communication with the contact author confirmed that the study was performed in a dental hospital setting with second- and third-year orthodontic postgraduates, supervised by clinical instructors, providing patient care.

### Characteristics of trial participants

The total number of participants across the included studies was 130. One hundred and twenty participants completed all follow-up assessments. The mean age of participants in the Bowen *et al.*<sup>16</sup> and Zotti *et al.*<sup>17</sup> trials was 15.1 and 13.9 years, respectively. More females were recruited in each of the studies and both study samples comprised 58% females and 42% males.

There was some heterogeneity between the included trials; Bowen *et al.*<sup>16</sup> included participants aged 10–18 years of age, whereas Zotti *et al.*<sup>17</sup> included participants aged 12–17 years of age. Bowen *et al.*<sup>16</sup> stated that participants were included if they had maxillary fixed appliances and had at least six months of treatment remaining, which suggests that participants were in active treatment before enrolment in the study. However, Zotti *et al.*<sup>17</sup> recruited participants before commencing treatment.

**Table 2 Risk of bias assessment, Bowen *et al.*<sup>16</sup>**

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	p. 544 'Subject group assignment was done before pre-assigning the first 20 subjects to either the text message or control group'.
Allocation concealment (selection bias)	Unclear risk	Not specified
Blinding of participants and personnel (performance bias)	Unclear risk	p. 544 'Subjects were blinded as to group status and were not made aware that text messages were part of the study'.
Blinding of outcome assessment (detection bias)	Unclear risk	Not specified
Incomplete outcome data (attrition bias)	Unclear risk	Fifty patients were consented, however, only data for 40 participants was available for the final analysis. There is some information on drop-outs (two from the control group and three from the intervention), however, this does not equate to 10.
Selective reporting (reporting bias)	Unclear risk	One outcome was reported in the manuscript and reported on. However, the study protocol is not available to allow for complete assessment of this domain.
Other bias	Unclear risk	The contact author was contacted by email to clarify inconsistencies in the manuscript and to obtain further information relating to study settings and operators, to date no response has been received.

**Table 3 Risk of bias assessment, Zotti *et al.*<sup>17</sup>**

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	p. 102 'A stratified randomisation list was produced by an external office, taking into account baseline dental health, gender, age, and socioeconomic status'.
Allocation concealment (selection bias)	Low risk	p. 102 'The external office was then contacted for patient allocation to the control group (CG) or study group (SG)'.
Blinding of participants and personnel (performance bias)	Unclear risk	It is not possible to blind participants.
Blinding of outcome assessment (detection bias)	Low risk	p. 102 'All patients were examined, and PI, GI, WS, and caries presence were recorded by the same blinded examiner'.
Incomplete outcome data (attrition bias)	Low risk	There were no dropouts.
Selective reporting (reporting bias)	Unclear risk	All outcomes described in the manuscript were reported on. However, the study protocol is not available to allow for complete assessment of this domain.
Other bias	Low risk	The study authors very kindly clarified any points of concern via email.

### Characteristics of interventions

The interventions and follow-up periods varied between the two included studies. Bowen *et al.*<sup>16</sup> provided participants in the intervention group with automated text messages two to three times a week for four weeks and followed participants up for three months. Zotti *et al.*<sup>17</sup> provided participants in the intervention group with access to smartphone-specific video tutorials and a chat room, as outlined in Table 1. Participants were followed up for 12 months.

In the Bowen *et al.*<sup>16</sup> trial, all participants watched an audio-visual presentation on how

to brush with a conventional toothbrush (using the Bass technique). In the Zotti *et al.*<sup>17</sup> trial, all participants received standardised oral hygiene instructions along with toothpaste, toothbrush, mouthwash, interproximal brush, dental floss and plaque-disclosing tablets.

None of the interventions were reported to have been developed based on a specific theory of behaviour change.

### Characteristics of outcome measures

Both studies reported plaque scores, however there was heterogeneity as the method of

plaque assessment differed. Bowen *et al.*<sup>16</sup> utilised planimetry which provides the percentage of plaque coverage on each tooth; whereas Zotti *et al.*<sup>17</sup> utilised the plaque index, scoring zero to three for each surface, and subsequently calculated the overall mean. It was therefore not possible to combine the data in a meta-analysis. Zotti *et al.*<sup>17</sup> also reported bleeding scores and caries. Neither of the included studies reported adverse events, cost-effectiveness or patient preferences.

### Excluded studies

Seven studies were excluded and the reasons for exclusion are as follows:<sup>18,19,20,21,22,23,24</sup>

- Patients were not the focus of the intervention
- Mobile phones were not used to deliver the intervention
- Patients over the age of 18 years were included, the authors were contacted to determine whether data were available for adolescents only but, to date, no response has been received
- Inadequate follow-up period.

### Ongoing studies

Two potentially relevant studies are currently ongoing and were identified by contact with experts in the field. However, no data are available as of yet. The protocol for one of these studies has been published.<sup>25</sup> The results of this study may be appropriate for inclusion when they become available.

### Risk of bias in included studies

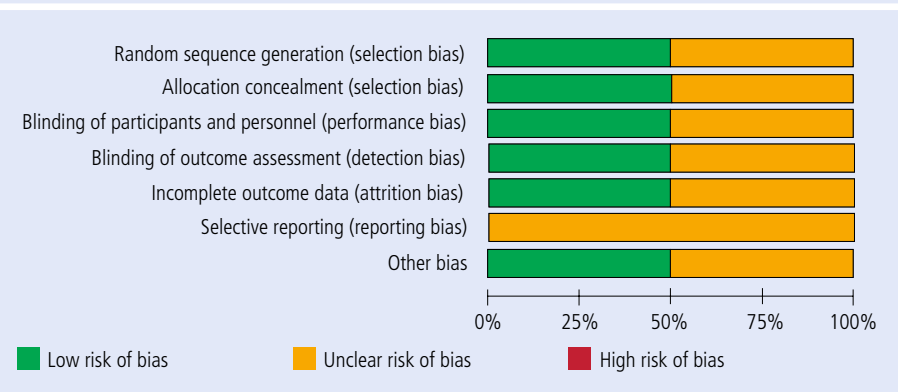
The Cochrane risk of bias tool, Review Manager 5.3,<sup>26</sup> was used to aid with presentation of the risk of bias. The assessment for each of the included studies is included in Table 2 and Table 3. The risk of bias graph and summary are presented in Figure 2 and Figure 3.

#### Allocation

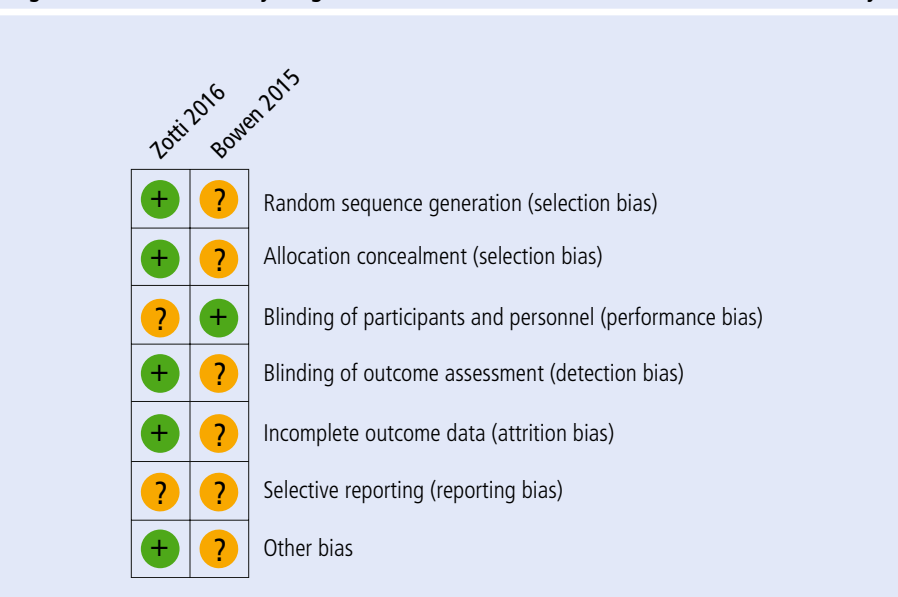
##### Sequence generation and allocation concealment

Random sequence generation and allocation concealment were assessed to be at unclear risk for Bowen *et al.*,<sup>16</sup> as insufficient detail was present to make a clear judgement and it has not been possible to obtain further information. The Zotti *et al.*<sup>17</sup> study was considered to be at low risk of bias, the authors reported using a stratified randomisation list produced by an external office which was contacted by the researchers to determine patient allocation.

**Fig. 2 Risk of bias graph. Judgements about each risk of bias item presented as percentages across all included studies**



**Fig. 3 Risk of bias summary. Judgements about each risk of bias item for each included study**



#### Blinding

Blinding of participants was judged to be a low risk for Bowen *et al.*<sup>16</sup> The authors reported that patients were not aware that messages were part of the study. The Zotti *et al.*<sup>17</sup> study was deemed to be at unclear risk of bias. However, it is appreciated that, given the nature of the study, it was not possible to blind subjects.

Blinding of outcome assessment was considered to be an unclear risk for Bowen *et al.*,<sup>16</sup> as the authors did not specify any measures taken to allow for this. The Zotti *et al.*<sup>17</sup> study was deemed to be at low risk of bias in this domain, as the authors reported blinding.

#### Incomplete outcome data

This domain was judged as an unclear risk for the Bowen *et al.*<sup>16</sup> study, as there were some inconsistencies regarding the flow of patients

through this trial, as detailed in Table 1. There were no dropouts reported in the Zotti *et al.*<sup>17</sup> study and therefore this was deemed to be at low risk of bias.

#### Selective reporting

Selective reporting was considered to be at unclear risk for both Bowen *et al.*<sup>16</sup> and Zotti *et al.*<sup>17</sup>

#### Other sources of bias

Bias from other sources was deemed to be an unclear risk for Bowen *et al.*<sup>16</sup> and as low risk for Zotti *et al.*<sup>17</sup>

#### Overall assessment of bias

All domains had to be assessed as being at low risk of bias for the study to be considered low risk of bias overall, both studies were therefore considered as being at unclear risk of bias overall.



Table 4 The COM-B component and behaviour change techniques addressed in the studies

Group	COM-B component	Behaviour change technique	Support for judgement
<b>Study 1: Bowen <i>et al.</i><sup>16</sup></b>			
<b>Control and intervention</b>	Psychological capability	4.1. Instruction on how to perform the behaviour	p. 544: 'Both groups watched an audio-visual presentation on how to properly brush with a conventional toothbrush, using the Bass technique.'
<b>Intervention</b>	Physical opportunity	7.1. Prompts and cues	p. 544: '...received automated text messages two to three times a week for 4 weeks (totalling 12 texts) as a reminder and encouragement to practice good oral hygiene.'
	Psychological capability	4.2. Information about antecedents	p. 545, Table 1: 'Brush & floss? We want no white spots or cavities. Remember 2 brush after every meal & your results will B fantastic. C U soon!'
	Reflective and automatic motivation	5.3. Information about social and environmental consequences	p. 545, Table 1: 'Your smile is the first thing people see!! keep those teeth clean and shu [sic] Orthodontics will get them straight.'
<b>Study 2: Zotti <i>et al.</i><sup>17</sup></b>			
<b>Control and intervention</b>	Psychological capability	4.1. Instruction on how to perform the behaviour	p. 102: '...patients were instructed to download smartphone-specific video tutorials regarding oral hygiene maintenance during their orthodontic treatment.'
<b>Intervention</b>	Reflective and automatic motivation	2.5. Monitoring of outcome(s) of behaviour without feedback	p. 102: '...all participants were instructed to share two selfies of their teeth weekly, before and after using the plaque-disclosing tablets, to show their ability in maintaining oral hygiene.'
	Social opportunity	3.1. Social support (unspecified)	p. 102: '...The patients were also allowed to use this chat room to share information, pictures, and movies regarding oral hygiene and orthodontic treatment.'

### The COM-B components and behaviour change techniques in included studies

In both studies, capability, opportunity and motivation were addressed to some degree and the BCTs used for this varied between studies. The results are summarised in Table 4, and some examples are provided to support the judgements made in the review.

### Effects of interventions

#### Plaque scores

For both studies, plaque scores were statistically significantly lower in the intervention group when compared with the control group at the final follow-up. However, the final follow-up time point differed between studies. Bowen *et al.*<sup>16</sup> followed patients up for a maximum of three months (T0: baseline, T1: one month and T2: three months) while Zotti *et al.*<sup>17</sup> followed patients up for 12 months (T0: baseline, T1: three months, T2: six months, T3: nine months and T4: 12 months).

Bowen *et al.*<sup>16</sup> reported significantly less plaque accumulation in the intervention group at one month and three months. Interestingly, Zotti *et al.*<sup>17</sup> reported no statistically significant difference in plaque scores between the intervention and control groups at three months; the difference was evident only from six months onwards ( $p < 0.01$ ).

#### Gingival bleeding scores

Only the Zotti *et al.*<sup>17</sup> study reported gingival bleeding scores. There was no significant

difference at baseline or three months between the intervention and control groups. However, at six, nine and 12 months there was significantly less gingival bleeding in the intervention group ( $p < 0.05$  for all three time points).

#### Caries

Only the Zotti *et al.*<sup>17</sup> study reported caries and there was no statistically significant difference in white spot lesions at baseline, three months or six months. However, at nine and 12 months, patients in the intervention group were significantly less likely to have white spots than the control group ( $p < 0.05$  for both time points).

### Summary

The results of the studies were not pooled as the content and delivery of interventions was different. Both studies reported plaque scores, however the method of plaque assessment differed and therefore it was not possible to combine these scores in a meta-analysis.

### Overall strength of evidence

The overall strength of evidence for the effectiveness of mobile phones in reducing plaque scores, as rated by GRADE,<sup>27</sup> was considered to be moderate while the effectiveness of mobile phones in reducing bleeding scores was considered to be high.

The results of the GRADE assessment are summarised in Table 5.

### Discussion

The studies included in this review were exclusively aimed at supporting orthodontic patients; because excellent oral hygiene is a prerequisite for orthodontic treatment, the results obtained cannot necessarily be generalised to the dental population as a whole. Although the interventions in both studies were delivered via a mobile phone, the content varied, with one trial providing text messages<sup>16</sup> and the other utilising video tutorials and a chatroom.<sup>17</sup> Both studies were deemed to be at unclear risk of bias, overall.

The results indicated that there is some evidence to suggest that the use of mobile phones is effective in improving adherence to oral hygiene advice. These findings are consistent with recently published systematic reviews assessing the effectiveness of reminders (including the use of mobile phones to deliver these) in improving the oral hygiene of orthodontic patients.<sup>15,28</sup>

### Overall completeness, quality and applicability of evidence

The overall strength of evidence for the effectiveness of mobile phones in reducing plaque scores, as rated by GRADE,<sup>27</sup> was considered to be moderate. The effectiveness of mobile phones in reducing bleeding scores was considered to be high. However, the generalisability of this review is limited due to the inclusion of only two trials which

Table 5 GRADE assessment summary table

Certainty assessment							Summary of findings		Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Impact	Certainty	
Plaque score (follow-up: range 3–12 months; assessed with planimetry and plaque index)									
2	Randomised trials	Serious	Not serious	Not serious	Not serious	None	Bowen <i>et al.</i> reported no difference in plaque score at baseline (T0), however, at the 4-week (T1) and 12-week (T2 - final) follow-up there was statistically significantly less plaque accumulation in the intervention group (p <0,05). Zotti <i>et al.</i> reported no difference in plaque scores at baseline (T0) or 3 months (T1), however, at 6 months (T2), 9 months (T3) and 12 months (T4 - final) there was statistically significantly less plaque accumulation in the intervention group (p <0.01 for all three time points)	3/4: moderate	Critical
Gingival bleeding scores (follow-up: 12 months; assessed with gingival index)									
1	Randomised trials	Not serious	Not serious	Not serious	Not serious	None	Zotti <i>et al.</i> reported no difference in bleeding scores at baseline (T0) or 3 months (T1). At 6 months (T2), 9 months (T3) and 12 months (T4 - final) there was statistically significantly less gingival bleeding in the intervention group (p <0.05)	4/4: high	Critical

were focused solely on orthodontic patients and their unclear risk of bias. Only one of the outcomes assessed was the same in both studies (plaque score) and the method of outcome assessment differed; meta-analysis, therefore, was not appropriate. In addition, the duration of follow-up differed in the two studies and neither study followed patients up for the whole duration of their orthodontic treatment.

### Behaviour change techniques utilised

Neither of the interventions were reported to have been developed based on a specific theory of behaviour change. This highlights a significant area for future research, given that the available evidence suggests interventions based on behaviour change theory and those with more BCTs are more effective than those that are not based on theory and have fewer BCTs.<sup>10,27</sup> Interestingly, from the 93 available, only six BCTs were utilised across the two trials to address psychological capability, physical and social opportunity, and automatic and reflective motivation to some degree.

### Implications for practice and future research

Neither of the included studies reported utilising digital interventions that

were designed using a 'ground up' approach with patient and professional engagement. However, given that there is now some evidence in support of digital interventions, the next stage should be to develop comprehensive behaviour change interventions based on behaviour change theory. In addition to the BCTs identified in this review, incorporation of others such as 'feedback on outcomes of behaviour' (2.7) and 'self-monitoring' (2.3) would seem logical, given their potential role for influencing adherence.

The maximum follow-up period identified in this review was 12 months. However, the aim of an intervention designed to improve adherence to oral hygiene advice would be to sustain change over much longer periods, preferably a lifetime. Therefore, future research also has a role in exploring the impact of digital interventions in terms of prolonged behaviour change.

This review has highlighted that there is significant heterogeneity in regards to outcome measures and interventions utilised in the current literature. Additionally, the risk of bias in the included studies is unclear. There is an increasing trend in the use of mobile phone technology, more specifically apps, in

supporting patients with health care. In July 2018, a screening search of apps relating to oral hygiene on Apple's App Store and the Google Play Store retrieved 1,075 potential apps for inclusion.<sup>29</sup> A detailed assessment of 20 apps for each search term utilised in this screening search revealed that the majority were developed after 2015, focused on the provision of oral hygiene information and were frequently free of charge. There was no indication of independent dental or oral health organisation approval or testing of effectiveness and acceptability for any of the apps. Given this availability, there is a need for practitioners to assess the quality and content of information available to patients and to direct patients towards high-quality, effective apps/resources to support them with their oral hygiene practices. A judgement must then be made in regards to recommending or guiding patients towards appropriate information resources to support their oral health. Furthermore, there is a need to assess mobile interventions utilising robust randomised controlled trial methodology including a core outcome set related to oral hygiene. This will help to ensure that the results of future studies may be synthesised in future systematic reviews.

## Conclusions

There is some evidence to suggest that mobile phones are effective in improving adherence to oral hygiene advice in orthodontic patients. However, the generalisability of this review is limited, as the included studies were exclusively aimed at supporting orthodontic patients and were associated with an unclear risk of bias.

In the short-term, given the rapid proliferation of apps and other online information aimed at improving oral hygiene, there is a need to assess the quality and effectiveness of these resources, as this will help dental professionals navigate patients towards effective resources. In the medium- to long-term, this review suggests the need to develop mobile phone interventions grounded in behaviour change theory; using core outcomes to allow for meta-analysis and the assessment of cost effectiveness. Future studies should utilise a core outcome set related to oral hygiene and explore outcomes related to patient satisfaction and engagement with the technologies being tested, this may help to identify features of successful digital interventions.

## Declaration of interests

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### Authors contributions

MOS, TN and SJC conceived the study, assisted in its design and developed the original protocol, conducted the review and developed this manuscript. The guarantor of the review is MOS.

## References

- Petersen P E. The World Oral Health Report 2003: continuous improvement of oral health in the 21st century - the approach of the WHO Global Oral Health Programme. *Community Dent Oral Epidemiol* 2003; **31** (Spec Iss): 3–23.
- Pitts N, Chadwick B, Anderson T. Children's Dental Health Survey 2013. Report 2: Dental Disease and Damage in Children: England, Wales and Northern Ireland. 2015. Available at <https://files.digital.nhs.uk/publicationimport/pub17xxx/pub17137/cdhs2013-report2-dental-disease.pdf> (accessed July 2019).
- NHS Digital. Hospital Admitted Patient Care Activity, 2016–17. 2017. Available at <http://digital.nhs.uk/catalogue/PUB30098> (accessed July 2019).
- Almeida A G, Roseman M M, Sheff M, Huntington N, Hughes C V. Future caries susceptibility in children with early childhood caries following treatment under general anaesthesia. *Pediatr Dent* 2000; **22**: 302–306.
- Thomson W M. Day-stay treatment for dental caries at a New Zealand hospital dental unit: a 5-year retrospective audit. *N Z Dent J* 1994; **90**: 139–142.
- Haworth S, Dudding T, Waylen A, Thomas S J, Timpson N J. Ten years on: Is dental general anaesthesia in childhood a risk factor for caries and anxiety? *Br Dent J* 2017; **222**: 299–304.
- Royal College of Surgeons of England. Actions for the government to improve oral health. 2015. Available at <https://www.rcseng.ac.uk/-/media/files/rcs/library-and-publications/non-journal-publications/actions-for-the-government-to-improve-oral-health--jul-2015.pdf> (accessed July 2019).
- Kay E, Vascott D, Hocking A, Nield H, Dorr C, Barrett H. A review of approaches for dental practice teams for promoting oral health. *Community Dent Oral Epidemiol* 2016; **44**: 313–330.
- Michie S, van Stralen M M, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci* 2011; **6**: 42.
- Webb T L, Joseph J, Yardley L, Michie S. Using the internet to promote health behaviour change: a systematic review and meta-analysis of the impact of theoretical basis, use of behaviour change techniques, and mode of delivery on efficacy. *J Med Internet Res* 2010; **12**: e4.
- Michie S, Johnston M. Behaviour change techniques. In Gellman M D, Turner J R (eds) *Encyclopaedia of Behavioral Medicine*. pp 182–186. New York: Springer, 2013.
- Michie S, Richardson M, Johnston M *et al*. The behaviour change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behaviour change interventions. *Ann Behav Med* 2013; **46**: 81–95.
- Kornstein S. The Rise of Mobile Phones: 20 Years of Global Adoption. 2015. Available at <https://blog.cartesian.com/the-rise-of-mobile-phones-20-years-of-global-adoption> (accessed July 2019).
- Mohammed H, Rizk M Z, Wafaie K, Ulhaq A, Almuzian M. Reminders improve oral hygiene and adherence to appointments in orthodontic patients: a systematic review and meta-analysis. *Eur J Orthod* 2019; **41**: 204–213.
- Lima I F P, de Andrade Vieira W, de Macedo Bernardino I *et al*. Influence of reminder therapy for controlling bacterial plaque in patients undergoing orthodontic treatment: A systematic review and meta-analysis. *Angle Orthod* 2018; **88**: 483–493.
- Bowen T B, Rinchuse D J, Zullo T, DeMaria M E. The influence of text messaging on oral hygiene effectiveness. *Angle Orthod* 2015; **85**: 543–548.
- Zotti F, Dalessandri D, Salgarello S *et al*. Usefulness of an app in improving oral hygiene compliance in adolescent orthodontic patients. *Angle Orthod* 2016; **86**: 101–107.
- Binkley C, Garrett B, Johnson K W. Increasing dental care utilization by Medicaid-eligible children: a dental care coordinator intervention. *J Public Health Dent* 2010; **70**: 76–84.
- Eppright M, Shroff B, Best A M, Barcoma E, Lindauer S J. Influence of active reminders on oral hygiene compliance in orthodontic patients. *Angle Orthod* 2014; **84**: 208–213.
- Brukiene V, Aleksejuniene J. Is the authoritative parenting model effective in changing oral hygiene behaviour in adolescents? *Health Educ Res* 2012; **27**: 1081–1090.
- Vangipuram S, Jha A, Raju R, Bashyam M. Effectiveness of peer group and conventional method (Dentist) of oral health education programme among 12–15 year old school children - A randomized controlled trial. *J Clin Diagn Res* 2016; **10**: ZC125–ZC129.
- de Farias I A, de Araujo Souza G C, Ferreira M A. A health education programme for Brazilian public schoolchildren: the effects on dental health practice and oral health awareness. *J Public Health Dent* 2009; **69**: 225–230.
- Li X, Xu Z R, Tang N *et al*. Effect of intervention using a messaging app on compliance and duration of treatment in orthodontic patients. *Clin Oral Investig* 2016; **20**: 1849–1859.
- Cozzani M, Ragazzini G, Delucchi A *et al*. Oral hygiene compliance in orthodontic patients: a randomized controlled study on the effects of a post-treatment communication. *Prog Orthod* 2016; **17**: 41.
- Scheerman J F M, van Meijel B, van Empelen P *et al*. Study protocol of a randomized controlled trial to test the effect of a smartphone application on oral-health behaviour and oral hygiene in adolescents with fixed orthodontic appliances. *BMC Oral Health* 2018; **18**: 19.
- Higgins J P, Green S. Cochrane Handbook for Systematic Reviews of Interventions version 5.1. 2011. Available at <https://training.cochrane.org/handbook> (accessed July 2019).
- Guyatt G H, Oxman A D, Vist G E *et al*. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008; **336**: 924–926.
- Mohammed H, Rizk M Z, Wafaie K, Ulhaq A, Almuzian M. Reminders improve oral hygiene and adherence to appointments in orthodontic patients: a systematic review and meta-analysis. *Eur J Orthod* 2019; **41**: 204–213.
- Parker K, Bharmal R V, Sharif M O. The availability and characteristics of patient focused oral hygiene apps. *Br Dent J* 2019; **226**: 600–604.