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Caries-preventive efficacy of a supervised school toothbrushing programme in Northland, New Zealand

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Background: Toothbrushing with fluoride toothpaste reduces the incidence of dental caries. ***Objective:*** To evaluate a supervised school toothbrushing programme to reduce dental caries experience in children. ***Basic Research Design:*** Quasi-experimental study. All children had routine dental examinations at baseline using the ICDAS to record dental caries, along with bitewing radiographs. Half of the children were involved in a supervised toothbrushing programme. Examinations were repeated at the end of the school year. ***Clinical setting:*** Northland, New Zealand. ***Participants:*** 335 10-13-year-old New Zealand children with high caries experience. ***Interventions:*** Half of the children participated in the supervised toothbrushing session each school day; the other half had no intervention. ***Main outcome measures:*** Caries increment, determined by comparing the baseline and follow-up status of each tooth surface. ***Results:*** At baseline, there were 335 children, of whom 240 (71.6%) were followed up. The ICDAS net caries increment for those in the toothbrushing group was a mean of 11.7 surfaces improved; the control group had a mean of 8.6 surfaces which had deteriorated. Caries incidence for those in the toothbrushing group was 7.3%; that for the control group was 71.5%. Multivariate analysis showed that membership of the brushing group was the only statistically significant predictor of a lower net caries increment. ***Conclusion:*** A supervised school toothbrushing programme can reduce caries increment in a population experiencing high levels of dental disease.

Keywords: *Supervised tooth brushing, prevention, caries, New Zealand*

Introduction

Dental caries is the most prevalent chronic disease globally. It is also the leading contributor to tooth loss worldwide, despite being largely preventable (Fejerskov, 2004; Fisher-Owens *et al.,* 2007; Selwitz *et al.,* 2007). Globally, 60–90% of school children are affected by dental caries (Marthaler, 2004; Whelton, 2004; Do, 2012; World Health Organisation, 2015). The worldwide mean DMFT (decayed, missing or filled teeth) in 12-year-old children in 2010 was reported by the World Health Organisation (WHO) to be 2.4 (Peterson, 2000). The prevalence of child caries differs greatly, between developed and underdeveloped countries, and by social status, class, sex, ethnic group, geographic location and access to health services (World Health Organization, 2015).

While the oral health of New Zealand children and adolescents has improved over the last few decades, only one in two are caries-free (Ministry of Health, 2010). Māori and Pacific children and those living in deprived areas have higher caries experience than those of European ethnicity or of high socio-economic status (SES). Northland is the northern-most region in New Zealand. It is home to 165,000 people, with twice the national Māori proportion (31.7% and 14.6% respectively) and relatively high rates of deprivation and unemployment. There are no areas with community water fluoridation. In 2014, the mean dmft score for 5-year-old Northland children was 3.0, the highest in the country and almost double the national mean. For 12-year-old children, the mean DMFT score was 1.6, again one of the highest scores in this age group nationally (Ministry of Health, 2017). The most recent study conducted in Northland confirmed child caries rates in the region to be well above national averages, with the mean DMFT of 12-year-olds in four communities in Northland observed to be 5.6 (Gowda *et al.,* 2009a).

When combined with the use of a fluoride toothpaste, it has been shown to be the single most effective self-care measure for controlling dental caries and maintaining periodontal health (Attin and Hornecker, 2005), yet only 42% of children in New Zealand brush twice daily with fluoride toothpaste (Ministry of Health, 2010). A review of toothbrushing studies showed that effective toothbrushing is associated with a lower prevalence and incidence of caries. The quality of toothbrushing is an important factor, and so brushing meticulously once per day is sufficient to prevent dental caries (Attin and Hornecker,

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2005). Supervision is an act of directing, managing or oversight. When a trained adult supervises a toothbrushing programme, he/she is responsible for children using the correct amount of toothpaste, ensuring that the supplies are adequate, and overseeing and assisting children brushing their teeth for an appropriate amount of time. Toothbrushing trials in schools date back as far as the 1950s (Jordan *et al.,* 1957). Twetman and colleagues' (2003) systematic review investigated the caries-preventive effect of fluoride toothpaste on the young permanent dentition. It found strong evidence to support daily toothbrushing with fluoride toothpaste, with a greater caries-preventive effect than placebo toothpaste. Toothpaste with 1500ppm fluoride had a superior preventive effect to 1000ppm, and a higher caries reduction was observed in programmes with supervised rather than non-supervised brushing.

In 2006, Scotland introduced *Child Smile*, a nationwide oral health programme involving daily toothbrushing and other initiatives for pre-school and early primary school children. National oral health survey data showed a dramatic decline in dental caries experience in 5-year-old children after three years (Macpherson *et al.,* 2013). Further analysis of the financial cost of the *Child Smile* toothbrushing programme has been undertaken, along with determining the cost savings through improvements in dental health of 5-year-old children through avoided dental extractions and fillings. That cost analysis showed savings ranging from £1.2 million in 2003/04 to £4.7 million in 2009/10. The population standardised analysis by deprivation group also showed that the largest decrease in modelled costs was for the most deprived cohort of children (Anopa *et al.,* 2015).

While many school-based tooth brushing trials have been conducted internationally, there have been no large-scale programmes in New Zealand. However, there have been many small-scale, unevaluated, unsustainable tooth brushing projects. A recent review of the international literature scrutinised supervised toothbrushing in schools and was unable to make a conclusion on its caries reduction effectiveness (Santos *et al.,* 2017). There have not been any studies using ICDAS and bitewing radiographs to assess the efficacy of a supervised tooth brushing programme. This study aimed to ascertain whether a tooth brushing programme can reduce dental caries experience in a high-risk population.

Methods

A quasi-experimental study design was used. The required sample size was calculated based on findings from two previously conducted toothbrushing studies (Kraivaphan *et al.,* 2013), assuming 80% power to detect a 10% difference in caries increment between the two intervention arms after two years of follow-up and allowing for 15% attrition. This resulted in a total required sample size of at least 104 (with 52 in each arm of the study). We recruited 335 10- to 13-year-old children from five Northland schools. As there were a small number of schools in the study, we were not able to randomise them into the control and intervention groups, since this would have changed the unit of analysis to the school rather than the child.

Each child had a full clinical dental examination with radiographs, completed a questionnaire and was given a toothbrush and tube of toothpaste to take home. Four schools were chosen as control schools, and one of the larger schools as the intervention school. Children in the latter took part in supervised tooth brushing throughout an entire school year. This involved 2 minutes per day brushing after morning tea supervised by a paid teacher aide. Fluoride toothpaste (1450ppm) was distributed by the supervisor at each session. The clinical examination with radiographs and questionnaire was repeated at the end of the school year (9 months later).

Ethical approval for the study was obtained from the Northern A Health and Disability Ethics Committee (14/NTA/176). Consent was obtained from both parent and child before proceeding. The trial was also registered with the Australia and New Zealand clinical trials registry (ACTRN12617000846325).

Sociodemographic characteristics

Information was gathered on each child's sex, age and ethnicity. An area-based deprivation measure was used to allocate each participant to a deprivation decile score, based on the child's residential address. Areas with scores 1 to 3 were classified as "low deprivation"; those with scores 8 to 10 were classified as "high deprivation".

Clinical measures

The International Caries Detection Assessment (ICDAS, 2017) Index was used to record a restoration and caries score for each tooth surface. An experienced dentist, calibrated in the use of ICDAS, undertook all of the clinical examinations, having been trained beforehand in the study protocol. A standardised approach was used for all clinical examinations. The child was reclined partially on the clinic chair with the examiner seated behind. A standard LED headlight was used. Each tooth was first charted as unerupted, missing or present, as well as whether it was primary or permanent. Teeth were first examined wet, before air drying. The data were recorded manually on a standard ICDAS scoring sheet. As well as the ICDAS scoring, a conventional DMFS/dmfs score was computed at the analysis stage for each child, using an ICDAS code 3 or higher.

Posterior bitewing radiographs were taken before the dental examination. Radiographs were taken due to the need to be able to accurately measure caries increment over a relatively short period (but are used routinely in the local service for children of this age because caries is so prevalent). These were read later and a separate radiographic diagnosis data-set compiled. This was later merged with the clinical caries status data-set and used to adjust (as appropriate) the caries status of the posterior teeth. Traditional DMFT and dmft scores were then calculated and, since all children were in the mixed dentition phase, the DMFT and dmft for each child were then combined to give an overall level of caries experience score. Repeat clinical examinations were conducted by one examiner on 33 children at baseline and 9 at follow-up. The intraclass correlation coefficients were 0.85 and 0.91 respectively, indicating acceptable intra-examiner reliability.

Follow-up data collection

Approximately one year later, a repeat data collection took place, capturing similar data to baseline. Any children in the intervention group who were not present for 80% of the toothbrushing sessions were not included in the final data analysis.

Data analysis

The analysis commenced with computation of scale scores and summary statistics for dental caries experience. Baseline caries data were summarised for the primary and permanent dentition ICDAS codes (0-6). The number of decayed missing and filled surfaces were then calculated based on an ICDAS 3 or higher being 'decayed' for both dentitions. The scores were "radiographically adjusted" using the bitewing score readings during the analysis, whereby a P3 or higher lesion was determined to be a 'decayed' surface. Caries prevalence was calculated using the case definition of one or more surface(s) with an ICDAS code of 3 or higher.

The analysis of caries data after follow-up involved comparing the baseline and follow-up status of each surface. Net caries increment was calculated by adding the number of changes in status from sound (ICDAS 0) to demineralised (ICDAS 1 and 2) or to decayed (ICDAS 3+) or to filled or both, or from filled to decayed, demineralised or filled, and then subtracting the number of reversals. "Traditional" net caries increment was calculated by identifying transitions from sound (ICDAS 0,1 and 2) to decayed (ICDAS 3+) or to filled or both, or from filled to decayed and filled, and then correcting for reversals. "Traditional" incident caries cases (DMFS) were those who had a net caries increment of 1 or more decayed (ICDAS 3+) or filled surfaces. Incident caries cases were also identified by including demineralisation (ICDAS 1 and 2) in the net increment. Surface-specific DMFS increment and incidence were calculated (for smooth surfaces, pits and fissures, and proximal and facial surfaces).

Multivariate analysis used logistic regression to determine the intervention group's odds of having a positive caries increment while controlling for sociodemographic characteristics. Data were analysed with SPSS (version 23.0).

Results

Baseline sociodemographic characteristics

The sample was an even split of males and females. Table 1 summarises the sociodemographic characteristics of the children by group. There were proportionately more younger and NonMāori children in the control group. Most children were in the 10-11-year age group. All children recruited from Dargaville (one of the schools) were year 7, which gave them a lower overall age. Most children lived in high-deprivation areas.

Baseline caries experience

Table 2 shows caries severity (dmf/DMF) and prevalence data (1 or more carious lesion) by sociodemographic characteristics and group.

Children in the younger age group had a lower caries experience in their permanent teeth than older children. The younger children had higher caries prevalence in their primary teeth than the older group. NonMāori children had a lower severity and prevalence of caries in their permanent teeth, but a higher caries severity and prevalence in their primary teeth, than Māori children. The control group had a significantly lower caries prevalence and severity in their primary dentition.

Table 1. Sociodemographic characteristics of children in the control and intervention groups

Characteristic	*Control N (%)*	*Intervention N (%)*	*Total Number N (%)*
Total	176 (52.5)	159 (47.5)	335 (100.0)
Sex			
Male	88 (50.0)	85 (53.5)	173 (51.6)
Female	88 (50.0)	74 (46.5)	162 (48.4)
Age			
10-11	131 (74.4)[a]	89 (56.0)	220 (65.7)
12-13	45 (25.6)	70 (44.0)	115 (34.3)
Ethnicity			
NonMāori	71 (40.3)[a]	42 (26.4)	113 (33.7)
Māori	105 (59.7)	117 (73.6)	222 (66.3)
NZDep13			
High	127 (74.7)	126 (81.3)	253 (77.8)
Medium	35 (20.6)	27 (17.4)	62 (19.1)
Low	8 (4.7)	2 (1.3)	1 (3.1)
School			
Bream Bay College	38 (21.6)	-	38 (11.3)
Dargaville Intermediate	60 (34.1)	-	60 (17.9)
Kaikohe Intermediate	72 (40.9)	-	72 (21.5)
Kaitaia Intermediate	-	159 (100.0)	159 (47.5)
Raurimu Ave School	6 (3.4)	-	6 (1.8)

Attrition analysis

Of the 335 children examined at baseline, 95 (28.4%) did not have follow-up examinations, giving a follow up rate of 71.6%.

Table 3 summarises the sociodemographic characteristics of the children who were followed up. The most common reason for children not being followed up was them leaving school: this accounted for 52 children (54.7%). There were 39 children (41.1%) who were absent on all of the examination days, although were still enrolled with the school. There were 4 (4.2%) children in the 'other' category, 2 of whom were suspended from school, while one was unlikely to return due to long-term illness (brain tumour), and another was missing for an unknown reason. A considerable proportion of Māori children were not followed up, of whom about half were in the intervention and half in the control group.

The baseline dental caries experience of those lost and those followed-up is presented in Table 4. Children who were lost to follow-up had greater primary caries severity and prevalence at baseline than those who were followed up. The children who were not followed up had a higher combined (primary and permanent) DMFS overall at baseline.

Table 2. Prevalence and severity of dental caries by sociodemographic characteristics and intervention group

	DMFS	*dmfs (SD)*	*DMFT (SD)*	*dmft (SD)*	*Permanent dentition caries prevalence N (%)*	*Primary dentition caries prevalence N (%)*
Total	2.1 (3.9)	2.4 (5.5)	1.1 (1.6)	1.3 (2.5)	202 (60.3)	120 (35.3)
Sex						
Male	2.4 (4.8)	3.1 (6.7)[a]	1.1 (1.5)	1.5 (2.9)	100 (61.7)	59 (36.4)
Female	1.9 (2.7)	1.7 (4.1)	1.1 (1.6)	1.1 (2.1)	102 (59.0)	61 (35.3)
Age						
10-11	2.0 (4.2)	3.4 (6.5)[a]	1.0 (1.6)[a]	1.8 (2.9)	130 (59.1)	98 (44.5)[a]
12-13	2.3 (3.2)	0.5 (1.5)	1.2 (1.5)	0.4 (1.1)	72 (62.6)	22 (19.1)
Ethnicity						
NonMāori	1.9 (3.2)	4.3 (7.5)[a]	1.0 (1.4)	2.2 (3.5)[a]	63 (55.8)[a]	51 (45.1)[a]
Māori	2.2 (4.2)	1.5 (3.9)	1.1 (1.6)	0.9 (1.7)	139 (62.6)	69 (31.0)
NZDEP13						
High	2.2 (3.8)	2.5 (5.7)	1.2 (1.6)	1.3 (3.3)	162 (63.0)	91 (35.4)
Medium	2.1 (4.4)	2.0 (4.9)	0.9 (1.5)	1.1 (2.3)	32 (51.6)	21 (33.9)
Low	0.6 (0.7)	3.0 (7.1)	0.4 (0.7)	1.8 (3.8)	5 (50.0)	4 (40.0)
Group						
Control	1.9 (3.7)	2.2 (5.3)	1.0 (1.4)	1.2 (2.8)	105 (59.7)	51 (29.0)[a]
Intervention	2.4 (4.1)	2.6 (5.6)	1.2 (1.8)	1.4 (2.2)	97 (61.0)	69 (43.4)

[a] $p < 0.05$

Table 3. Attrition analysis: comparison of the sociodemographic characteristics of children followed and not followed up

	Baseline (%)	*Followed up (%)*	*Not followed up (%)*
Total	335 (100.0)	240 (71.6)	95 (28.4)
Sex			
Male	162 (48.4)	116 (48.3)	46 (48.4)
Female	173 (51.6)	124 (51.7)	49 (51.6)
Age			
10 and 11	220 (65.7)	157 (65.4)	63 (66.3)
12 and 13	115 (34.3)	83 (34.6)	32 (33.7)
Ethnicity			
NonMāori	113 (33.7)	91 (37.9)	22 (23.2)
Māori	222 (66.3)	149 (62.1)	73 (76.8)
NZDep13			
High	253 (77.8)	172 (74.8)	76 (83.5)
Medium	62 (19.1)	49 (21.3)	15 (16.5)
Low	1 (3.1)	9 (3.9)	0 (0.0)
Group			
Control	176 (52.5)	130 (54.2)	46 (48.4)
Intervention	159 (47.5)	110 (45.8)	49 (51.6)

Caries incidence

Data on net caries increment (with ICDAS 'demineralisation criteria') and traditional net caries (using 'DMFS criteria') are presented in Table 5. The difference in DMFS increment and incidence between the control and intervention group is highly significant, both overall and by tooth surface type. When considering traditional DMFS criteria (ICDAS 0, 1 and 2 as sound), the differences between the control and intervention group surfaces for both caries increment and incidence were statistically significant. The intervention group had fewer surfaces that progressed, and more reversals, than the control group.

The ICDAS net caries increment for the children in the toothbrushing group was a mean of 11.7 surfaces improved; those in the control group had a mean of 8.6 surfaces which had deteriorated. When considering traditional DMFS criteria (ICDAS 0, 1 and 2 as sound), the differences between the control and intervention group for both caries increment were also statistically significant. The intervention group had fewer lesions that progressed, and more reversals, than the control group.

Caries incidence for those in the toothbrushing group was 7.3%; the caries incidence for the control group was 71.5%. Using traditional DMFS criteria, the differences in caries incidence between the control and intervention group surfaces were statistically significant.

Logistic regression (Table 6) showed that, adjusting for sociodemographic characteristics, those in the intervention group had 0.32 times the odds of having a positive caries increment.

Discussion

This study set out to determine the caries-preventive efficacy of a supervised toothbrushing programme in an area with very high dental caries experience. The intervention was efficacious, with almost 12 surfaces (on average) per child in the intervention group showing remineralisation while children in the control schools had almost 9 surfaces (on average) which deteriorated over just one year of the programme. Those in the intervention group had lower odds of having a caries increment.

Table 4. Baseline caries experience by follow-up status

	Baseline	*Followed up*	*Not followed up*
Primary dentition			
Caries prevalence (%)	120 (35.8)	71 (29.6)	49 (51.6)[a]
Mean dmfs (SD)	2.4 (5.5)	1.8 (4.5)	4.0 (7.3)[a]
Permanent dentition			
Caries prevalence	202 (60.3)	151 (62.9)	51 (53.7)
Mean DMFS (SD)	2.1 (3.9)	2.3 (3.7)	1.7 (4.3)
Combined			
DMFS mean (SD)	4.5 (6.7)	4.1 (6.0)	5.7 (8.1)[b]

[a] $p < 0.001$
[b] $p < 0.05$

Table 5. Dental caries increment and incidence

	Intervention	*Control*	*P value*
Inclusion of demineralisation (ICDAS 1 & 2)			
DMFS increment (SD)	-11.7 (10.1)	8.6 (12.1)	<0.001
DMFS incidence (%)	8 (7.3)	93 (71.5)	<0.001
Traditional DMFS[a]			
DMFS increment (SD)	-1.0 (3.1)	-0.2 (3.1)	<0.05
DMFS incidence (%)	15 (13.6)	36 (27.7)	<0.05
Surfaces			
Smooth Surface caries only			
DMFS increment (SD)	-9.8 (9.2)	8.2 (11.7)	<0.001
DMFS incidence (%)	8 (7.3)	93 (71.5)	<0.001
Pit and Fissure caries only			
DMFS increment (SD)	-1.8 (2.4)	0.4 (2.4)	<0.001
DMFS incidence (%)	15 (13.6)	63 (48.5)	<0.001
Proximal surfaces			
DMFS increment (SD)	-1.8 (3.1)	5.0 (6.7)	<0.001
DMFS incidence (%)	26 (23.6)	95 (73.1)	<0.001
Facial surfaces			
DMFS increment (SD)	-8.1 (7.4)	3.1 (7.2)	<0.001
DMFS incidence (%)	7 (6.4)	79 (60.8)	<0.001

[a]Sound = ICDAS 1, 2 and 3

Table 6. Logistic regression model for one-year caries incidence

	Odds ratio (95% CI)
Male[a]	1.29 (0.68, 2.47)
Age	1.47 (0.82, 2.63)
European ethnicity[b]	0.86 (0.42, 1.74)
High deprivation[c]	1.65 (0.73, 3.76)
Intervention group[d]	0.32 (0.15, 0.64)

[a]Reference category = Female
[b]Reference category = Non-European
[c]Reference category = Lower deprivation
[d]Reference category = Control group

Before discussing the findings, it is appropriate to first consider the study's weaknesses. The first issue is the make-up of the control and intervention groups. The control group had younger and more NonMāori children. Ideally, the intervention and control groups would not differ systematically by any of their sociodemographic or oral health characteristics; such a situation would have been achievable through randomised allocation, but it is not practical to use a randomised control design with school toothbrushing, so a quasi-experimental design was used. This could have introduced a degree of allocation bias. However, the scale of the observed differences in caries increment means that any such effect is likely to have been minor. Not every child who could have participated did so; both parental consent and child assent were required for participation. Some children were also absent on the days when the data were collected. The research team attempted to minimise this by having multiple data collection days at each school; however, some children were absent on all those days. Long-term absence was controlled for in the intervention school by identifying children away from school for more than one month, who were then excluded from the analysis. This did not happen in the control group schools; it was assumed that, if a child was absent from school, his/her home oral hygiene habits would remain the same. The assessments could not be masked to the allocation. The children and examiner were aware of the children's group allocation, which could have led to behaviour and examiner bias in the clinical data which would have affected ICDAS demineralisation scores, predominantly on anterior teeth, and on the buccal, lingual and occlusal surfaces of posterior teeth. Since bitewing radiographs were used to adjust caries data for the other surfaces—and the radiograph reader was unaware of the child's group (control or intervention) at the time of radiograph reading—these would not have differed. Many of the children were in the mixed dentition. Since some primary teeth exfoliated between baseline and follow-up, the eruption of new sound permanent teeth and the exfoliation of primary teeth may have resulted in some apparent improvements in dental caries status that would not have been due to the intervention. However, the surface-level determination of caries increment between baseline and follow-up was limited to teeth in the same dentition, and so this is unlikely to have been an issue in the final analysis.

Turning to the study's strengths, we checked the design and reporting against the Joanna Briggs Institute (2018) Critical Appraisal Checklist for Quasi-Experimental Studies, and found the criteria to have been met. Having only one examiner involved in collecting the data meant there was no need for inter-examiner calibration, and errors arising from using more than one examiner were eliminated. Baseline and follow-up repeat clinical examinations showed excellent intra-examiner reliability (0.85 and 0.91 respectively), which is more than acceptable when undertaking ICDAS scoring (Winter *et al.*, 2016). That bitewing radiographs were used is a strength because caries experience in Northland children is grossly underestimated if only clinical examination is used in oral epidemiological examinations (Gowda *et al.,* 2009b). Another strength was using the ICDAS index, which provided the sensitivity necessary to detect any important changes in caries. The ICDAS index has the ability to make precise distinctions in the continuum of disease at the non-cavitated level; it represents lesion progression stages in enamel, not relying on surface cavitation before caries can be diagnosed. It has been thoroughly tested and shown to be valid, reliable and predictable[19]. The ICDAS data could also be collapsed into traditional DMFS and DMFT scores. This made it consistent with the existing literature (ICDAS Co-ordinating Committee, 2009) as DMFS and DMFT are more frequently used to measure and report dental caries experience in clinical and epidemiological studies (World Health Organisation, 1997). Converting and reporting our data allows comparison with the international literature on toothbrushing programmes. An additional strength was the surface-by-surface determination of caries incidence and increment. That is, caries increment was determined not by merely subtracting the baseline DMFS from the follow-up score (an approach which ignores reversals) but by a systematic comparison of the baseline and follow-up status of each surface, and then adjusting for apparent reversals.

Turning to the findings, the study showed substantially better dental caries outcomes after one year for children involved in a supervised toothbrushing programme. It is the first New Zealand study to demonstrate such a difference. It also reinforces findings from overseas studies that show benefits from supervised toothbrushing programmes (Curnow *et al.,* 2002; Rong *et al.*, 2003; Twetman *et al.,* 2003; Jackson *et al.,* 2005; Al-Jundi *et al.,* 2006; Macpherson *et al.*, 2013; de Silva *et al.,* 2016; Wolff *et al.,* 2016). The efficacy of an intervention is best determined using a randomised control trial, while determining effectiveness requires that the investigation be conducted in a real-world setting. Unfortunately, those effectiveness studies carry higher risks of loss to follow-up, along with the possibility that, because allocation was not done randomly, the observed differences way have occurred anyway, with no intervention effect. Such an argument might be tenable with a relatively marginal difference or small effect size, but the scale of the difference observed in the current study suggests that there was indeed an effect of the intervention. However, its exact magnitude would need to be determined in a randomised control trial.

Overall, data from international toothbrushing studies show an improvement in dental caries experience for children (Curnow *et al.,* 2002; Rong *et al.*, 2003; Twetman *et al.,* 2003; Jackson *et al.,* 2005; Al-Jundi *et al.,* 2006; Macpherson *et al.*, 2013; de Silva *et al.,* 2016; Wolff *et* *al.,* 2016). The caries increment data from toothbrushing studies using the ICDAS are hard to compare because these studies have used different samples, with different caries experience and different methods. The few studies that have been conducted using ICDAS with preventive interventions have shown mixed findings (Hilgert *et al.,* 2015). Only one study of a supervised toothbrushing programme has used the ICDAS. It investigated whether there was any benefit of adjunctive use of a 10% Casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) paste for 296 high caries-risk preschoolers (mean baseline dmfs = 9.1) in a non-fluoridated area near Bangkok, Thailand. After one year, there was no benefit from the adjunctive 10% CPP-ACP paste. All children had an increase in enamel and dentine lesions (ICDAS criteria) and dmfs, with a mean increment of approximately 4 surfaces. However, the level of brushing supervision was questionable, which may have affected the findings (Sitthisettapong *et al.,* 2012).

Our multivariate analysis showed the only significant predictor of incidence to be whether the child was in the control or intervention group. This suggests that, by undertaking a simple daily toothbrushing programme at school, the effect of the sociodemographic characteristics (Māori ethnicity and deprivation) that are commonly associated with greater caries experience appeared to have been removed. It is noteworthy that lower inequalities have also been observed in New Zealand children with access to community water fluoridation (Ministry of Health, 2003). Children with higher experience of caries at baseline had the same net caries increment (improvement) as those who were NonMāori or who live in low deprivation areas, but only if they were in the toothbrushing group. This means that the toothbrushing intervention appeared to reduce inequalities, which is one of the main objectives of current Ministry of Health Policy, as seen in the New Zealand Health Strategy. There was a significantly lower DMFS increment in the toothbrushing (a mean of 1.0 surfaces) than in the control group (a mean of 0.2 surfaces), showing that one year of supervised toothbrushing had a positive effect on DMFS scores. That is, the effect was even detectable using the conventional DMF approach.

These findings are similar to those from other studies showing an improvement in DMF/dmf following a supervised toothbrushing programme. In one such programme in a group of high-caries-risk Dundee children, the 2-year mean DMFS caries increment on first permanent molars was 0.8, but was 1.2 for children who were not brushing. The authors concluded that high-caries-risk children in their supervised toothbrushing programme with fluoridated toothpaste had significantly lower caries experience after 2 years (Curnow *et al.,* 2002). A toothbrushing programme over 2 years with 3,706 preschool children in Thailand found dmfs increments of 0.4 and 0.3 (respectively) in the control and intervention schools (Petersen *et al.,* 2015). These studies did not use a paid supervisor to carry out the toothbrushing with students every day. Instead, school staff were relied upon to deliver the programme, and so brushing may have been intermittent, with a smaller difference observed between the groups.

The DMFS incidence data are particularly interesting. At the point of cavitation, a traditional 'treatment' intervention is required for a surface. The control group had twice as many children (27.7%) presenting with a new case of caries at the cavitated stage (1+ DMFS). A cost-benefit analysis would aid in converting these numbers into an associated cost to treat, to assess the cost benefit of a toothbrushing intervention, versus treating these teeth (and the future burden of restorative treatment). Such analysis is beyond the scope of this study, but is planned. Internationally, large-scale brushing programmes have found a considerable cost-benefit ratio in providing supervised toothbrushing on a large scale (Anopa *et al.*, 2015).

Conclusion

This quasi-experimental study has demonstrated that a toothbrushing programme can be successfully implemented in an Intermediate school. The children who completed the brushing programme had improvements in oral health, with more caries reversals and a lower incidence of new carious lesions than those in the control group. Membership of the brushing group was the only significant predictor of a lower caries increment. Toothbrushing at school appeared to reduce oral health inequalities. This programme was a successful evaluated supervised toothbrushing programme set up and run in Northland, New Zealand.

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