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Comparison of the efficacy of a dentifrice containing 1.5% arginine and 1450 ppm fluoride to a dentifrice containing 1450 ppm fluoride alone in the management of early coronal caries as assessed using Quantitative Light-induced Fluorescence

P. Srisilapanan^a, N. Korwanich^a, W. Yin^b, C. Chuensuwonkul^c, L.R. Mateo^d, Y.P. Zhang^e, D. Cummins^e, R.P. Ellwood^{f,*}

^a Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand

^b State Key Laboratory of Oral Disease, Sichuan University, Chengdu, China

^c Chiang Mai Municipality Hospital, Chiang Mai, Thailand

^d LRM Statistical Consulting, Hoboken, NJ, USA

^e Colgate-Palmolive Technology Center, River Road, Piscataway, NJ, USA

^f Dental Health Unit, Skelton House, Manchester Science Park, Lloyd St North, Manchester M15 6SH, United Kingdom

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ABSTRACT

Objective: To compare the efficacy of a new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride to a matched, positive control dentifrice containing 1450 ppm fluoride in arresting and reversing early coronal caries lesions in children using Quantitative Light-induced Fluorescence (QLF).

Study design: 331 children from Chiang Mai, Thailand, aged 7–14 years, with one or more visible early enamel caries lesions on the upper anterior teeth, completed the study. The new dentifrice contained 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride, as sodium monofluorophosphate; the matched positive control contained 1450 ppm fluoride only. Subjects brushed twice daily at home and additionally once on school days under teacher's supervision. Digital images of the upper six anterior teeth were captured at the baseline, 3- and 6-month examinations using a custom apparatus for reproducible acquisition of Quantitative Light-induced Fluorescence data.

Results: At the 3-month examination, the ΔQ (representing lesion volume) for the test group decreased from a mean of 28.62 at baseline to 20.53 mm²% and for the positive control group to 23.38 mm²%. The difference between groups was not statistically significant ($p = 0.055$). At the 6-month examination, the ΔQ decreased for the test group to 15.85 mm²% and for the positive control group to 20.35 mm²%. The difference between groups was statistically significant ($p < 0.001$).

Conclusion: A new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride, as sodium monofluorophosphate, provided statistically significant superior efficacy in arresting and reversing active coronal caries lesions in children than brushing with a matched positive control dentifrice containing fluoride alone.

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* Corresponding author. Tel.: +44 0161 232 4705; fax: +44 0161 232 4700.

E-mail address: roger.p.ellwood@manchester.ac.uk (R.P. Ellwood).

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1. Introduction

During the last two decades, the management of dental caries has improved significantly as our understanding of both the methods available to identify lesions and the therapeutic approaches to arrest or reverse them have become more clearly understood. The most successful therapeutic interventions are based on the arrest or re-mineralization of initial enamel or root caries lesions that are not cavitated.¹ Such lesions are amenable to plaque control measures that remove the biofilm and reduce acid production by cariogenic bacteria. They are also readily amenable to treatment with various forms of fluoride to facilitate re-mineralization and inhibit de-mineralization with the formation of fluorapatite.² Fluoride dentifrice augments the effects of plaque removal attained through brushing by delivering fluoride throughout the mouth for the treatment and prevention of carious lesions. Fluoride dentifrice is one of the few therapeutic interventions currently available in dentistry with a strong evidence base for efficacy in caries prevention.³

Recently, an alternative approach to the management of dental caries has been identified and validated. The basis of the approach, which combines arginine and an insoluble calcium compound, is to complement and enhance the effects of fluoride by specifically targeting dental plaque, modulating its metabolism to reduce the production and effects of bacterial acid and, thereby, to reduce its pathogenicity.^{4,5} The arginine component is metabolized to ammonia by non-pathogenic arginolytic organisms, such as *S. sanguis*, that possess an arginine deiminase pathway. This ammonia, in turn, neutralizes plaque acids and stabilizes the residual plaque biofilm on susceptible tooth surfaces. By this means, arginine can prevent a shift in oral flora to aciduric bacterial species, such as *S. mutans*, and can help to maintain a non-cariogenic plaque after sugar challenge.⁴⁻⁶ The result is that plaque pH is more basic, encouraging re-mineralization; while, at the same time, less acid is produced reducing de-mineralization.⁷ Further, the insoluble calcium compound is available as a source of free calcium ions to supplement the re-mineralization process.^{4-6,8}

The anti-caries benefits of this approach have been demonstrated in two studies which compared the ability of a new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride, as sodium monofluorophosphate (MFP), to re-mineralize non-cavitated primary root caries lesions. In one study, use of the new dentifrice was compared to that of both a positive and negative control dentifrice. After 6 months use of the arginine-containing dentifrice, only one lesion (0.7%) had become worse and 61.7% of subjects improved with lesions becoming hard. In contrast, for the positive control dentifrice containing 1450 ppm fluoride, as sodium fluoride, in a silica base, 9.0% of subjects became worse and 56.0% improved. For the fluoride-free, matched negative control, 18.2% became worse and only 27% improved. The differences between the new arginine-containing dentifrice and both the positive and negative control dentifrices were statistically significant

($p < 0.001$).⁹ In the other study use of the new dentifrice was compared to a matched positive control. After 6 months use, 70.5% of subjects in the arginine-containing dentifrice group and 58.1% of subjects in the matched positive control improved; the difference was statistically significant ($p < 0.05$).¹⁰

The anti-caries benefits of this approach on the arrest and reversal of buccal enamel carious lesions have also been investigated in three 6-month studies using Quantitative Light-induced Fluorescence (QLF) methods to measure changes in mineralization of enamel lesions. One of these studies is reported in this paper. In the other two studies, the new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride, as MFP, was compared to a matched dentifrice with neither fluoride nor arginine as a negative control, and to a 1450 ppm fluoride only dentifrice as a positive control. In the first study, after 6 months use of the product, the mean lesion size reduced by 50.7% for the arginine-containing dentifrice, 32.3% for the positive control, and 11.4% for the negative control. The differences between the arginine-containing dentifrice and both the positive and negative control dentifrices were statistically significant ($p < 0.005$).¹¹ In the second study, after 6 months product use, the mean lesion size was reduced by 50.6% for the arginine-containing dentifrice, 34.0% for the positive control and 13.1% for the negative control. Again, the differences between the arginine-containing dentifrice and both the positive and negative control dentifrices were statistically significant ($p < 0.01$).¹²

The Quantitative Light-induced Fluorescence (QLF) method is based upon the principle that when a tooth is stimulated with blue light it fluoresces green. When dental caries is present, the emitted green light is scattered within the lesion and, hence, this area of the tooth surface appears to be dark against a green background. By comparing the loss of fluorescence, due to scattering in the lesion, to the background level of fluorescence, both the area and degree of de-mineralization (ΔF) of the lesion can be quantified. Further, the product of the lesion area and the loss of fluorescence (ΔF) can be used to estimate the volume of the lesion, known as ΔQ . This method has been employed in a number of clinical studies and has been shown to be both valid and highly reliable in quantifying the progression and reversal of early coronal caries lesions.¹³⁻¹⁶

Finally, a 2-year conventional caries clinical study has proven that two dentifrices containing 1.5% arginine and 1450 ppm fluoride in a calcium base, one with di-calcium phosphate and the other with calcium carbonate, are significantly more effective in preventing the formation of cavitated caries lesions than a dentifrice containing 1450 ppm fluoride alone. Three trained and calibrated dentists examined the children at baseline and after one and two years using the National Institute of Dental Research Diagnostic Procedures and Criteria. The number of decayed, missing, and filled teeth (DMFT) and surfaces (DMFS) for the three study groups were very similar at baseline, with no statistically significant differences among groups. After one year, there were no statistically significant differences in caries increments among the three groups. After two years, the two groups using the dentifrices containing 1.5% arginine,

an insoluble calcium compound and 1450 ppm F had statistically significantly ($p > 0.02$) lower DMFT increments (21.0% and 17.7% reductions, respectively) and DMFS increments (16.5% and 16.5%) compared to the control dentifrice. The differences between the two groups using the new dentifrices were not statistically significant. The results of this pivotal clinical study support the conclusion that dentifrices containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride provide superior protection against caries lesion cavitation to dentifrices containing 1450 ppm fluoride alone.¹⁷

The aim of the current study was to confirm the hypothesis that the new dentifrice containing 1.5% arginine, an insoluble calcium compound and 1450 ppm fluoride, as sodium monofluorophosphate (MFP), is more effective in arresting and reversing naturally occurring buccal caries lesions in children than a regular dentifrice containing fluoride alone using QLF.

2. Methods

This study was a randomized, double-blind controlled clinical trial of 6 months duration in which a new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride, as MFP, was compared to an identical fluoride dentifrice without the inclusion of arginine as a positive control. The study received ethical approval from the Ethics Committee of the Faculty of Dentistry, Chiang Mai University, Chiang Mai, Thailand.

The subjects who consented to take part in the study were 7–14 years old school children with one or more visible early enamel buccal caries lesions (white spot caries) on the upper anterior permanent teeth. They were recruited from eight schools in Chiang Mai, Thailand that were selected on the basis that they were able to take part in a daily supervised tooth brushing program. The fluoride level in the drinking water of the communities included in the study was <0.03 ppm F.

For consenting subjects, a screening examination was conducted to see if they were suitable to be included in the study. Participants in the study had to be 7–14 years old, available for the duration of the study, and have visual evidence of early enamel buccal caries in one or more of the upper anterior permanent teeth.

Students meeting the inclusion criteria were centrally, randomly allocated to study group by the study administrator using a randomly generated series of numbers. They were instructed to use their dentifrice twice daily at home. On school days, they also brushed their teeth in school after lunch under the supervision of school teachers. On approximately half the brushing days, tooth brushing was monitored by study personnel and compliance logged. During the 6 months of the study, the children brushed on approximately 105 days in school.

At each brushing, subjects were instructed to cover the head of the toothbrush with paste. Colgate Extraclean Professional 35 toothbrushes (Colgate-Palmolive, New York, NY, USA) were provided for use at home and in school. All dentifrices were supplied in identical white laminated tubes

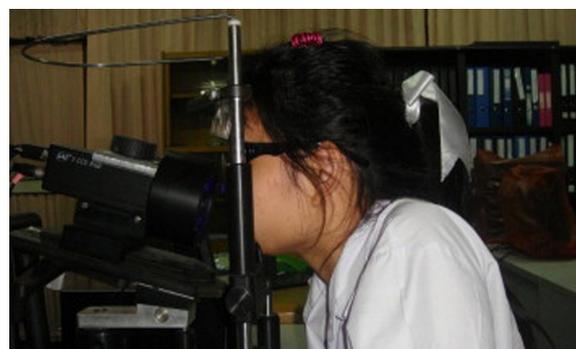


Fig. 1 – Geometry stabilizing equipment and imaging equipment.

and the products were identical in terms of taste and consistency. Toothbrushes and dentifrice were distributed to each subject on the day of the baseline examination and again at the 3-month examination. Intermediate supplies of dentifrice were supplied by the school teacher when required.

At the screening examination and all subsequent examinations (baseline, 3 and 6 months), an examination of the soft and hard tissues of the mouth was conducted. Subjects then had digital images taken of the upper six anterior teeth using a custom apparatus. Prior to imaging, plaque was removed from the upper anterior teeth, first by the student brushing and second by a dentist manually, to ensure that lesions could be clearly identified and measured. The equipment was designed to enable the capture of Quantitative Light-induced Fluorescence images in a reproducible manner. The geometry stabilizing equipment is illustrated in Fig. 1. The imaging equipment consisted of a 3 CCD camera (Jai M91P, Jai Corporation, Copenhagen, Denmark), a 16-mm f1.4 lens (Pentax, Slough, UK), and a long pass yellow filter (495 nm, Schott, Stafford, UK). The light source was a custom-made blue LED array with band pass filter at 370 nm.

Images were acquired using QLF Patient software (Version 3.03 Inspektor Research Systems BV, Amsterdam, The Netherlands). At the 3- and 6-month visits, the integral video repositioning software was employed with a grab level of 0.95 to accurately reposition students relative to the baseline image. Images were analyzed to calculate lesion area and loss of fluorescence (ΔF) using QLF 2.00 (Inspektor Research Systems BV). All images were taken by the same examiner. For 34 subjects, duplicate baseline images were captured without the video repositioning function to assess the reproducibility of the method. For ΔQ , the Intra Class Correlation Coefficients (ICC) at the baseline, 3- and 6-month examinations were, respectively, 0.95, 0.95 and 0.94 between the original and duplicate image sets.

2.1. Statistical analysis

The QLF software was used to calculate the area (mm^2) and loss of fluorescence (ΔF) of the lesion using a threshold of difference of 5% from the reconstructed image. Then ΔF and

area were used to calculate ΔQ which indicated the volume of the lesion.^{18,19}

The primary outcome for this study was the mean subject ΔQ at the 6-month examination. The two study groups were compared using a Linear Model controlling for baseline ΔQ , and number of lesions per subject, with a level of statistical significance set at $p < 0.05$.

3. Results

3.1. Disposition of subjects

Consent forms were sent out to a total of 445 children and 437 of them consented to take part in the study. The other eight children had left the school between the consent form being sent out and the study commencing. Of the consenting students, 341 children satisfied the inclusion criteria and were recruited into the study. Between the baseline and 3-month examination, six students were lost from the study as they had moved to other schools. Between the 3- and 6-month examinations, a further four children were lost from the study for the same reason. A total of 331 students completed the study of which 166 used the test dentifrice containing 1.5% arginine, and 165 used the positive control dentifrice with fluoride alone (Fig. 2). Of children completing the study, 55% were male and the mean age of the subjects was 11.3 (± 1.2) years at the baseline examination

3.2. Clinical results

It can be seen in Table 1 that subjects had a mean of 3.8 lesions included in the study with a range of 1–6. The baseline mean ΔF , area and ΔQ were 8.62%, 2.56 mm² and 28.62 mm²%. For both groups, the mean values for all parameters were not statistically significant different indicating good baseline balance.

At the 3-month examination (Table 2), all three QLF metrics improved in both groups, with decreases in both lesion size and loss of fluorescence. For the arginine-containing dentifrice group, the ΔQ decreased from a mean of 28.62–20.53 mm²% representing a 28% improvement. For the fluoride only positive control group, the adjusted mean decreased to 23.38 mm²%, an improvement of 18% compared to the baseline mean. The difference in improvement between the test and control groups just failed to attain statistical significance ($p = 0.055$).

At the 6-month examination, further improvements in lesions were observed for all QLF metrics for both groups. For the arginine-containing dentifrice group, the baseline adjusted ΔQ decreased from a mean of 28.62 at baseline to 15.85 mm²% representing a 44.6% improvement. For the fluoride only positive control group, the adjusted mean decreased to 20.35 mm²%, an improvement of 28.9% compared to the baseline mean. The difference between the two groups was statistically significant ($p < 0.001$). The difference in lesion area between the two groups also attained statistical significance ($p = 0.003$).

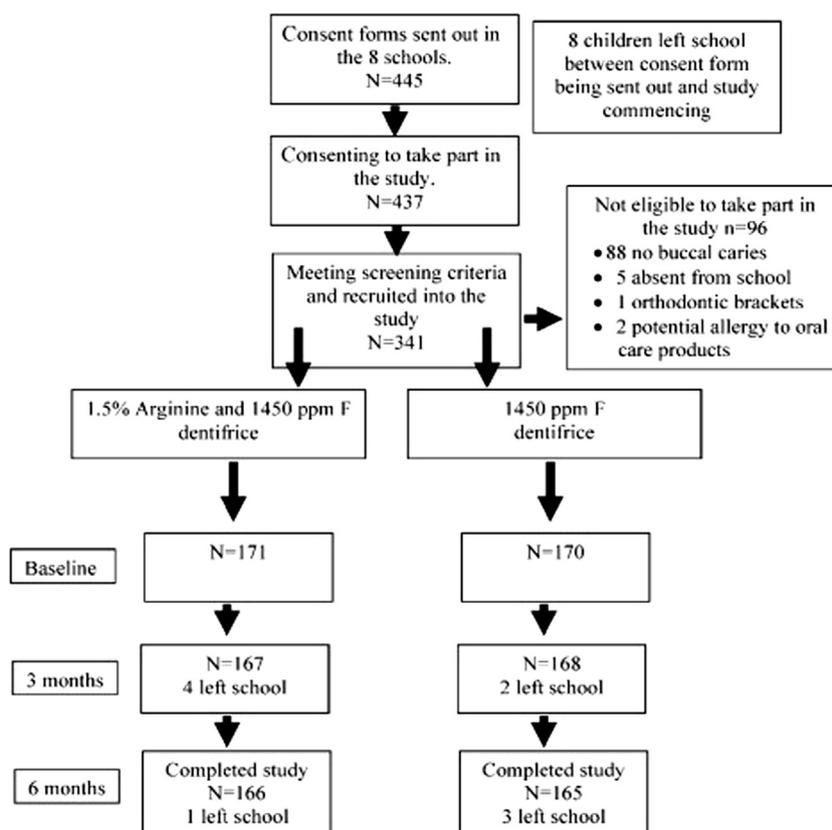


Fig. 2 – Disposition of children throughout the study.

Table 1 – Subject mean (SD) QLF metrics (ΔF , area and ΔQ) at baseline and 3 and 6 months for the three study groups and number of lesions at baseline.

Groups	N lesions/ subject	Baseline			3 Months			6 Months		
		ΔF (%)	Area (mm ²)	ΔQ (mm ² %)	ΔF (%)	Area (mm ²)	ΔQ (mm ² %)	ΔF (%)	Area (mm ²)	ΔQ (mm ² %)
1.5% arginine/ 1450 MFP	3.81 (1.14)	8.56 (2.25)	2.53 (2.92)	28.89 (42.50)	7.94 (2.01)	1.94 (2.34)	20.72 (30.45)	7.65 (1.79)	1.59 (1.90)	16.00 (23.70)
1450 MFP	3.85 (1.21)	8.68 (2.31)	2.59 (2.17)	28.35 (30.38)	8.09 (2.22)	2.12 (2.09)	23.20 (30.05)	7.97 (2.09)	1.94 (1.78)	20.20 (24.82)

Table 2 – Baseline adjusted subject mean (SE) QLF metrics (ΔF , area and ΔQ) at 3 and 6 months for the three study groups with number of lesions at baseline as covariable.

Groups	Adjusted 3 months			Adjusted 6 months		
	ΔF (%)	Area (mm ²)	ΔQ (mm ² %)	ΔF (%)	Area (mm ²)	ΔQ (mm ² %)
1.5% Arginine/1450 MFP	7.98 (0.10)	1.96 (0.08)	20.53 (1.05)	7.68 (0.10)	1.61 (0.07)	15.85 (1.00)
1450 MFP	8.05 (0.10)	2.10 (0.08)	23.38 (1.05)	7.93 (0.10)	1.92 (0.07)	20.35 (1.00)
Baseline mean employed in linear regression	8.62	2.56	28.62	8.62	2.56	28.62
Statistical significance of difference between groups	0.66	0.24	0.055	0.095	0.003	0.001

4. Discussion

This study has, once again, demonstrated that the new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride, as MFP, significantly improves the anti-caries efficacy as compared to conventional 1450 ppm fluoride dentifrice. After 6 months use of the arginine-containing product, lesions had reduced in mean size from baseline by 44.6% compared to only 28.9% reduction for the conventional 1450 ppm fluoride dentifrice. In fact, the reduction in lesion size of 28% achieved after just 3 months use of the arginine-containing dentifrice was very similar to that achieved after 6 months use of the conventional fluoride dentifrice indicating that lesions were re-mineralizing twice as quickly with the arginine-containing dentifrice as with the fluoride dentifrice. Thus, this study confirmed the hypothesis that the new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm fluoride is more effective than a matched positive control dentifrice containing 1450 ppm fluoride alone in arresting and reversing early caries lesions in children.

In two studies, using the same methods, very similar results were observed, with reductions in lesion area of approximately 50% in the group using the dentifrice containing 1.5% arginine, and insoluble calcium compound and 1450 ppm fluoride, as MFP, and of approximately 33% in the groups using the 1450 ppm fluoride positive control dentifrices.^{11,12} In the two previous studies, fluoride-free matched negative control dentifrices were also included to assess the effect of brushing with dentifrice without fluoride. An approximately 12% reduction in lesion size was attributable to brushing alone at the 6-month examination in these two studies.^{11,12} Thus, this study and the two further studies confirmed the hypothesis that the new dentifrice containing 1.5% arginine, an insoluble calcium compound, and 1450 ppm

fluoride is more effective than a positive control dentifrice containing 1450 ppm fluoride alone in arresting and reversing early caries lesions in children.

Based upon an in vivo plaque metabolism study,⁷ as well as in situ remineralization and demineralization studies,⁸ the mechanism of action of this new dentifrice in providing superior remineralization of early caries lesions to dentifrices containing 1450 ppm fluoride alone is comprised of two critical elements: (1) metabolic breakdown of the delivered arginine to ammonia in plaque, which helps neutralize acids formed from dietary sugars, resulting in higher resting and terminal plaque pH values and a higher degree of super-saturation by calcium and phosphate to drive the remineralization process, and (2) delivery of an insoluble calcium compound which acts as a reservoir of free calcium to aid remineralization.^{4,5}

Traditional clinical studies are routinely conducted on large numbers of subjects (4000) and last 2–3 years in order that cavities develop sufficiently to be detected using conventional visual or visual/tactile criteria. The ethics of conducting such studies when the most likely resulting intervention will be restoration, is now being questioned. It is known that therapeutic treatment of initial carious lesions is both possible and practical, and by employing sophisticated detection and measurement methods, outcomes can be monitored so that participants receive optimum, minimally invasive treatment.

In particular, the QLF method has proven to be a powerful tool in the caries clinical hierarchy providing unique insights regarding efficacy and mechanism of action of anti-caries products on early coronal caries lesions that complement and augment those generated in traditional 2-year caries studies of cavitation.

This study confirms that the use of Quantitative Light-induced Fluorescence (QLF) in studies of early coronal caries significantly improves the ability to discriminate between anti-caries products, enabling the studies to be conducted

effectively in shorter time periods with fewer participants. In addition, the ability of products to re-mineralize initial carious lesions is measured accurately and at the stage prior to cavitation, when such products are likely to be most beneficial.

5. Conclusion

It is concluded from this, and other studies, that a new dentifrice containing 1.5% arginine, an insoluble calcium compound and 1450 ppm fluoride, as MFP, significantly improves the re-mineralization of carious lesions as compared to dentifrice containing 1450 ppm fluoride alone.

Conflict of interest statement

Drs Zhang, Cummins and Ellwood are employees of the Colgate-Palmolive Company. Drs Srisilapanan, Korwanich, Yin, and Chuensuwonkul have no conflict of interest. Mr Mateo provided independent statistical review of the data for the Colgate-Palmolive Company on a consultancy basis.

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REFERENCES

- National Institute of Health Consensus Development Panel. National Institute of Health Consensus Development Conference statement. Diagnosis and management of dental caries throughout life. *Journal of the American Dental Association* 2001;132:1153-61.
- Featherstone JD. The science and practice of caries prevention. *Journal of the American Dental Association* 2000;131:887-99.
- Marinho VCC, Higgins JPT, Logan S, Sheiham A. Fluoride dentifrices for preventing dental caries in children and adolescents. *The Cochrane Database of Systematic Reviews* 2005. Cochrane Library, ISSN 1464-780X.
- Cummins D. Dental caries: A disease which remains a public health concern in the 21st century. The exploration of a breakthrough technology for caries prevention. *Journal of Clinical Dentistry* 2013;24(Spec Iss A):A1-14.
- Cummins D. The development and validation of a new technology, based upon 1.5% arginine, an insoluble calcium compound and fluoride, for everyday use in the prevention and treatment of dental caries. *Journal of Dentistry* 2013;41S:1-11.
- Kleinberg I. A new saliva based anti-caries composition. *Dentistry Today* 1999;18:98-103.
- Wolff M, Corby P, Klaczany G, Santarpia P, Lavender S, Gittins E, et al. In vivo effects of a new dentifrice containing 1.5% arginine and 1450 ppm fluoride on plaque metabolism. *Journal of Clinical Dentistry* 2013;24(Spec Iss A):A45-54.
- Cantore R, Petrou I, Lavender S, Santarpia P, Liu Z, Gittins E, et al. In situ clinical effects of new dentifrices containing 1.5% arginine and fluoride on enamel de and re-mineralization and plaque metabolism. *Journal of Clinical Dentistry* 2013;24(Spec Iss A):A32-44.
- Hu DY, Yin W, Li X, Feng Y, Zhang YP, Cummins D, et al. A clinical investigation of the efficacy of a dentifrice containing 1.5% arginine and 1450 ppm fluoride, as sodium monofluorophosphate in a calcium base, on primary root caries. *Journal of Clinical Dentistry* 2013;24(Spec Iss A):A23-31.
- Souza MLR, Cury JA, Tenuta LMA, Zhang YP, Mateo LR, Cummins D, Ellwood RP. Comparing the efficacy of a dentifrice containing 1.5% arginine and 1450 ppm fluoride to a dentifrice containing 1450 ppm fluoride alone in the management of primary root caries. *Journal of Dentistry* 2013;41S:35-41.
- Yin W, Hu DY, Fan X, Feng Y, Zhang YP, Cummins D, et al. A clinical investigation using quantitative light-induced fluorescence (QLF) of the anti-caries efficacy of a dentifrice containing 1.5% arginine and 1450 ppm fluoride as sodium monofluorophosphate. *Journal of Clinical Dentistry* 2013;24(Spec Iss A):A15-22.
- Yin W, Hu DY, Li X, Fan X, Zhang YP, Pretty IA, et al. The anti-caries efficacy of a dentifrice containing 1.5% arginine and 1450 ppm fluoride as sodium monofluorophosphate assessed using quantitative light-induced fluorescence (QLF). *Journal of Dentistry* 2013;41S:22-8.
- Angmar-Månsson B, ten Bosch JJ. Optical methods for the detection and quantification of caries. *Advances in Dental Research* 1987;1:14-20.
- Hall AF, DeSchepper E, Ando M, Stookey GK. In vitro studies of laser fluorescence for detection and quantification of mineral loss from dental caries. *Advances in Dental Research* 1997;11:507-14.
- Ferreira Zandoná AG, Analoui M, Beiswanger BB, Isaacs RL, Kafrawy AH, Eckert GJ, Stookey GK. An in vitro comparison between laser fluorescence and visual examination for detection of de-mineralization in occlusal pits and fissures. *Caries Research* 1998;32:210-8.
- Shi XQ, Tranaeus S, Angmar-Månsson B. Comparison of QLF and DIAGNOdent for quantification of smooth surface caries. *Caries Research* 2001;35:21-6.
- Kraivaphan P, Amornchat C, Triratana T, Mateo LR, Ellwood R, Cummins D, DeVizio W, Zhang YP. Two-year caries clinical study of the efficacy of novel dentifrices containing 1.5% arginine, an insoluble calcium compound and 1450 ppm fluoride. *Caries Research* 2013. 10,1159/000353183.
- de Josselin de Jong E, Sundström F, Westerling H, Tranaeus S, ten Bosch JJ, Angmar-Månsson B. A new method for in vivo quantification of changes in initial enamel caries with laser fluorescence. *Caries Research* 1995;29:2-7.
- van der Veen MH, de Josselin de Jong E. Application of quantitative light-induced fluorescence for assessing early caries lesions. *Monograph Oral Science* 2000;17:144-62.