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ORIGINAL ARTICLE

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Long-term effectiveness of the midwifery initiated oral health-dental service program on maternal oral health knowledge, preventative dental behaviours and the oral health status of children in Australia

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ABSTRACT

Background: The Midwifery Initiated Oral Health-Dental Service was developed to train midwives to promote maternal oral health, and a large trial showed it substantially improved the oral health, knowledge and behaviours of pregnant women.

Aim: Evaluate the long-term effectiveness of the program (post-trial) on maternal oral health knowledge, dental behaviours, and early childhood caries in offspring.

Methods: A prospective cohort study involving 204 women and children 3–4 years (followed after trial) was conducted in Sydney, Australia from 2017 to 2019.

Results: The program did not have a significant impact on the study measures. Mothers who received the program did have comparatively better knowledge around preventative behaviours to reduce early childhood caries and significantly more mothers were engaging in a key behaviour of using a cup to feed their child. Overall maternal oral health knowledge and level of education did have a protective effect on the dental decay of children. Higher knowledge and levels of education reduced the odds of having a dmft of one or more by over half (OR 0.473), and almost 80% (OR 0.212) respectively.

Conclusions: Although the MIOH-DS program was not effective, there is still value in exploring other complementary interventions to improve maternal oral health, especially for disadvantaged families. Future research should focus on co-designing an antenatal and postnatal oral health intervention and exploring its long-term impact on the oral health of children.

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Oral health; dental decay; caries; pregnancy; mother

Introduction

The initiation of dental caries is a complex process where the presence of dental bacteria, specifically high levels of *Streptococcus mutans* and lactobacilli, have been associated with commencing and advancing dental decay [1,2]. The presence of high sucrose levels accelerates this process as the dental biofilm and bacteria shift to metabolise sugars, increase acidity, and create an environment conducive to caries development [3]. Early childhood caries (ECC), defined as presence of at least one carious lesion in children under 6 years of age, is a common chronic disease that affects children globally. Many countries across the world report a prevalence of more than 50% of ECC among children, and up to 90% in some regions, by the age of five years [4]. In Australia, around 42% of pre-school children experience decay in their primary teeth [5]. ECC can affect a child's quality of life in the short term, and impede speech, cognitive, psychological, and physical development over the long term [6]. The dental treatments for ECC can be costly [7] and delays in treatment can exacerbate the child's poor oral health, potentially resulting in the need for more extensive dental treatment including hospitalisation [8]. ECC has also been found to be a predictor of future dental carries in permanent teeth [9].

Although ECC is a multifactorial disease, its onset and progression in children can be mitigated through cost-effective educational interventions for parents and children around

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oral hygiene practices [10]. Many interventions that have been designed to manage ECC are focussed on the early infancy period (around 0–2 years of age). However, the World Health Organisation suggested that strategies should include a caries risk assessment by the child's first year and preventative measures such as behavioural management (oral hygiene, diet and the use of fluoridated toothpaste) for parents as well as pregnant women [11].

Pregnancy is a period where women are more amenable to changes in health behaviours for a range of reasons, including the desire to maintain good health during pregnancy and beyond [12]. Thus, targeted oral health educational interventions during pregnancy, especially among mothers with fewer educational qualifications, could increase the effectiveness of existing interventions to reduce dental decay for children during early infancy [13]. One Cochrane review found that although giving feeding and dietary advice to pregnant women and mothers likely results in a small reduction in ECC, this review did not focus on the role of antenatal care providers [14]. Previous studies have demonstrated that antenatal care providers can effectively promote oral health through education, risk assessment and referrals among pregnant women [15–20]. To date, only one study conducted in the United States has followed up children from an oral health intervention during pregnancy involving non-dental professionals like nurses [21]. Larsen et al. [21] followed the cohort of children ($n = 91$) to assess the program's effectiveness in improving oral health outcomes. Children of the mothers who were part of the program, were found to have had fewer dental caries and extractions after three years.

In Australia, however, there are currently no studies evaluating the effectiveness of an antenatal intervention delivered during antenatal care in reducing the incidence of dental caries among children [22]. The Midwifery Initiated Oral Health-Dental Service (MIOH-DS) program was the first model of care in Australia where midwives were trained through an online platform to promote oral health among pregnant women [18]. This model involved training midwives in providing oral health education, performing an oral health screening assessment and following clear referral pathways to dentists. The model was designed so that antenatal care providers could raise awareness about the importance of oral health during an antenatal appointment with a woman, undertake a risk assessment, and connect them with a dental service [18]. A multi-center randomised controlled trial ($n = 638$), conducted between 2012 to 2015, found that the model significantly improved the rate of pregnant women accessing a dentist, the mother's oral health and knowledge about appropriate oral health practices during pregnancy and in early childhood [23]. However, further research is needed to assess its effectiveness in maintaining the knowledge and practices in the long-term and reducing ECC among the children of mothers who received this intervention during pregnancy. Having this knowledge will greatly inform future antenatal strategies to help address the ongoing prevalence of ECC in Australia and worldwide. It will also help reinforce the important role of antenatal care providers in improving maternal and infant oral health.

Research aims and hypotheses

The aim of this study was to establish whether the MIOH-DS program is an effective antenatal intervention to: (i) maintain long-term maternal oral health knowledge and behaviours, and (ii) enhance infant oral health. This longitudinal study involved following up women and their children who had participated in the MIOH-DS program multicenter trial [23]. The specific aims were to determine the impact of the MIOH-DS program on:

- Mothers' knowledge retention in oral health care of their children
- Preventative dental behaviours (dentist visits, oral hygiene, eating and feeding habits) among their children aged between three to four years of age
- Prevalence of cariogenic bacteria and dental decay among children (ECC)

It was hypothesised that women who received the MIOH-DS program would demonstrate sustained improvement in knowledge regarding oral health care for their children. It was also hypothesised that the children of the women who received the MIOH-DS intervention program would have improved preventative dental behaviours and reduced prevalence of ECC.

Materials and methods

Study design

A prospective cohort study design was used to follow up the children of mothers who were part of the MIOH-DS multicenter trial. The reporting for this study was guided by the STROBE statement, a checklist for cohort studies [24].

Setting

The study was conducted between 2017 to 2019 across three large metropolitan health services within Greater Western Sydney (GWS) region in New South Wales (NSW), Australia where the MIOH-DS trial was undertaken. The GWS region is the residence of over 2.5 million people and is the third largest economy in Australia [25]. Compared to other regions of Sydney, however, GWS residents experience slightly higher rates of unemployment and have a smaller proportion of households with higher income [26].

Participants

Participants included mothers who participated in the MIOH-DS trial (any group) and their child. Mothers were purposively sampled according to the group they were allocated to in the trial. Specifically, this study followed up mothers and children from the intervention groups who received the MIOH-DS program which involved a midwifery and dental intervention (midwives providing oral health education, assessment and referrals to a designated public

dental service clinic), the MIOH program which involved only the midwifery intervention (midwives providing oral health education, assessment and referrals to existing services – public dental service/private dentist/health fund), and the control group who did not receive the MIOH-DS/MIOH program but did receive an oral health promotional brochure to maintain equipoise [27]. The electronic medical records were checked to exclude mothers who had adverse pregnancy outcomes such as miscarriage. As part of current NSW state health department practice, all children had access to the early childhood oral health (ECOH) program (oral health education, assessment and referrals provided by child health professionals) during their child health checks (6–8 months, 12 months, 18 months, 2, 3 and 4 years of age) [28].

Sampling and recruitment

All women in the MIOH-DS trial were invited to participate. It was expected that 30% [27] would not be contactable or lost to follow-up (due to incorrect or disconnected telephone number) and a further 10% would refuse participation. Therefore, a total of 398 contactable women were potentially able to join this longitudinal follow-up. The medical record numbers of mothers who could not be contacted were supplied to the data custodians of the electronic medical records system and obstetric database to assist in locating updated contact details.

Flyers advertising the study along with information sheets, a checklist, and reply-paid envelopes, were sent to mothers inviting their attendance with their child (when aged 3-4 years) to a free dental check-up and treatment (if required), at a nearby public dental service. Interested mothers could opt-into the study by contacting the project team directly *via* phone or using the checklist and reply-paid envelopes provided. Follow-up calls were made after two weeks of no response. Interested mothers completed a survey and had a dental appointment booked for their child. As part of current practice all children in NSW under the age of 18 years have access to free dental assessments and treatment through the public dental services [29].

Sample size calculations were conducted based on the outcome measure for early childhood caries; colonisation of decay-causing bacteria (Streptococcus mutans) in the saliva. Based on values from Günay et al. [30], detecting a 15% difference between groups would provide sufficient sensitivity [15]. To detect a 15% difference between proportions (alpha of 0.05, 80% power), 100 participants were required in each group at follow up, that is, a total of 200 participants. Given that the effect of oral health knowledge on dmft became of interest following analysis, post hoc power analysis was conducted to verify if these tests had sufficient power. These found that, with the 118 participants included in the regression model, there was sufficient power (81%) to detect an odds ratio of 0.473 with 95% confidence.

Study measures

The study measures included maternal oral health knowledge, preventative dental behaviours (eating and feeding habits, oral hygiene, and dental visits), presence of cariogenic bacteria and dental decay among children.

Oral health knowledge

Oral health knowledge was measured using 29 knowledge items, for which participants were prompted to select the correct response(s) from multiple response options. Of these, 12 items had two response options: true or false; eight items had four assorted multiple choice response options; and one item had nine response options from which participants had to select all that applied. See Table 1 for all knowledge items.

Preventative dental behaviours

Preventative dental behaviours were measured across three sections of the questionnaire, respectively regarding dental visits, oral hygiene habits and eating habits. Dental visits were measured as part of 13 items that asked parents about their perceptions on their child's oral health status, any oral health problems and their impact on daily living, and their frequency of dental service utilisation, using a variety of response formats. The six items regarding oral hygiene habits focussed on the frequency and method of toothbrushing, and also used a variety of response formats. Finally, eating habits were measured using 26 items that focussed on the consumption of sugary foods and drinks, cup and bottle use, breastfeeding status, pacifier use and other feeding practices associated with dental caries. Items on frequency of consumption of sugary foods and drinks were presented on a 7-point Likert scale (1 = Never to 7 = More than once a day), whereas items regarding bottle and cup use were presented on a 5-point Likert scale (1 = Never to 5 = Always). Four items regarding breastfeeding, bottle and pacifier use had two response options: yes or no; two items were numerical responses (number of years) and two items were multiple choice questions with four response options.

Presence of cariogenic bacteria

Presence of cariogenic bacteria was measured using a Caries Risk Test kit [31] which provided a count of cariogenic bacteria in the saliva (*Streptococcus mutans*/*lactobacilli*). The Caries Risk Test assessed the bacterial count as either $<10^5$ (negative for *Streptococcus mutans*/lactobacilli) or $>10^5$ (positive for *Streptococcus mutans*/*lactobacilli*).

Dental decay

Dental decay among children was measured using the dmft index. The dmft index is the sum of the total number of decayed, missing due to caries, and filled deciduous or permanent teeth respectively in the child's mouth and ranges from 0 to 20 [32]. The mean dmft is the sum of individual dmft values divided by the total number of children examined.

Table 1. Knowledge comparison between the MIOH-DS and Active Control group ($n = 204$).

Variable	MIOH-DS *n*(%)	Active Control *n*(%)	Total *n*(%)	Pearson's χ^2	*p*-Value
Having healthy baby teeth is not as important as having healthy permanent teeth because baby teeth will fall out (CR: False)					
Correct	67 (98.5)	125 (91.9)	192 (94.1)	3.586	0.058
Incorrect	1 (1.5)	11 (8.1)	12 (5.9)		
It is ok to use the same spoon to taste baby's food (CR: False)					
Correct	60 (88.2)	115 (84.6)	175 (85.8)	0.502	0.478
Incorrect	8 (11.8)	21 (15.4)	29 (14.2)		
It is safe to put baby to bed with a bottle of milk (CR: False)					
Correct	67 (98.5)	113 (83.1)	180 (88.2)	10.413	0.001
Incorrect	1 (1.5)	23 (16.9)	24 (11.8)		
A good way to prevent cavities in children is to give sugary snacks only at meal times (CR: True)					
Correct	18 (26.5)	26 (19.1)	44 (21.6)	1.449	0.229
Incorrect	50 (73.5)	110 (80.9)	160 (78.4)		
Dental caries is a disease in which bacteria in your mouth use sugar to produce acid that breaks down your tooth enamel. (CR: True)‡					
Correct	66 (98.5)	133 (97.8)	199 (98.0)	0.118	0.731
Incorrect	1 (1.5)	3 (2.2)	4 (2.0)		
Early tooth decay appears as yellow areas that later break down into brownish holes. (CR: True)					
Correct	64 (94.1)	128 (94.1)	192 (94.1)	0.000	*
Incorrect	4 (5.9)	8 (5.9)	12 (5.9)		
Undetected tooth decay can cause a child to suffer considerable pain and even hospitalisation (CR: True)					
Correct	68 (100.0)	134 (98.5)	202 (99.0)	1.010	0.315
Incorrect	0 (0.0)	2 (1.5)	2 (1.0)		
Children of mothers who have tooth decay are more likely to get tooth decay (CR: True)					
Correct	53 (77.9)	94 (69.1)	147 (72.1)	1.753	0.186
Incorrect	15 (22.1)	42 (30.9)	57 (27.9)		
Cheese is a snack that is least likely to cause decay (CR: True)					
Correct	50 (73.5)	93 (68.4)	143 (70.1)	0.573	0.449
Incorrect	18 (26.5)	43 (31.6)	61 (29.9)		
A pea sized amount of toothpaste should be used when brushing children's teeth (CR: True)					
Correct	67 (98.5)	135 (99.3)	202 (99.0)	0.252	0.615
Incorrect	1 (1.5)	1 (0.7)	2 (1.0)		
Children should be assisted in brushing till the age of 8 years (CR: True).					
Correct	64 (94.1)	127 (93.4)	191 (93.6)	0.041	0.839
Incorrect	4 (5.9)	9 (6.6)	13 (6.4)		
Parents should regularly perform a 'lift the lip' check on their child (CR: True)‡					
Correct	55 (82.1)	90 (66.2)	145 (71.4)	5.570	0.018
Incorrect	12 (17.9)	46 (33.8)	58 (28.6)		
A child's first dental visit should be: (CR: At one year old)					
Correct	21 (30.9)	42 (30.9)	63 (30.9)	0.000	*
Incorrect	47 (69.1)	94 (69.1)	141 (69.1)		
Which is not a risk factor for tooth decay in early childhood? (CR: Sleeping with a bottle filled with plain water)					
Correct	68 (100.0)	136 (100.0)	204 (100.0)	0.000	*
Incorrect	0 (0.0)	0 (0.0)	0 (0.0)		
Before infant's teeth appear, parents should: (CR: Clean an infant's gums with a damp washcloth after meals and before bed)					
Correct	33 (48.5)	83 (61.0)	116 (56.9)	2.888	0.089
Incorrect	35 (51.5)	53 (39.0)	88 (43.1)		
Tooth decay in early childhood is caused by a combination of many factors that include the following: (CR: All of the above)					
Correct	68 (100.0)	133 (97.8)	201 (98.5)	1.522	0.217
Incorrect	0 (0.0)	3 (2.2)	3 (1.5)		

(*continued*)

Table 1. Continued.

Variable	MIOH-DS *n*(%)	Active Control *n*(%)	Total *n*(%)	Pearson's χ^2	*p*-Value
Which of the following drinks do not cause tooth decay? (CR: Water)					
Correct	68 (100.0)	135 (99.3)	203 (99.5)	0.502	0.478
Incorrect	0 (0.0)	1 (0.7)	1 (0.5)		
Untreated tooth decay can lead to: (CR: All of the above)					
Correct	65 (95.6)	124 (91.2)	189 (92.6)	1.295	0.255
Incorrect	3 (4.4)	12 (8.8)	15 (7.4)		
When should you start brushing a child's teeth? (CR: When the first tooth appears)[†]					
Correct	53 (77.9)	103 (80.5)	156 (79.6)	0.175	0.676
Incorrect	15 (22.1)	25 (19.5)	40 (20.4)		
Tooth decay in early childhood is: (CR: The single most common chronic childhood disease)[‡]					
Correct	45 (75.0)	97 (78.9)	142 (77.6)	0.346	0.556
Incorrect	15 (25.0)	26 (21.1)	41 (22.4)		
What are factors that might increase the risk of tooth decay? Taking too much sugary food or drinks (CR: True)					
Correct	68 (100.0)	135 (99.3)	203 (99.5)	0.502	0.478
Incorrect	0 (0.0)	1 (0.7)	1 (0.5)		
Not brushing teeth with fluoride toothpaste in the morning and at night (CR: True)					
Correct	68 (100.0)	133 (97.8)	201 (98.5)	1.522	0.217
Incorrect	0 (0.0)	3 (2.2)	3 (1.5)		
Eating or drinking too frequently (CR: False)					
Correct	21 (30.9)	56 (41.2)	77 (37.7)	2.044	0.153
Incorrect	47 (69.1)	80 (58.8)	127 (62.3)		
Not rinsing after meals (CR: True)					
Correct	62 (91.2)	106 (77.9)	168 (82.4)	5.464	0.019
Incorrect	6 (8.8)	30 (22.1)	36 (17.6)		
Lack of calcium (CR: False)					
Correct	5 (7.4)	17 (12.5)	22 (10.8)	1.248	0.264
Incorrect	63 (92.6)	119 (87.5)	182 (89.2)		
Breastfeeding beyond 12 months of age (CR: False)					
Correct	50 (73.5)	105 (77.2)	155 (76.0)	0.336	0.562
Incorrect	18 (26.5)	31 (22.8)	49 (24.0)		
Discontinuing bottle feeding before 12 months (CR: False)					
Correct	57 (83.8)	119 (87.5)	176 (86.3)	0.517	0.472
Incorrect	11 (16.2)	17 (12.5)	28 (13.7)		
Sipping from a bottle/cup throughout the day with something sweet in it (CR: True)					
Correct	66 (97.1)	111 (81.6)	177 (86.8)	9.412	0.002
Incorrect	2 (2.9)	25 (18.4)	27 (13.2)		
None of the above (CR: False)					
Correct	68 (100.0)	135 (99.3)	203 (99.5)	0.502	0.478
Incorrect	0 (0.0)	1 (0.7)	1 (0.5)		

[‡]1–5 missing cases.
[†]6–10 missing cases.
[‡]11–25 missing cases.
*Not applicable.

Data collection

Data were collected across the span of one year when the child was between three to four years old. It involved collecting dental assessment data from the child, administering questionnaires to mothers, and verifying if the participant had received the ECOH program. The medical record numbers (MRNs) of the mother and child were used to link the various data. Data for both intervention and control groups were collected in the same way.

The child's dental decay was assessed by qualified and trained dental/oral health therapists using the validated decayed-missing-filled teeth (dmft)/decayed-missing filled surface (dmfs) index [32] and a Caries Risk Test kit [31] which provided a count of cariogenic bacteria in the saliva

(*Streptococcus mutans/lactobacilli*). Prior to the study six dental/oral health therapists were trained and calibrated by senior clinicians on the MIOH team to follow a standardised dental protocol during the oral assessments. More than 80% inter-rater reliability was achieved after training.

A questionnaire was administered to mothers when the child was between 3 and 4 years old via telephone or at their child's dental appointment. It assessed the self-reported oral health status, oral hygiene habits, uptake of dental services, diet, feeding practices, dental-related hospitalisations of the child, and oral health knowledge of the parent (Supplementary File 1). Demographic data were also collected to complement the existing data collected from the MIOH study. The questionnaire was pilot tested with a small sample of mothers and included validated (self-reported oral health status, uptake of dental services and previously tested items (oral hygiene habits, oral health knowledge) [27].

Statistical methods

Data were analysed using the IBM SPSS Statistics software, version 22. Demographics were analysed with descriptive statistics and frequencies. The categorical data yielded from the caries risk tests were analysed using chi-squared statistics. Data obtained from the questionnaire regarding preventative dental behaviours and oral health care knowledge were in the format of Likert-type scales and frequencies and were analysed using cross tabulations and chi-square statistics. Only the MIOH-DS group received both the midwifery and dental intervention while participants in the control and MIOH group received oral health promotion through a brochure and midwifery intervention, respectively. Further, per protocol analysis of the initial trial showed that the MIOH-DS group had the most significant improvement in oral health outcomes and knowledge [23]. Thus, the MIOH group was combined with the control group for group comparisons and termed the active control group for this study. This terminology is used to describe control groups that do receive some sort of intervention due to issues like ethical consideration [33,34]. Analyses compared participants from the MIOH-DS (intervention) group with participants from the active control group. Upon identification of any significant differences in study outcomes between these groups, logistic regression models were constructed to adjust for any related confounders. With total knowledge being the only variable that significantly differed between groups, a logistic regression model was constructed to control for variables such has having received information regarding oral health in childhood or pregnancy, visiting a dentist regularly or in the last 12 months, level of education and having private health insurance. Furthermore, the differences in proportions for the Caries Risk Tests between the groups were analysed using odds ratios. The mean dmft for each group was compared using distribution-free tests such as Mann-Whitney U tests. After inspection of untransformed variables using crosstabulations or correlation matrices as appropriate (Supplementary File 2), logistic regression was undertaken to identify predictors of having a dmft score of one or more. Variables were selected for this model on the basis of the research aims, potential to be confounding variables, as well as statistically significant associations at $p < 0.05$, and these came from various time points over the course of the MIOH project as shown in Figure 1.

Variables entered into this model included dietary habits related to sugar consumption, oral health behaviours such as sharing eating utensils, using mouth to clean pacifier, coating pacifier with sweet substances or giving a bottle when child is lying down to sleep, MIOH-DS group participant or not (1,0) and whether the mother received information about child oral health. Nagelkerke *R*-Square and Hosmer Lemeshow goodness-of-fit tests were used to explore the model fit.

Ethical considerations

Informed written and verbal consent was obtained from parents at the time of the appointment. The study was approved by the South Western Sydney Local Health District Human Research Ethics Committee (HE16/225). Reciprocal approval was also granted from Western Sydney University (HE16/225). Participating in the study was voluntary and informed written and verbal consent was obtained from all

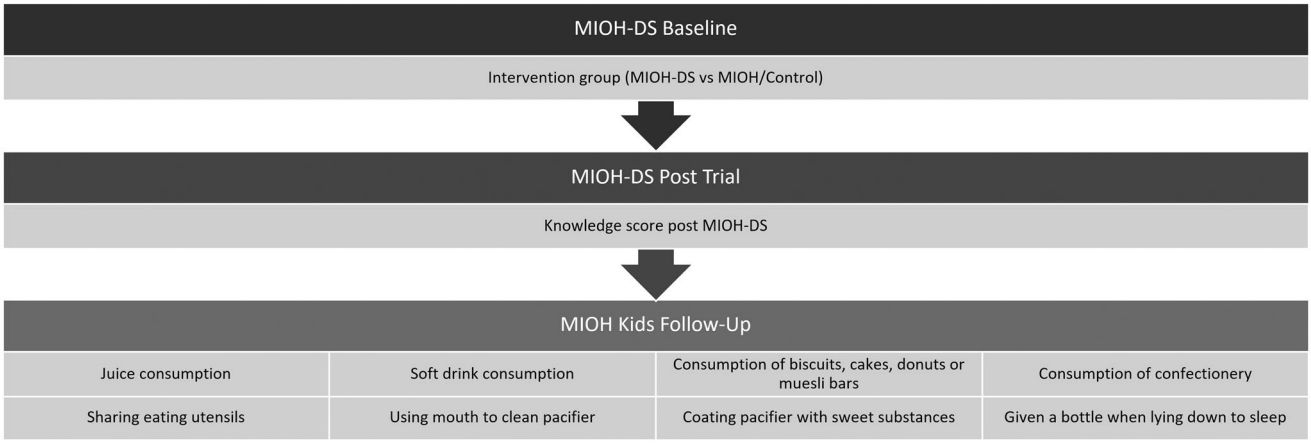

Figure 1. Timepoints for data collection.

participants. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Results

Recruitment and demographics

Of the 638 mothers who were part of the MIOH-DS trial, 204 women were followed up and completed the questionnaire (31.9% response rate, 68 (33.3%) from MIOH-DS group, 136 (66.7%) from active control group). Among the 435 mothers who did not participate, 162 (37.0%) were lost to follow up, 171 (39.3%) declined participation, 98 (22.5%) moved out of the study area and 4 (0.9%) experienced pregnancy loss. For full drop out analysis, please see Supplementary File 3. Most respondents who agreed to participate ($n = 166$, 81.2%) agreed for their children ($n = 169$) to receive an oral health assessment. Three of the mothers whose children received an oral health assessment had twins. Respondents were 33.56 ± 5.18 (SD) years old on average, most were born in Australia (62.7%) and spoke English only at home (71.1%). About half (47.8%) were not working at the time of the survey. A majority of respondents (78%) had either vocational or university education. (Table 2)

Table 2. Demographic characteristics of respondents ($n = 204$).

Variables	*n* (%)
MIOH group	
Active control	136 (66.7)
MIOH-DS	68 (33.3)
Age in years, mean [median] (SD) (range, 22–50)	33.56 [32.96] (5.18)
Country of birth	
Australia	128 (62.7)
Overseas	76 (37.3)
Language spoken at home	
English only	145 (71.1)
English and another language	35 (17.2)
Language other than English	24 (11.8)
Parity	
Primipara	34 (16.7)
Multipara	170 (83.3)
Employment status ($n = 203$)	
Working full-time	40 (19.7)
Working part-time	66 (32.5)
Not working	97 (47.8)
Highest educational qualification	
Secondary school	24 (11.8)
High school	21 (10.3)
Vocational education	105 (51.5)
University	54 (26.5)
Marital status	
Single	39 (19.1)
Married/Partnered	159 (77.9)
Divorced	6 (2.9)
Average fortnightly household income	
	4 (2.0)
$700 – $1,200	32 (15.7)
$1,200 – $2,000	38 (18.6)
$2,000 – $3,000	35 (17.2)
	34 (16.7)
Don't know	43 (21.1)
Refused	18 (8.8)
Had private health insurance	68 (33.3)
Had concession/Health Care Card ($n = 199$)	87 (42.6)
Child attending day care/pre-school ($n = 203$)	168 (82.8)

Oral health knowledge of mothers

There was a small yet significant difference in total knowledge score between MIOH-DS and active control group (22.51 in MIOH-DS vs 21.39 in active control, Mann–Whitney $U = 2710.5$, $p = 0.029$), however adjusted analyses yielded no significant associations (Supplementary File 4). Overall, participants ($n = 176$) had high knowledge scores, with an average score of 21.77 ± 2.70 out of a total of 26 points. The higher proportions of incorrect responses were seen on items related to risk factors for tooth decay such as lack of calcium (89%) and sugary snacks at mealtimes (78%) as well as the recommended age for a child's first dental visit (69%) (Table 1). Most significant differences were seen for knowledge regarding putting baby to bed with bottles of milk, performing regular 'lift the lip' checks, rinsing after meals, and sipping sweet beverages from bottles/cups throughout the day (Table 1).

Child preventative dental behaviours

Dental visits

A significant difference was found between the MIOH-DS intervention and active control group whereby those who were in the MIOH-DS group were more likely to have received information about oral health care for their child by the time of this study ($p < 0.04$).

Of the mothers who had some concern with their child's teeth (25.0%), about half (49.0%) visited a dental professional for this problem. Around 24% of mothers reported their children having their first dental visit at or before the age of one. Most children who had visited the dentist last saw a dentist in a private dental practice (65.0%) or a government dental clinic (18.8%). See Table 3 for full dental visit data. Although more than half of respondents received information about oral health care during early childhood (61.7%), few (1.6%) received the ECOH program at child health checks

Oral hygiene

There were no significant differences in the oral hygiene practices between groups. Most mothers reported that their child's teeth were brushed once or twice a day (92.1%). A majority of participants used children's toothpaste for their child's teeth (85.2%), followed by standard fluoride toothpaste (9.9%).

Eating and feeding habits

There was no significant difference in the eating habits of children across the groups. Overall, just over a quarter (27.6%) of mothers reported their child consuming juice at least once a day. A similar proportion (25.1%) reported their child consuming biscuits, cakes doughnuts or muesli bars, at least once per day. Cup usage was the only variable that varied significantly across groups in terms of feeding habits,

Table 3. Child preventative dental behaviour comparison between the MIOH-DS and Active Control group as reported by mothers ($n = 203$).

Variable	MIOH-DS *n* (%)	Active Control *n* (%)	Total *n* (%)	Pearson's χ^2	*p*-Value
Dental visits					
Sought dental professional for oral health problems/concerns[J]	7 (43.8)	18 (51.4)	25 (49.0)	0.259	0.611
Hospitalisation related to dental problems[‡]	2 (3.1)	2 (1.5)	4 (2.0)	0.558	0.455
Child regularly visits dentist every year[‡]	33 (50.8)	59 (43.7)	92 (46.0)	0.882	0.348
Last visit within past 12 months[‡]	22 (30.1)	51 (39.9)	73 (36.3)	3.518	0.475
Age of first dental visit[J]					
Under one year old	2 (4.3)	3 (3.6)	5 (3.8)	2.008	0.848
One year	8 (17.0)	18 (21.4)	26 (19.8)		
Two years	15 (31.9)	23 (27.4)	38 (29.0)		
Three years	12 (25.5)	25 (29.8)	37 (28.2)		
Four years	1 (2.1)	4 (4.8)	5 (3.8)		
Never	9 (19.1)	11 (13.1)	20 (15.3)		
Setting of child's last dental visit[J]					
Private practice	26 (63.4)	50 (65.8)	76 (65.0)	1.404	0.843
Government dental service	8 (19.5)	14 (18.4)	22 (18.8)		
School dental service	0 (0.0)	2 (2.6)	2 (1.7)		
Other	5 (12.2)	7 (9.2)	12 (10.3)		
Don't know	2 (4.9)	3 (3.9)	5 (4.3)		
Received information about child oral health[†]	46 (71.9)	73 (56.6)	119 (61.7)	0.4228	0.040
Received ECOH program[†]	2 (3.2)	1 (0.8)	3 (1.6)	1.564	0.211
Oral hygiene					
Frequency of tooth brushing with toothpaste[‡]					
Less than once a day	4 (6.0)	10 (7.4)	14 (6.9)	0.715	0.870
Once a day	34 (50.7)	63 (46.3)	97 (47.8)		
Twice a day	28 (41.8)	62 (45.6)	90 (44.3)		
More than twice a day	1 (1.5)	1 (0.7)	2 (1.0)		
Type of toothpaste used[‡]					
Standard fluoride toothpaste	7 (10.4)	13 (9.6)	20 (9.9)	0.590	0.899
Children's toothpaste	56 (83.6)	117 (86.0)	173 (85.2)		
Non-fluoride toothpaste	2 (3.0)	4 (2.9)	6 (3.0)		
None	2 (3.0)	2 (1.5)	4 (2.0)		
Amount of toothpaste used[‡]					
Less than a pea sized amount	16 (24.6)	35 (26.1)	51 (25.6)	0.087	0.957
A pea sized amount (recommended)	45 (69.2)	90 (67.2)	135 (67.8)		
More than a pea sized amount	4 (6.2)	9 (6.7)	13 (6.5)		
Assists child with tooth brushing[‡]	67 (100.0)	132 (97.1)	199 (98.0)	2.010	0.156
Eating and feeding habits					
Consumes juice at least once per day[‡]	18 (26.9)	38 (27.9)	56 (27.6)	0.026	0.872
Consumes soft drink at least once per day[‡]	2 (3.0)	4 (2.9)	6 (3.0)	0.000	0.986
Consumes biscuits, cakes doughnuts or muesli bars at least once per day[‡]	21 (31.3)	30 (22.1)	51 (25.1)	2.057	0.152
Consumes confectionary at least once per day[‡]	9 (13.4)	13 (9.6)	22 (10.9)	0.697	0.404
Drinks from bottle at least sometimes	7 (10.3)	28 (20.7)	35 (17.2)	7.015	0.135
Always drinks from regular cup	56 (82.4)	83 (61.0)	139 (68.1)	11.734	0.019
Child currently using bottle	22 (32.4)	42 (30.9)	64 (31.4)	0.046	0.831
History of regular pacifier use	28 (41.2)	57 (41.9)	85 (41.7)	0.010	0.920
Shares eating utensils with child	41 (33.3)	82 (66.7)	123 (60.3)	0.000	*
Used mouth to clean pacifier for child	8 (30.8)	18 (69.2)	26 (12.7)	0.088	0.767
Coated pacifier or teat with sweet substances	3 (42.9)	4 (57.1)	7 (3.4)	0.296	0.586
Given a bottle when lying down to sleep	28 (34.1)	54 (65.9)	82 (40.2)	0.041	0.840

[‡]1–5 missing cases.
[]6–10 missing cases.
[†]11–25 missing cases.
[J]More than 25 missing cases.

with 19.4% more mothers in the MIOH-DS group reporting their child always drank from a cup (Pearson's $\chi^2 = 11.734$, $p = 0.019$) (Supplementary File 2). A third of participants reported that their child currently uses a bottle (31.4%), and just under half of mothers reported that their child (41.7%) regularly used a pacifier at some point in their lives. Most parents reported having practiced, or currently practicing, sharing utensils while feeding their child (60.3%). Some mothers reported giving their child a bottle when lying down to rest (40.2%), using their mouth to clean a pacifier for their child (12.7%), or coating a pacifier or bottle tea with honey or other sweet substance (3.4%), at some point.

Dental decay among children

The dental decay among children did not vary significantly between the MIOH-DS and active control group (Supplementary file 5). A quarter of mothers (25.0%) reported to have some concern with their child's teeth, gums, or mouth (Table 4). These women reported the following concerns: cavities (10.8%), toothache (1.5%), broken teeth (1.0%), bleeding gums (0.5%), loose teeth (0.5%) or other problems (12.7%). The oral assessment found that overall, the 169 children who were assessed, had adequate oral health, with the mean dmfs and dmft being 0.66 and 0.56 respectively (Table

Table 4. Child characteristics and oral assessment ($n = 204$).

Variable	*N* (%)
Age (mean ± SD [median])	4.07 ± 0.41 [3.92]
Parent reported concerns with child's oral health	51 (25.0)
Parent perception of child oral health	
Very good	89 (43.6)
Good	85 (41.7)
Average	23 (11.3)
Poor	7 (3.4)
Streptococcus mutans positive	32 (15.5)
Lactobacilli positive	33 (15.9)
dmft (mean ± SD [median])	0.56 ± 1.31 [0]
dmfs (mean ± SD [median])	0.66 ± 1.87 [0]
dmft at least 1	37 (21.9)
Dmft ≥1 indicates any child who had at least one decayed, missing or filled tooth.	

Table 5. Regression model of determinants of having a dmft score of 1 or more ($n = 118$).

Covariate	Odds ratio (exp(B))	Standard error	Wald	95% Confidence interval for odds ratio		*p* Value
				Lower	Upper	
Child consumes juice at least once a day	3.444	0.636	3.872	0.990	11.974	0.052
Child consumes biscuits, cakes, doughnuts or muesli bars at least once a day	0.855	0.637	0.060	0.246	2.979	0.806
Child consumes confectionery at least once a day	0.461	1.186	0.425	0.045	4.717	0.514
Shares eating utensils with child	1.306	0.572	0.217	0.425	4.007	0.641
Given a bottle when lying down to sleep	0.442	0.627	1.693	0.129	1.512	0.193
Knowledge score (MIOH Kids)	1.077	0.111	0.454	0.867	1.338	0.500
Knowledge score (post MIOH-DS)	0.473	0.299	6.262	0.263	0.850	0.012
MIOH-DS vs MIOH/Control groups	0.863	0.588	0.063	0.273	2.734	0.802
Mother received information about child oral health	1.633	0.595	0.732	0.518	5.339	0.392
Level of education	0.212	0.654	5.641	0.059	0.762	0.018
Had private insurance	1.812	0.580	1.049	0.581	5.651	0.306

5). Of these children, 15.5% tested positive for *Streptococcus mutans* and 15.9% tested positive for lactobacilli (Table 4).

The regression model for predictors of dmft scores of one or more found mothers' oral health knowledge scores at the end of the MIOH-DS trial, and highest level of education to be significantly associated with their child's dmft at the time of assessment (Table 5). With each additional knowledge score point at the end of MIOH-DS trial, the odds of having a dmft of one or more were reduced by over half (OR 0.473). Additionally, each additional level of education (primary, secondary or tertiary) decreased odds of a dmft of one or more by just under 80% (OR 0.212). This model was shown to have good fit, with a Hosmer and Lemeshow goodness of fit test yielding a non-significant result ($p = 0.211$, 8df) and a Nagelkerke *R* Square of 0.231.

Discussion

This is the first study that has evaluated the long-term oral health outcomes in infants of mothers who received a comprehensive oral health program delivered by antenatal care providers during pregnancy. Results revealed that the intervention program did not have a significant effect on the oral health knowledge of mothers, preventative dental behaviours of children (except for cup usage in feeding) and the dental decay of the children. Overall, however, the study found that high maternal oral health knowledge provided a protective effect for dental decay in children across the groups.

The limited impact of the antenatal program could be attributed to several reasons. Firstly, sleep deprivation and the stress of caring for young children have been cited as key contributing factors to memory loss among mothers [35–37]. Thus, it is possible that mothers in the intervention group may have forgotten the oral health advice for children that was provided during their pregnancy, particularly as it was delivered between 3 and 4 years prior to the present study. Some studies have also suggested that the challenges of pregnancy and the post-partum period can influence cognitive capacity of mothers, leading to forgetfulness and memory loss [35,38]. Secondly, due to the ethical requirement to maintain equipoise in the initial MIOH-DS trial, the control group also received oral health promotion through brochures which may have influenced the high knowledge score in the comparison group and the resulting non-significant adjusted analysis. In addition, the low incidence of dental decay in study participants coupled with the limited sample size would have contributed to the insufficient power to observe any statistical significance between groups.

Similar to the current study, previous research involving antenatal oral health interventions have also found no significant change in maternal oral health knowledge between groups [15,16]. However, the study intervention group did have better knowledge about key risk factors for early childhood caries such as putting the baby to bed with a bottle and sipping sweet beverages from bottles/cups as well preventative strategies like performing regular oral health checks (lift the lip). It is also encouraging to see that significantly more mothers in the intervention group were using a cup to feed their child. This is an important preventative dental behaviour as the continued use of a bottle in children

beyond 14 months of age can increase the risk of early childhood caries [6].

Although the MIOH-DS intervention had a limited impact on the study outcomes, a key finding was the protective effect that overall maternal oral health knowledge had on the dental decay of children. This finding has clinical relevance as it indicates there is still value in improving maternal oral health knowledge and suggests the need for other interventions to be explored to complement or replace the MIOH-DS intervention. Reinforcement of oral health education postnatally through care providers is an avenue that could be explored. This would be particularly useful as previous reported data on the MIOH-DS program has showed that oral health outcomes and knowledge among pregnant women were improved in the short term only [22]. In fact, changes in oral health knowledge appeared to diminish during the follow up period. Such a strategy was recently noted by a review conducted by George et al. [21]. This work suggested that a combined intervention across both the antenatal and postnatal periods may deliver results in improved oral health outcomes among children. Further, some studies have suggested that health advice from clinicians can assist to educate and remind parents about preventative behaviours [37]. It is important to point out though the ECOH program is currently available for parents in Sydney supported by the state health department [28]. In the ECOH program, delivered postnatally, oral health promotion along with certain feeding and dietary behaviours are reinforced through child health professionals; however, in this study very few mothers received the ECOH program. Low uptake of the ECOH program among participants suggests the need for other intervention strategies involving various stakeholders, such as general practitioners, pharmacies, and childcare services, to be considered to reinforce maternal and infant oral health. Further, studies show co-designing strategies with parents may also improve uptake and acceptability of such interventions [39,40]. Focussing such interventions on socioeconomically disadvantaged communities could have added benefits as level of education of mothers was also a predictor of dental decay in children and this association is well supported in the literature [41,42].

When developing new interventions in this area it might be worthy to consider some of the study findings to inform key messages that need to be reemphasized and strengthened. Although it was not asked as a knowledge item, some mothers reported coating their child's pacifier in a sugar sweetened substance, sharing utensils while feeding and giving a bottle to the baby while lying down. These behaviours significantly increase the risk of early childhood caries [6] and highlight a knowledge gap among parents. Understanding the oral health impact of sugar consumption is important as caregivers tend to have greater intention to limit sugary foods and drinks they offer to their child, when higher knowledge is evidenced [43].

Another potential focus area is around timing of dental visits for young children. About 50% of children in our sample had seen a dentist by the age of two years, but only a few had seen the dentist by the recommended age of one. Strategies that have the potential to change intention to see the dentist and thus, improve dental visits are a very important step towards diminishing the ECC inequality. This has recently been suggested by Peres et al. [44]'s findings from the analysis of a National Child Oral Health Survey conducted in Australia. The need for timely messages about seeing the dentist is also supported by literature in other high-income countries, which have found that caregivers may not book dental appointments by the recommended age due to lack of awareness or misinformation [45–47]. Thus, this reinforces the need for educational interventions on dental visits during the postnatal and early childhood period.

Lastly, it is important to ensure in future interventions that parents are made aware of affordable dental referral pathways for children. In this study only 19% of parents reported accessing public dental clinics for their child despite the service being free and easily accessible [29]. Reasons for the poor uptake of these services were not explored in this study. Various other Australian surveys; however, have found that about 30% of parents were not aware that their child was eligible for free public dental services [48,49]. Further, only about half of parents in Queensland were aware of the Child Dental Benefits Schedule that subsidises the cost of preventative or general dental treatment for children in public or private practices [48]. This vital information could be easily reinforced through post-natal interventions.

The strengths of this study include prospectively collected data in a large cohort using validated measures. The limitations include a smaller sample size than calculated, and the impact of a lack of statistical power was evidence by a lack of statistical significance in this study. Thus, future research would need to include a larger number of participants. It is also important to note that our sample had an overall low incidence of dental caries; therefore, sampling at a later age where dental caries is more prevalent could improve power.

The long latency period before the follow up likely contributed to the 32% follow up of participants who received the original program. This may have contributed to the low response rate as many participants had moved away or changed contact details. At the same time, due to the high non-response rate, those who responded may likely be people who have a greater interest in oral health. Similarly, this loss to follow-up of women may have contributed to selection bias; however, as indicated in the drop-out analysis, there was not a large difference between groups and group characteristics so the impact of selection bias was likely to be minimal. Although the ECOH program is recommended state-wide, very few women in this study, received the program for their children. Consequently, it is difficult to ascertain the impact of the ECOH program on early childhood oral health when combined with an antenatal oral health intervention. Furthermore, due to the presence of incomplete data, certain covariates did not have enough responses to be included in adjusted analysis, including household income and possession of a health care card.

Conclusions

The MIOH-DS antenatal program did not have a significant impact on long-term maternal oral health knowledge,

preventative dental behaviours among children and the prevalence of early childhood decay. Those who received the program though did have comparatively better knowledge around preventative strategies to reduce ECC and significantly more mothers were engaging in a key behaviour of using a cup to feed their child. Further, overall maternal oral health knowledge did have a protective effect on the dental decay of children. These findings suggest there is still value in exploring other interventions to improve maternal oral health, especially for disadvantaged families that could potentially complement the MIOH-DS program. Future research should explore the long-term impact of a co-designed antenatal and postnatal oral health intervention on the oral health of children in children. Such strategies should align with the Australian governments focus on preventative initiatives across pregnancy and first 2000 days [50].

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Data availability statement

The dataset used during the current study are available from the corresponding author on reasonable request.

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