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Effects of nutrition and hygiene education on oral health and growth among toddlers in rural Uganda: follow-up of a cluster-randomised controlled trial

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Abstract

OBJECTIVE To examine the effect of a nutrition and hygiene education intervention on oral health behaviour and whether early onset of caries was related to child growth in rural Uganda.

METHODS Follow-up study of a cluster-randomised controlled trial conducted between October 2013 and January 2015. Data were available from 399 mother/child pairs (203 in the intervention and 198 in the control group) of the original trial (78%) when the children were 36 months old. Oral health behaviour was evaluated using questionnaires. Photographs of the maxillary anterior teeth were examined for unmistakably carious lesions, and 115 water samples from the study area were analysed for fluoride concentration.

RESULTS The frequency of cleaning of the child's teeth at 36 months was about twice as high in the intervention as in the control group (84.3% *vs.* 46.6%; $P = 0.0001$). Cavitated carious lesions occurred more frequently in the control than the intervention group (27.8% *vs.* 18.2%; $P = 0.04$). Extraction of 'false teeth' (*ebiino*), a painful and crude traditional operation, was profoundly reduced in the intervention group (8.9% *vs.* 24.7%; $P = 0.001$). There was no evidence of association between the occurrence of caries and child growth.

CONCLUSIONS The education intervention improved oral hygiene practices and reduced the development and progression of caries and extraction of *ebiino*. Early childhood caries was not clearly associated with child growth.

keywords children, nutrition education, oral hygiene, teeth, caries, Uganda

Introduction

Inadequate nutrition continues to impact negatively on growth and cognitive development in low-resource settings including rural sub-Saharan Africa [1]. A vicious cycle develops as poor nutrition leads to poor oral health, and poor oral health impacts negatively on eating [2–4]. Early childhood caries (ECC), or nursing caries, is characterised by rapidly developing carious lesions, chronic inflammation and mouth pain [5–7]. The main contributing factor to ECC is nutrition with frequent consumption of fermentable carbohydrates or highly processed sugary foods [8]. Oral bacteria act on sugary or fermentable carbohydrate foods [9] producing an acidic environment, and this causes dissolution of the underlying dental minerals [8] in the tooth resulting in dental caries.

Caries in primary teeth may result in compromised chewing and speech problems, reduced growth and development, odontogenic infections and bacteremia with premature loss of these teeth that may harm the permanent dentition [10, 11]. ECC may also confer an increased risk of future caries development [12, 13]. Furthermore, beliefs and lack of knowledge about oral hygiene and diet in different cultures may cause ECC through dietary and feeding practices, but also child-rearing habits [14, 15].

Water fluoridation with the recommended optimum amount of 0.7 mg/l of fluoride is a cheap and efficient public health measure to prevent caries [16–18], but it remains elusive for socially disadvantaged groups within rural communities. Fluoride in water and toothpaste slows down the progression of caries in tooth surfaces by reducing demineralisation [19, 20]. Lack of access to dental care, poor accessibility to fluoride supplementation or water fluoridation and lack of knowledge of the importance of oral health are contributing factors to oral health decline among impoverished young children [10].

A malpractice in many parts of rural Africa, including Uganda, involves removal of deciduous canine tooth buds, locally known as *Ebiino* ('false teeth'), from infants and young children [21, 22]. 'False teeth' are perceived as a disease which is associated with diarrhoea and high fever and are thought to cause death if not removed [23]. The removal may involve a crude method of operation where an incision is made in gingival margin and with a sharpened bicycle spoke, wire, nail or knife (usually unsterilised) and the un-erupted deciduous tooth is removed [21, 23].Other local treatment for 'false teeth' may include among others, making an incision on the gum and rubbing herbs or simply rubbing herbs on the gum [24, 25]. Nuwaha *et al.* found that nearly 60% of rural households in South-Western Uganda reported that at least one child under 5 years had suffered from perceived 'false teeth' [23].

Few studies have examined the relationship between feeding habits, undernutrition, poor oral hygiene and fluoride in water and ECC in developing countries [6, 26, 27], and even fewer have addressed these issues in rural communities. Moreover, these studies have mainly been cross-sectional. Thus, it would be of interest to include oral health in nutritional programmes for children in longitudinal studies in rural communities in developing countries. We therefore hypothesised that including oral health in mothers' nutrition education programmes would improve markers of oral health (e.g. caries and 'false teeth removal') in children in these communities.

We previously performed an open, cluster-randomised trial to test the effect on growth and development of a 6 months' intervention consisting of nutrition, sanitation/hygiene and stimulation education, including oral health, among impoverished mothers of children aged 6–8 months in rural Uganda [28]. However, this education intervention did not improve children's growth at the age of 20–24 months, cognitive, language and motor development improved markedly. We conducted a follow-up of this trial when the children were 36 months old. Specifically, the aim of this follow-up study was to examine whether (i) the education intervention had an impact on oral health behaviour and early onset of caries, and (ii) whether early onset of caries was related to the nutritional status, a proxy for growth, of the children.

Methods

Study area and participants

Here, we report on a subcohort of our original cluster-randomised trial performed between October 2013 and June 2015 and detailed recently [28]. Briefly, the trial was conducted in Kabale and Kisoro districts in South-Western Uganda because of the high levels of child stunting reported in that region [29]. Town centres within the districts were excluded to minimise differences in socio-economic status, oral hygiene and feeding practices. Districts are made up of several subcounties, and each subcounty is an administrative unit consisting of 18–25 villages.

Randomisation and allocation to study groups

Participant recruitment is detailed [28] elsewhere. In brief, proportionate sampling was used to obtain 10 subcounties (i.e. clusters; six of 19 in Kabale and four of 14 in Kisoro) to participate in the trial. We used a three-stage procedure to obtain households for the trial. First, by simple random sampling, subcounties in both districts were allocated to the intervention or control group. Second, all the villages in each participating subcounty (intervention or control) were listed alphabetically and assigned numbers in ascending order. By use of computer-generated random numbers, villages whose position matched with the random numbers were identified eligible. Third, by complete enumeration, all consenting households with children aged 6–8 months within a participating village were recruited to the study. Households were excluded if the child had (i) congenital malformation(s), (ii) a physical disorder that would influence growth or preclude anthropometric measurements or influence nutrient intake, (iii) been diagnosed with a mental or brain illness as reported by the mother or a health worker, (iv) if the household was likely to migrate within the study period, or (v) if the mother was unable to provide information or unwilling to participate in the study. The study personnel collecting the data and analysing the study outcomes was blinded to group allocation.

Approvals

The study was reviewed by the Makerere University School of Public Health, Higher Degrees Research and Ethics Committee, and was approved by the Uganda National Council for Science and Technology. It was also approved by the Norwegian Regional Committee for Medical and Health Research Ethics. The consent form was translated into the local language for the participants, and all of them gave written or thumb-printed, informed consent to participate. The trial is registered at ClinicalTrials.gov, number NCT02098031.

Delivery and content of the education intervention

The main education intervention started when the children were between 6 and 8 months old and lasted 6 months. Thereafter, the intervention group (mothers in their village groups) was followed up periodically after every 3 months (eight times in all) with booster education sessions until the children were 36 months old. In these sessions, mothers were reminded of the oral hygiene messages, encouraged to continue cleaning children's teeth, and we replaced damaged or lost toothbrushes. Details regarding this intervention are given elsewhere [28]. Briefly, it was delivered to groups of mothers by a team of nutrition educators who demonstrated breastfeeding practices and cookery. They advised the mothers to start complementary feeding of children with nutrient-rich foods while breastfeeding continued, to increase the number of feeds to 3–4 times a day and to provide nutritious healthy snacks (such as fruit) to children between the main meals. The mothers were also encouraged to practice responsive feeding and allow the children to feed themselves. Furthermore, the nutrition educators formulated recipes and demonstrated their cooking using locally available foods with emphasis on high-quality (preferably animal) protein.

The importance of hygiene and sanitation was given special emphasis. In particular, we focused on washing of hands of mother and child and the utensils used in cooking and feeding the child. Mothers were advised to always clean the mouth of the infant with a clean cloth and boiled warm water. The mothers were educated about the consequences of removing tooth buds ('false teeth' removal). The habit of removing 'false teeth' was discouraged, and the mothers were counselled to take sick children to hospital even when they suspected 'false teeth'.

Oral hygiene promotion

During the follow-up period when the children were 12–16 months old, and all the children had erupted at least four teeth (two upper and two lower incisors), the mothers in the intervention group were educated on the importance of good oral hygiene to prevent early onset of caries in their children. The children were given age-appropriate toothbrushes, and the team of nutrition educators demonstrated the cleaning of the children's teeth. The rest of the household also received toothbrushes to avoid other family members sharing the index child's toothbrush. Moreover, the mothers were given instructions to (i) brush the child's teeth with clean, boiled and cooled water at least twice a day, especially before going to bed; (ii) clean the brushes after use before storing them safely in a clean container, preferably with a cover; and (iii) not to share the toothbrushes.

Mothers were counselled to stop the habits of licking the children's feeding utensils and chewing food/herbal medicine to spit in the baby's mouth. During the follow-up period, the mothers were encouraged to continue the good oral hygiene practices and if the children's toothbrushes were lost or damaged, they were replaced.

Collection of anthropometric measures

We recently detailed our data collection procedures for anthropometric measurements [28]. Data collection took place at 20–24 months and at 36 months. In case of child illness, data collection was postponed. Nutritional status was evaluated using weight and length, following standard procedures and calibrations recommended by WHO [30]. Weight (to the nearest 0.1 kg) was measured with a Seca-scale model 881 (Hamburg, Germany), whereas recumbent length was measured (to the nearest 0.1 cm) with a length board (Seca, SO114530). The date of birth was obtained from the child health card. These anthropometric data were converted to z-scores, height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) using the WHO Anthro (version 3.2.2) software [31]. Undernutrition (stunting, underweight and wasting) was defined as a z-score below minus two SD from the median of the WHO reference standards for HAZ (stunting), WAZ (underweight) or WHZ (wasting), respectively [30]. A score of less than three SD below the median was defined as severe undernutrition.

Collection of oral data

Oral data was first collected when the children were 20–24 months. This consisted of a dental questionnaire with questions concerning oral health, in particular 'false teeth', feeding practices, teething and oral pain. Dentists at the Faculty of Dentistry, University of Oslo, developed the questionnaire about oral health. It was organised as an interview with both closed and open-ended questions exploring relevant symptoms related to teething problems and/or oral pain interfering with eating. Trained assistants who were conversant with both English and the local language conducted the interviews and filled in the questionnaires. Mothers were required to retrospectively recall among others, whether the children had teething problems, symptoms, if there had been 'false teeth' and 'if yes', what had been done. The questions were phrased in simple English, translated into the local language and finally back-translated to English. They were then pre-tested on a group of mothers of children with the same age outside the study area before being administered to the participants. The number of erupted teeth was also counted. At 36 months, we again asked the mothers about 'false teeth' and cleaning of teeth using an assessment questionnaire. We then also took close-up intra-oral photographs of the upper front teeth of the child to determine the occurrence of carious lesions, registered as unmistakable cavities progressing into the dentine as recommended by WHO [32]. The photographs were taken with a Canon EOS 1100D Camera (Canon Inc., Taiwan) with a 60 mm macro-lens and a macro-ring flash. We aimed at an aperture of F stop 22 for the sharpness of the picture. ECC is defined as the occurrence of any signs of dental caries on any tooth surface during the first 3 years of life [33]. However, as the early stages of dental caries are not possible to identify on photographs, only obvious, cavitated lesions into the dentine were registered as caries. The photographs of the upper front teeth were evaluated by two experienced dentists (ABS and TW) who were blinded to the children's group allocation. Interexaminer agreement measured by kappa was 0.97. In case of disagreement, the tooth was scored as sound.

Measurements of fluoride concentration in drinking water

To determine the fluoride concentration in the water, we collected 115 samples from the various water sources (protected springs, $n = 70$; gravity (i.e. tap) water, $n = 14$; unprotected, free-flowing springs, $n = 14$; ponds, $n = 10$; swamp, $n = 3$; and rain harvested water, $n = 4$) in the different villages in the study area (54 from intervention villages and 61 from control villages). The fluoride concentration was analysed by Vestfold Lab Ltd. (Sem, Norway) using ion chromatography (Lachat QuikChem; Hach Company, Loveland, CO, USA). The fluoride concentration was classified as low <0.7 mg/l or high ≥0.7 mg/l, in line with the WHO recommendations for drinking water [34, 35].

Statistical analyses

The original trial included 511 households. This number would enable us to detect a positive difference of 0.3 SD HAZ (i.e. primary outcome; power 0.8 and P-value <0.05) at 20–24 months between the intervention and control group, corresponding to about half a percentile in HAZ and deemed clinically relevant [28, 36]. The assessment was by intention-to-treat. Due to time and cost restraints, the child had to be 20–24 months during the period of January-May 2015 to be included in this follow-up study. At this age (20–24) months, most of the primary teeth have erupted.

We performed the statistical analyses with SPSS version 24 and StataSE 14 (64-bit). Significance was set at $P < 0.05$. Pearson's chi-squared tests and Fisher's exact test (where the expected number of at least one cell was smaller than 5) and logistic regression were performed to determine possible relations between various factors with caries and nutritional status. To determine the difference between the two groups, we performed a logistic regression with an interaction term in the model.

Results

Inclusion of participants into the follow-up study

Figure 1 depicts the inclusion profile, starting from the original sample of 511 children and showing the number of children in both study groups who were available for relevant data analyses (i.e. information on oral characteristics, front teeth photographs and assessment responses) in the current follow-up study. Notably, for both study groups, the participant sample number at 20–24 months differed somewhat from that sampled at 36 months. This was partly due to the mothers not appearing at the specified assessment dates and partly because the children did not cooperate.

Baseline socio-demographic characteristics

The baseline characteristics (obtained when the children were 6–8 months) of the original trial cohort and those of the follow-up study cohort were similar (Table 1), except that in the follow-up cohort, breastfeeding frequency was significantly higher in the intervention group.

Occurrence of caries, other oral characteristics, hygiene and care practices

The occurrence of caries was significantly higher in the control group than in the intervention group (Table 2). Although not significant, the number of teeth with caries was slightly higher in the control group than in the intervention group. Notably, the less severe cavitation and severe decay (i.e. caries) were significantly higher in the control group (Table 2). Figure 2 shows close-up photographs of the upper front teeth giving examples of both

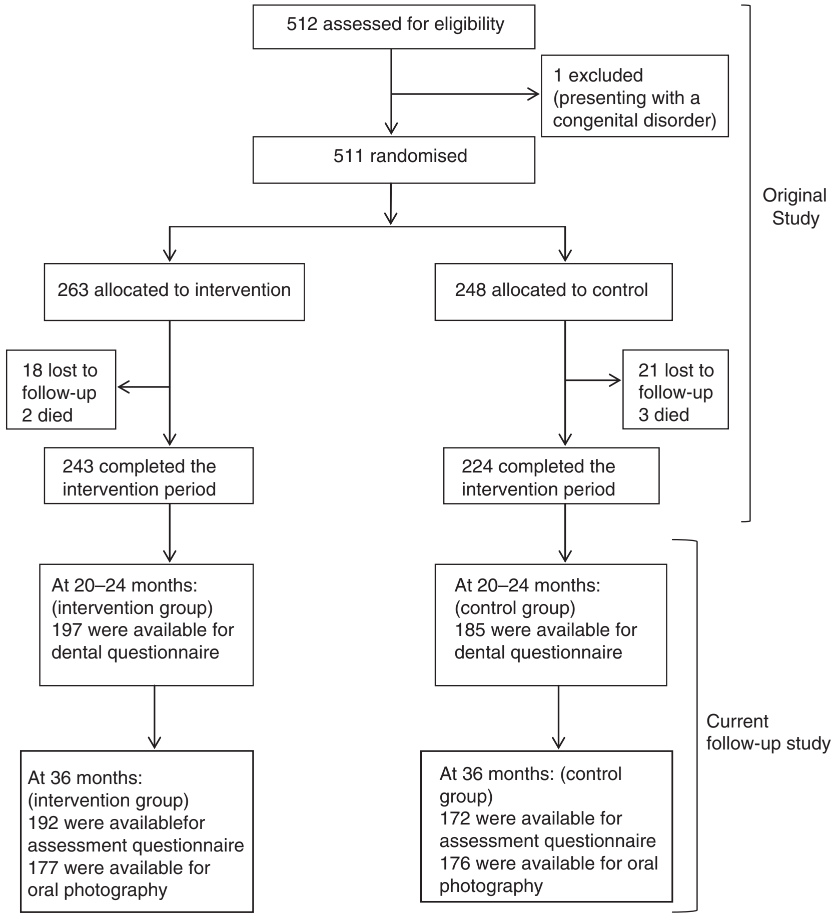

Figure 1 Flow chart of trial progress.

sound and decayed teeth. By 20–24 months, only 47 (12.3%) of all children had completed tooth eruption. The intervention group had a significantly higher proportion of children with more teeth than the control group (Table 2).

We also enumerated night feeds as the risk of caries is increased during night-time due to reduced saliva secretion which plays a role in neutralisation of bacterial acids. The proportion of mothers who reported giving night feeds to the children was higher in the control group than the intervention group (Table 2).

Children in the control group were reported to have experienced teeth eruption symptoms significantly more often than children in the intervention group (Table 2). However, the symptom types that were reported did not differ (Table 2). Pain in the oral cavity (at time of study and previously) was about the same in both study groups and did not differ significantly in the way it interfered with food intake in any of the two study groups (Table 2).

At 20–24 months and at 36 months, the control group reported a significantly higher occurrence of 'false teeth' (Table 2). While the two study groups did not differ significantly in seeking treatment of 'false teeth' from traditional healers, the removal rate of the 'false teeth' was significantly more common in the control group than in the intervention group.

Seventy-four percentage of mothers (both study groups combined) reported cleaning the oral cavity of their children. The frequency of cleaning the child's teeth was significantly higher in the intervention group than among the controls, and mothers in the intervention group reported a significantly higher frequency of cleaning teeth (at least once a day) compared with the control group (Table 2). The materials which were reportedly used in the cleaning of the child's oral cavity included toothbrush with water, clean cloth and water, stick or herbs and a finger and water. The use of toothbrush and water was reported significantly more common in the intervention group than in the control group (Table 2).

Table 1 Study population characteristics at baseline†

Characteristic	Original trial Intervention (n = 263)	Original trial Control (n = 248)	Follow-up study Intervention (n = 159–203)§	Follow-up study Control (n = 175–196)§
Children				
Males	139 (52.9)	123 (49.6)	111 (54.7)	99 (50.5)
Females	124 (47.1)	125 (50.4)	92 (45.3)	97 (49.5)
Age at inclusion (months; mean ± SD)	7.4 ± 0.8	7.3 ± 0.9	7.4 ± 0.8	7.2 ± 0.9
Age range at inclusion	6.0–8.9	6.0–8.9	6.0–8.9	6.0–8.9
Nutritional status (<−2SD)				
Stunting‡	55 (20.9)	70 (28.0)	41 (20.2)	56 (28.6)
Underweight‡	25 (9.5)	36 (14.5)	16 (7.9)	26 (13.3)
Wasting‡	12 (4.6)	12 (4.8)	9 (4.4)	9 (4.6)
Breastfeeding frequency				
≥8 times/day	170 (64.6)	172 (69.4)	131 (64.5)	138 (75.4)*
<8 times/day	93 (35.4)	76 (30.6)	72 (35.5)	45 (24.6)
Started complementary feeding				
Yes	254 (96.6)	236 (95.2)	197 (97.0)	185 (94.4)
No	9 (3.4)	9 (4.8)	6 (3.0)	11 (5.6)
Illness at baseline				
Yes	94 (35.7)	71 (28.6)	75 (54.0)	56 (44.8)
No	169 (64.3)	177 (71.4)	128 (46.0)	140 (55.2)
Maternal data (mean ± SD)				
Maternal education (years)	4.9 ± 2.8	4.9 ± 2.8	4.8 ± 2.7	4.8 ± 2.7
Maternal education				
0–4 years (0 – lower primary)	122 (46.4)	108 (43.5)	95 (46.8)	88 (44.9)
5–7 years (upper primary)	103 (39.2)	109 (44.0)	83 (40.9)	86 (43.9)
8+ years (lower secondary and tertiary)	38 (14.4)	31 (12.5)	25 (12.3)	22 (11.2)
Maternal age (years)	26.1 ± 5.8	26.8 ± 6.3	26.4 ± 5.8	27.1 ± 6.5
Maternal age (range)	18–44	18–44	18–44	18–44
Number of children per mother	3.4 ± 2.2	3.3 ± 2.2	3.5 ± 2.3	3.5 ± 2.3
Number of children (range)	1–9	1–9	1–9	1–9
Household data (mean ± SD)				
Household head education (years)	6.4 ± 3.1	5.9 ± 3.1	6.4 ± 3.1	6.1 ± 3.0
Household head education				
0–4 years (0 – lower primary)	82 (31.2)	84 (33.9)	60 (29.6)	64 (32.7)
5–7 years (upper primary)	107 (40.7)	111 (44.8)	87 (42.9)	90 (45.9)
8+ years (lower secondary and tertiary)	74 (28.1)	53 (21.4)	56 (27.6)	42 (21.4)
Household head age (years)	31.4 ± 7.9	33.4 ± 10.7	31.4 ± 8.1	33.2 ± 10.9
Household head age (range)	20–63	20–70	20–63	20–70
Household size	5.5 ± 2.1	5.5 ± 2.1	5.5 ± 2.1	5.5 ± 2.1
Household size (range)	3–10	3–10	3–10	3–10
Household poverty score¶	47.8 ± 11.7	47.6 ± 11.4	47.8 ± 11.7	47.1 ± 11.1
Sanitation composite score**	7.2 ± 1.9	7.3 ± 1.9	7.2 ± 1.8	7.3 ± 1.9

Description and cut-off points for household poverty scores and sanitation composite score have been explained elsewhere [26].
†Values are n (%) unless otherwise specified.
‡Z-score values are <−2 SD of the median reference group.
§The variation in n is due to missing data.
¶Household poverty score (range 0–100) measured by 'Simple Poverty Scorecard for Uganda' [57].
**Sanitation composite score ranges between 0 and 13 with increasing numbers indicating better sanitation.
*$P < 0.05$.

Caries and growth at 36 months

The risk of being stunted (HAZ ≤ −2SD) among children with and without caries was approximately the same in both study groups (Table 3). There was no association between stunting and the factors of night feeds, frequency of cleaning teeth, severity of caries

Table 2 Oral cavity characteristics, behaviours and practices

	Intervention (n = 153–203)*	Control (n = 168–196)*	P-value
Occurrence of caries in upper front teeth at 36 months			
Yes	31 (18.2)	47 (27.8)	
No	139 (81.8)	122 (72.2)	0.04
No. of teeth with caries at 36 months			
Sound	139 (83.7)	126 (75.0)	
One	7 (4.2)	9 (5.4)	
Two	7 (4.2)	11 (6.5)	
Three	4 (2.4)	9 (5.4)	
Four	9 (5.4)	13 (7.7)	0.30
Severity of caries at 36 months			
Sound	144 (83.2)	126 (73.3)	
Less severe cavitation	19 (11.0)	23 (13.4)	
Severe decay	10 (5.8)	23 (13.4)	0.03
Number of teeth at 20–24 months			
4–15	56 (28.4)	74 (40.2)	
16–20	141 (71.6)	110 (59.8)	0.01
Night feeds at 20–24 months			
Yes	94 (46.3)	107 (54.6)	
No	109 (53.7)	89 (45.4)	0.10
Type of night feed given at 20–24 months			
Cow milk	28 (31.1)	49 (45.7)	
Fruit juice and soft drinks	6 (6.7)	1 (0.9)	
Porridge	56 (62.2)	57 (53.4)	0.02
Pain at 20–24 months			
Child had teeth eruption symptoms			
Yes	68 (35.2)	98 (51.6)	
No	128 (64.8)	93 (48.4)	0.001
Eruption symptom types reported			
Diarrhoea	45 (65.2)	70 (71.4)	
Gum itching	10 (14.5)	8 (8.2)	
Fever	10 (14.5)	19 (19.4)	
Others†	4 (5.8)	1 (1.0)	0.15
Pain/eruption symptoms interfere with eating			
Yes	55 (28.8)	47 (25.1)	
No	136 (71.2)	140 (74.9)	0.43
Perceived 'False teeth'			
Reported at 20–24 months			
Yes	27 (13.7)	42 (22.3	
No	170 (86.3)	146 (77.7)	0.03
Reported at 36 months			
Yes	29 (18.5)	49 (31.2)	
No	128 (81.5)	108 (68.8)	0.01
Place for treatment of 'false teeth' reported at 36 months			
Hospital	1 (3.4)	2 (4.1)	
Traditional healer	26 (89.7)	47 (95.9)	
Self-treated	2 (6.9)	0 (0.0)	0.32
Treatment given reported at 36 months			
'False teeth' extracted	14 (8.9)	39 (24.7)	
Other treatments‡	14 (8.9)	10 (6.3)	
Not applicable	129 (82.2)	109 (69.0)	0.001
Cleaning children's teeth at 36 months			
Is it necessary to clean teeth?			
Yes	151 (98.7)	136 (90.7)	
No	2 (1.3)	14 (9.3)	0.002
Do you clean the child's teeth?			
Yes	144 (94.1)	79 (52.7)	
No	7 (4.6)	59 (39.3)	
No response	2 (1.3)	12 (8.0)	0.0001
Frequency of cleaning teeth			
At least once a day	129 (84.3)	69 (46.6)	
At least once a week	16 (10.5)	9 (6.1)	
Rarely/never	8 (5.2)	70 (47.3)	0.0001
Items used to clean teeth			
Toothbrush and water	128 (87.6)	29 (35.4)	
Clean cloth and water	16 (11.0)	13 (15.9)	
Stick or herbs	0 (0.0)	12 (14.6)	
Finger and water	2 (1.4)	28 (34.1)	0.0001

Values are n (%).
*The variation in n is due to missing data.
†Others – others included irritability, drooling and ear rubbing.
‡Other treatments – these included cutting the gum and rubbing in herbs, rubbing herbs on the gum and medicine given at the hospital.

and number of teeth with carries; both within and between the two groups (intervention and control groups (Table 3)).

Similarly, the risk of being underweight (WAZ ≤ −2SD) among children with and without caries, and other putative factors did not differ between the two study groups, as shown in Table 3.

Socio-demographic characteristics and other factors with caries

Various socio-demographic characteristics such as maternal age and education, household poverty score, fluoride concentration in water and other habits (frequency of cleaning teeth and feeding at night) did not show any association with the occurrence and severity of caries. The odds of occurrence of caries and severe decay among children with and without the socio-demographic factors

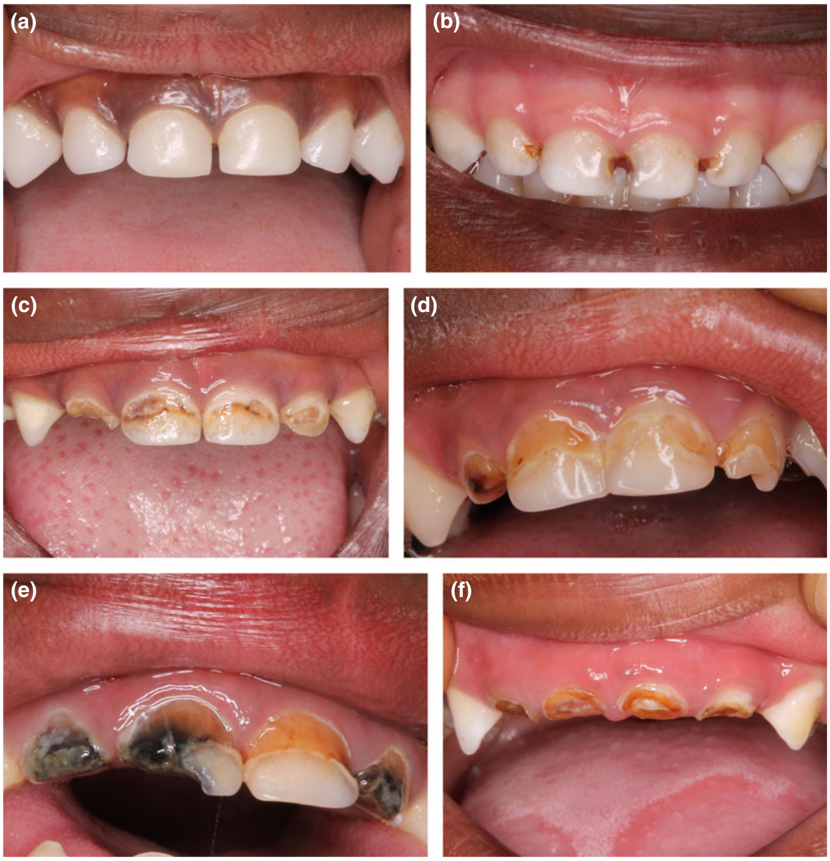

Figure 2 Clinical photographs of the upper front teeth showing sound teeth and different degrees of tooth decay. (a) Sound teeth. (b) Approximal dentine caries in the four upper incisors. (c) Dentine caries with severe tooth decay of the right lateral incisors. (d) Dentine caries with severe tooth decay of the lateral incisors. (e) Near total tooth decay of all the four incisors. The central incisors soon to break (f) Severe tooth decay with pulp involvement of all four incisors.

did not differ either within the groups or between the groups as shown in Table 4.

Fluoride concentration of water used in households

The overall mean (SD) fluoride concentration in water in the study area (both study groups combined) was below the levels of caries prevention effect. Generally, most households (89.5%, both study groups combined) used water that was low in fluoride (<0.70 mg/l). There was no difference in the concentration of fluoride in water between the two groups ($P = 0.39$).

Discussion

This is the first randomised trial testing the effect of an education intervention on ECC among rural Ugandan children. Specifically, in this follow-up study, we examined whether increasing the oral hygiene knowledge of the mother and caregivers together with provision of toothbrushes would influence self-care habits, oral hygiene of the children and dietary practices and thereby the frequency of ECC.

Data on oral hygiene of young children in Uganda are scarce [37], and rural communities have not benefited from studies that have oral hygiene components. The present study revealed early development of caries in the maxillary anterior teeth, which has been shown to be positively associated with posterior caries in the primary teeth dentition and may also be a good predictor for caries development in the permanent dentition [38]. The overall proportion (23.0%) of caries at 36 months is not readily comparable to other studies from Uganda as we diagnosed caries only in the upper four front teeth. Hence, the occurrence of caries was probably underdiagnosed in our study. Among Ugandan children, one study found that 45% of 3-year-

Table 3 Relationship between caries and other factors with nutritional status in the groups at 36 months

	Intervention			Control			Between groups§		
	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Stunting†									
Occurrence of caries									
Yes	1.84	0.73–4.62	0.20	1.50	0.68–3.30	0.31	1.22	0.36–4.11	0.75
No¶									
Night feeding									
Yes	1.16	0.62–2.16	0.64	0.80	0.41–1.56	0.52	1.45	0.58–3.60	0.43
No¶									
Frequency of cleaning teeth									
At least once a day¶									
At least once a week	1.92	0.59–6.30	0.28	0.77	0.19–3.15	0.72	2.49	0.40–15.60	0.33
Rarely/never	1.92	0.37–9.91	0.43	1.97	0.94–4.16	0.07	0.97	0.16–5.90	0.98
Severity of caries									
No caries¶									
Less severe	2.31	0.73–7.33	0.16	2.27	0.71–7.19	0.17	1.02	0.20–5.22	0.98
Severe caries	1.03	0.24–4.47	0.97	0.99	0.37–2.68	0.99	1.04	0.19–6.13	0.97
No. of teeth with caries									
0 (sound)¶									
One	1.53	0.29–8.17	0.62	0.89	0.20–3.91	0.88	1.72	0.18–16.11	0.63
Two	0.82	0.18–3.79	0.80	1.42	0.36–5.66	0.62	0.57	0.07–4.52	0.60
Three	1.00	–	–	4.27	0.52–35.33	0.18	1.00	–	–
Four	2.14	0.43–10.70	0.35	1.20	0.35–4.14	0.77	1.78	0.23–13.59	0.57
Underweight‡									
Occurrence of caries									
Yes	1.91	0.63–5.82	0.26	0.60	0.16–2.23	0.45	3.16	0.57–17.64	0.19
No¶									
Night feeding									
Yes	1.30	0.50–3.37	0.59	1.11	0.39–3.13	0.85	1.17	0.29–4.81	0.82
No¶									
Frequency of cleaning teeth									
At least once a day¶									
At least once a week	1.00	–	–	2.00	0.20–20.17	0.56	1.00	–	–
Rarely/never	1.00	–	–	2.17	0.62–7.58	0.23	1.00	–	–
Severity of caries									
No caries¶									
Less severe	3.19	1.00–10.18	0.05	1.31	0.34–5.05	0.70	2.44	0.41–14.49	0.33
Severe caries	1.00	–	–	1.00	–	–	1.00	–	–
No. of teeth with caries									
0 (sound)¶									
One	1.46	0.16–13.06	0.73	1.12	0.13–9.85	0.92	1.31	0.06–28.54	0.87
Two	6.59	1.34–32.50	0.02*	1.00	–	–	1.00	–	–
Three	2.93	0.29–30.09	0.37	0.98	0.11–8.48	0.99	2.98	0.12–71.46	0.50
Four	1.00	–	–	0.65	0.08–5.45	0.69	1.00	–	–

HAZ, height-for-age *z*-score; WAZ, weight-for-age *z*-score; SD, standard deviation.
†Stunting – a categorical variable (HAZ > −2 SD = 0 (not stunted children), this is the reference category; HAZ ≤ −2 SD = 1 (stunted children).
‡Underweight – a categorical variable (WAZ > −2 SD = 0 (not underweight children), this is the reference category; WAZ ≤ −2 SD = 1 (underweight children).
§The odds ratio for difference between two groups is on multiplicative scale, that is additive difference between the two groups, first estimated on log scale and then the antilog of the additive difference.
¶Reference category; OR – odds ratio; CI – confidence interval.
*$P < 0.05$.

Table 4 Socio-demographic characteristics and caries

	Intervention			Control			Between groups†		
	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Occurrence of caries (0 = No, 1 = Yes)‡									
Maternal age									
18–35 years*									
36+ years	1.09	0.22–5.39	0.92	0.83	0.28–2.42	0.73	1.32	1.19–9.05	0.78
Maternal education									
0–4 years in school*									
5–7 years in school	1.23	0.54–2.81	0.62	1.37	0.68–2.77	0.38	0.90	0.30–2.67	0.85
8+ years in school	0.75	0.19–2.92	0.68	0.57	0.15–2.18	0.41	1.32	0.20–8.89	0.78
Poverty score									
20–35*									
36–50	1.29	0.38–4.46	0.68	1.11	0.39–3.20	0.85	1.16	0.23–5.93	0.85
50+	1.25	0.38–4.17	0.72	1.26	0.44–3.62	0.67	0.99	0.20–4.92	0.99
Fluoride content in water									
≥0.70 mg/l*									
<0.70 mg/l	1.13	0.31–4.17	0.86	0.92	0.30–2.76	0.88	1.23	0.22–6.80	0.81
Frequency of cleaning teeth									
At least once/day *									
At least once/week	0.33	0.04–2.68	0.30	0.26	0.03–2.22	0.22	1.28	0.06–25.31	0.87
Rarely/never	1.56	0.30–8.25	0.60	0.49	0.22–1.07	0.07	3.22	0.51–20.30	0.21
Feeding at night									
Yes	0.82	0.37–1.81	0.63	1.09	0.55–2.13	0.81	0.76	0.27–2.14	0.60
No*									
Severity of caries (0 = sound; 1 = less severe; 2 = Severe)§									
Maternal age									
18–35 years*									
36+ years	1.20	0.24–5.99	0.82	0.87	0.30–2.55	0.80	1.38	0.20–9.54	0.74
Maternal education									
0–4 years in school*									
5–7 years in school	1.26	0.54–2.95	0.59	1.41	0.69–2.86	0.34	0.90	0.30–2.71	0.85
8+ years in school	0.86	0.23–3.35	0.82	0.61	0.16–2.34	0.47	1.40	0.21–9.51	0.73
Poverty score									
20–35*									
36–50	1.17	0.34–4.06	0.80	1.31	0.43–3.99	0.64	0.89	0.17–4.76	0.90
50+	1.20	0.36–4.02	0.77	1.45	0.48–4.42	0.51	0.83	0.16–4.27	0.82
Fluoride content in water									
≥0.70 mg/l*									
<0.70 mg/l	1.57	0.34–7.27	0.56	0.87	0.30–2.62	0.81	1.80	0.27–11.91	0.81
Frequency of cleaning teeth									
At least once/day *									
At least once/week	0.35	0.04–2.84	0.33	0.26	0.03–2.22	0.22	1.35	0.07–26.80	0.84
Rarely/never	1.65	0.31–8.75	0.56	0.49	0.22–1. 07	0.07	3.40	0.54–21.52	0.19
Feeding at night									
Yes	0.96	0.43–2.14	0.92	1.03	0.52–2.03	0.93	0.93	0.22–0.60	0.90
No*									

*Reference category; OR – odds ratio; CI – confidence interval.
†The odds ratio for difference between two groups is on multiplicative scale, that is additive difference between the two groups, first estimated on log scale and then the antilog of the additive difference.
‡Caries (0 = no caries (reference category), 1 = yes (caries present)).
§Severity of caries (0 = sound teeth (reference category); 1 = less severe caries; 2 = severe caries).

olds had at least one tooth with evidence of caries [37], whereas another showed that 11.8% of 25- to 36-months-olds had caries, but only 5% were found in the upper front teeth [6]. As opposed to the current study, these two studies were undertaken in urban areas using dental mirrors as well as a dental probe where the higher caries prevalence was found [37]. Thus, putting our results in this context, it seems that dental caries is a problem of concern among children in rural Uganda.

The night feeds did not show significant association with caries. However, they could be a contributing factor as they are a known risk factor for the development of ECC as observed in other studies [8, 39–41].

The significantly lower prevalence and extraction levels of the 'false teeth' in the intervention compared with the control group could be attributed to the education intervention where mothers were educated about 'false teeth' and discouraged from the traditional practice of removing them. The removal of false teeth is associated with many complications due to the procedure, either total enucleation of the tooth bud or the incision of the alveolar process. Both procedures may pose risk and cause general as well as dentoalveolar complications, both in the primary and in the permanent dentition. Examples of general complications include overt bleeding, anaemia, septicaemia and transmission of blood-borne diseases such as hepatitis B and HIV [23]. A study in Northern Uganda reported that complications from removal of 'false teeth' were among the leading causes of death in the children's ward [21]. A noma (cancrum oris) case has been reported following extraction of 'false teeth' in a hospital in South-Western Uganda [42]. The other complications include missing or malformed permanent teeth due to the operation trauma, osteomyelitis of the jaw, ablation of neighbouring teeth and dentofacial malocclusions [25, 43]. Figure 3 shows missing primary canine teeth (having been removed as 'false teeth') both in the lower and upper jaws and mineralisation disturbances and malformation of neighbouring primary teeth. This practice is common in communities of low socio-economic status, where education of mothers is poor and strong reliance on traditional practices as well as inadequate health care and health education activities [21, 22]. It was observed that despite the education intervention, the two study groups did not differ in seeking treatment of 'false teeth' from traditional healers. One study found that traditional healers were more often the first point of contact for most people seeking healthcare provision in Uganda, and this was attributed to traditional healers being close to the people and the sharing of beliefs, culture and values [23]. It could also be due to pressure from the family and neighbours and the fear that the child will die unless the 'false teeth' are treated by the traditional healer.

The significant difference in the frequency of cleaning of teeth and proportion of use of toothbrushes between the intervention and control groups could be attributed to the education intervention messages and the provision of toothbrushes for the children in the intervention group. This was the first study to provide toothbrushes to children and their family members. We, however, did not provide toothpaste to the children. We noted a group of mothers (more in control) who practiced an unhygienic method of cleaning children's teeth with finger and water. Still at 36 months, the difference in caries occurrence was significant between the two groups (being higher in the control group). Active hygiene by brushing with toothbrushes in the intervention group probably prevented development of new caries and their progression to more severe cavitation. Poor oral hygiene, together with fermentable carbohydrate fluids and lack of preventive actions, has been related to poor dental conditions including caries [44]. In one study, the brushing behaviour, particularly onset of toothbrushing before the age of 2 years, was most strongly associated with being caries free at 4 years of age [45], and also, oral health education was identified as a feasible tool for the prevention of ECC [46]. Studies have recommended guidance and provision of information about oral health care to mothers of newborn babies, through tooth eruption time. As a strategy for prevention of ECC, toothbrushing should be recast as a developmental skill and parents should be guided on how to support children to acquire

Figure 3 Clinical photographs showing missing canine teeth and mineralisation disturbances in the lower and upper jaws due to 'false teeth' extraction. At 36 months of age, canine teeth missing due to extraction of 'false teeth' (blue arrows) and showing mineralisation disturbances on neighbouring teeth. Data from two children are shown.

the skill [45, 47]. The Ugandan national oral health policy does not have a clear strategy for preventing ECC and this being a rural setting in a country with very few oral health specialists, such dental services are unavailable [48].

The occurrence of caries did not show evidence of association with stunting and underweight. However, given the large estimated ORs and the wide 95% confidence intervals, we cannot confidently rule out the association between caries and nutritional status (especially HAZ). Studies have associated ECC with low height and weight in children [5]. Children in this study were chronically undernourished [28] meaning that their diets were inadequate in both quality and quantity. A combination of a good diet and oral hygiene has been found to interact in controlling development of caries in children [49]. The significantly higher proportion of children with more erupted teeth in the intervention group at 20–24 months could be attributed to the intervention where mothers were encouraged to feed children on a more varied diet and 'silver fish' (*mukene*). Feeding children 'silver fish' was reportedly significantly more common in the intervention group than the control group (results in another paper [28]). This small fish, which is consumed whole, is rich in minerals [50] which could have facilitated the eruption of more teeth in the intervention group. Studies have attributed delayed tooth eruption to inadequate nutrition, illness and low socio-economic status [51–53].

The household factors did not show significant associations with the occurrence and severity of caries in children within or between the groups. This observation is contrary to what other studies have found in rural setting [53, 54]. Children from low socio-economic status background were not likely to access oral hygiene aids and therefore more prone to caries [53]. Low socio-economic status is said to relate to characteristics (education, depression and health) of rural mothers that compromise their personal oral hygiene and that of their infants to contribute to ECC. It is worth noting that the 95% confidence intervals of the ORs were quite wide, and therefore, we cannot confidently rule out associations of between the socio-demographic factors and caries.

Almost all water samples had fluoride concentrations below the recommended level for caries prevention (0.7 mg/l) [35]. The mean (SD) fluoride concentration in water of 0.30 (0.48) mg/l was lower than the 2.5 mg/l previously found in Kisoro [55], but comparable with values in tap and spring water in an earlier study [56]. The study area being within the Western arm of the East African rift valley and on slopes of a volcanic mountain, we expected a higher concentration of fluoride in water. The observed fluoride concentration in water in both groups was far below the recommended values (0.6–0.7 mg/l) [34, 35, 56] for preventing caries. Thus, people living in these areas have a higher risk of developing dental caries than people living in areas with adequate fluoride in water.

This study is the first of this kind in a rural and low-resource setting. The randomised design constitutes a major strength and it was performed in as many as 80 villages, many of them located far from the nearest village market/trading centre. The study also had some weaknesses: the sample size being smaller than the original, we could have possibly lost the statistical power and the examinations were in the field and not undertaken by dental staff. Consequently, the prevalence of caries based on photographs is most probably underestimated.

Conclusions

In this follow-up study of 36 months' old children participating in a randomised trial, we found that an education intervention improved oral hygiene which prevented the development and progression of caries. This education was also able to reduce the practice of 'false teeth' removal. There was no evidence of any effect of ECC on the nutritional status of the children. There is a need for further studies to establish the risk factors for development of ECC in such low-resource areas. Finally, the results of this follow-up study can be a valuable resource in developing policies for communities to prevent ECC by education in nutrition, hygiene, use of fluoride and prevention of removal of 'false teeth'.

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