SCIENTIFIC PAPER SUMMARIES

JOURNAL OF DENTISTRY
VOLUME 42 SUPPLEMENT 1
JUNE 2014

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ENAMEL SCIENCE

ENAMEL MINERAL LOSS

West NX, and Joiner A. J Dent 2014; 42 (Suppl. 1):S2–S11.

Introduction

- Enamel mineral loss can result in degradation of the surface and sub-surface enamel, leading to changes in the hardness, shape, function and aesthetic qualities of the tooth, as well as increased sensitivity and the possibility of complete tooth loss.
- Tooth wear has been shown to have an impact on patients' well-being regardless of severity, and tooth loss can lead to psychological shock, depression and loss of self-esteem.

Aim

- The aim of this review was to examine the mechanisms of enamel mineral loss, highlight approaches to management, and summarise emerging trends and challenges.

Data sources

- Principal key words tooth, enamel, *mineral*, caries and erosion were used to search Medline and Scopus databases.

Conclusions

- Enamel mineral loss can result from a number of different mechanisms such as dental caries, and tooth wear through erosion, abrasion and attrition.
- Dental caries result from plaque bacteria metabolising dietary carbohydrates to produce acids, leading to progressive demineralisation beneath the relatively intact tooth surface and development of a lesion in sub-surface tooth enamel.
- Erosion is caused by direct contact between dietary acids and the tooth surface, leading to chronic loss of enamel, while abrasion and attrition involve mechanical removal of hard tissue due to either foreign bodies in the oral cavity or direct contact between teeth, respectively.
- While the prevalence of caries is declining in developed countries due to improved oral hygiene and fluoride therapy, enamel erosion is on the increase.
- Many individuals now retain their natural dentition for longer, increasing exposure to risk factors for enamel mineral loss. With increasing life expectancy, tooth wear is likely to become a more frequent dental problem.
- Erosive tooth wear also affects young people, with recent data from a large multicentre European study finding tooth wear in around one-third of the population aged 18–35 years.
- The consumption of acidic drinks and foods is increasing as populations aspire to a healthy, yet erosive, diet and lifestyle.
- Evidence-based oral hygiene and dietary advice is imperative and should form the basis of dental management.

"Prevention of enamel loss from caries and toothwear should form the basis of lifelong dental management. Evidence based oral hygiene and dietary advice is imperative, alongside preventive therapy, to have a healthy lifestyle, whilst retaining hard tooth tissue."

THE REMINERALISATION OF ENAMEL: A REVIEW OF THE LITERATURE

Li X, Wang J, Joiner A, Chang J. J Dent 2014; 42 (Suppl. 1):S12–S20.

Introduction

- The action of acid on enamel can give rise to enamel demineralisation, leading to the softening of the enamel structure.
- If the softened layer of enamel is not re-hardened by a remineralising agent such as saliva, and the erosive challenge persists, further degradation of surface and sub-surface enamel takes place, leading to a permanent loss of volume.
- The process of tooth remineralisation has been studied over many decades of research and has led to the development of technologies that can promote enamel remineralisation, with potential oral health benefits.

Aim

- The aim of this review was to summarise the current knowledge concerning enamel remineralisation technologies and their modes of action.

Data sources

- Principal key words of *miner*, teeth and enamel were used to search the Scopus and Web of Knowledge databases from the year 1971.

Conclusions

- It is now well established that fluoride treatments are generally effective in helping to protect dental enamel from demineralisation and enhancing remineralisation.
- Continued efforts to increase the efficacy of fluoride have focused, in particular, on the addition of calcium-based materials to oral care products, which may enhance the delivery and retention of fluoride into the oral cavity.
- *In vitro* experiments have shown that increasing calcium concentrations, whilst maintaining the fluoride concentration in the remineralisation solution, has an impact on enamel remineralisation of sub-surface enamel lesions.
- Bioglass materials – in particular calcium silicate-based compounds, inspired by the concept of bioactive materials for bone repair and regeneration – show potential for enamel health benefits and are a growing area of research.

"Inspired by the concept of bioactive materials for bone repair and regeneration, bioglass and in particular calcium silicate type materials show potential for enamel health benefits and is a growing area of research."

MEASUREMENT OF THE EFFICACY OF CALCIUM SILICATE FOR THE PROTECTION AND REPAIR OF DENTAL ENAMEL

Parker AS, Patel AN, Al Botros R, Snowden ME, McKelvey K, Unwin PR, Ashcroft AT, Carvell M, Joiner A, Peruffo M. J Dent 2014; 42 (Suppl. 1):S21–S29.

Introduction

- The aetiologies of dental caries and erosion are very different but they both result from mineral loss due to acids.
- Fluoride can both provide protection from acid challenges and repair demineralised enamel. Adding calcium-containing minerals appears to enhance these benefits.
- A new oral health technology combining calcium silicate (CaSi), sodium phosphate salts and fluoride is proposed to augment natural mineralisation via the release of calcium from CaSi, its transformation into hydroxyapatite (HAP) and subsequent remineralisation of enamel.

Aims

- The aims of the current study were to determine if HAP is formed from CaSi, to investigate if CaSi can repair acid-eroded enamel surfaces and to determine if CaSi can protect sound enamel surfaces from acid challenge.

Methods

- CaSi was mixed with phosphate buffer for 7 days and the resulting solids analysed by Raman spectroscopy.
- Acid-etched regions were produced on bovine enamel surfaces using scanning electrochemical cell microscopy.
- The enamel was treated with CaSi, and deposition visualised with field emission-scanning electron microscopy. Etch pit volumes were measured by atomic force microscopy (AFM).
- A second set of bovine enamel specimens were pre-treated with either CaSi or fluoride, or CaSi and fluoride, before acid exposure. The volumes of the acid-etched pits were measured using AFM and the intrinsic rate constant for calcium loss was calculated.

Results

- This study demonstrated that following treatment with phosphate buffer for 7 days, HAP is formed from CaSi.
- CaSi deposition occurred on acid-etched regions of bovine enamel specimens, with much larger distribution of CaSi in etched samples compared with polished samples.
- There was a significant reduction in pit volume following one treatment with CaSi ($P < 0.0001$).
- The study demonstrated a clear decrease in surface calcium loss for each of the treated samples, with significant reductions with CaSi treatments ($P < 0.0001$).

Conclusions

- HAP is formed from CaSi upon exposure to phosphate buffer.
- CaSi deposited onto acid-eroded enamel can provide a potential repair mechanism.
- Pre-treatment with CaSi can provide sound enamel with protection from acid challenge.

"Thus, the potential for calcium silicate to give enamel protective benefits has been demonstrated using the current experimental set up. It is postulated that the protective properties of calcium silicate may be due to a combination of its calcium release profile, pH buffering capability and the formation of sacrificial HAP."

MODE OF ACTION STUDIES ON THE FORMATION OF ENAMEL MINERALS FROM A NOVEL TOOTHPASTE CONTAINING CALCIUM SILICATE AND SODIUM PHOSPHATE SALTS

Sun Y, Li X, Deng Y, Sun JN, Tao D-Y, Chen H, Hu Q, Liu R, Liu W, Feng X, Wang J, Carvell M, Joiner A. J Dent 2014; 42 (Suppl. 1):S30–S38.

Introduction

- Tooth enamel is primarily composed of a mineral rich in calcium and phosphate known as hydroxyapatite (HAP).
- If exposed to acid challenge, calcium and phosphate can be lost from enamel, compromising its integrity and strength.
- Saliva naturally contains calcium and phosphate ions that can re-integrate into the acid-damaged enamel surface, restoring the lost enamel minerals.
- This process is enhanced by fluoride-containing products and calcium-based compounds.
- A novel technology has been developed based on the combination of calcium silicate (CaSi), sodium phosphate salts and fluoride. The technology is proposed to augment the natural mineralisation of human saliva by providing additional calcium and phosphate, with subsequent HAP formation and remineralisation of tooth enamel minerals.
- This technology has been formulated into a novel toothpaste containing CaSi, sodium phosphate salts and fluoride.

Aims

- The aim of this study was to investigate, *in vitro* and *in situ*, the deposition and formation of HAP on enamel surfaces following brushing with this novel toothpaste.

Methods

- Polished enamel blocks were brushed *in vitro* with a slurry of CaSi toothpaste. After one brush and 4 weeks' simulated brushing, the enamel surfaces were analysed for deposits.
- In an *in situ* protocol, enamel blocks were attached to first or second molar teeth of healthy subjects, exposed to 4 weeks' twice-daily brushing with the CaSi toothpaste and then analysed.
- In addition, the CaSi toothpaste was slurried in simulated oral fluid over a 3-hour period, and the solids isolated and analysed.

Results

- The study showed that *in vitro* brushing with the CaSi toothpaste led to the deposition of CaSi onto enamel surfaces *in vitro*, with evidence of HAP formation.
- The *in situ* study confirmed these findings.

Conclusions

- This study has demonstrated that a novel toothpaste containing CaSi and sodium phosphate salts can effectively deposit CaSi onto enamel surfaces both *in vitro* and *in situ*.
- From the first brushing, HAP formation begins and continues over a period equivalent to at least 4 weeks of brushing.

"It has been demonstrated that the CaSi and phosphate based technology forms an enamel mineral phase on enamel surfaces, both in vitro *and* in situ*, and there is evidence that indicates a templating role for CaSi."*

ENHANCED ENAMEL BENEFITS FROM A NOVEL TOOTHPASTE AND DUAL PHASE GEL CONTAINING CALCIUM SILICATE AND SODIUM PHOSPHATE SALTS

Hornby K, Ricketts SR, Philpotts CJ, Joiner A, Schemehorn B, Willson R. J Dent 2014; 42 (Suppl. 1):S39–S45.

Introduction

- Enamel demineralisation, which occurs in both caries and erosion processes, can result from the action of acid on enamel.
- Efforts to improve the efficacy and enamel health benefits of fluoride toothpastes have generally focused on enhancing fluoride delivery or adding other beneficial agents.
- A new fluoride toothpaste containing calcium silicate (CaSi) and sodium phosphate salts may provide enhanced enamel health benefits. A new dual-phase gel containing CaSi, sodium phosphate and fluoride is proposed as an adjunct to daily use of the toothpaste for additional enamel remineralisation benefits.

Aim

- The aim of this study was to investigate the enamel health benefits of this novel toothpaste in combination with the dual-phase gel.

Methods

- Surface microhardness (SMH) measurements were used to assess enamel demineralisation following treatment with either lactic acid (early caries) or citric acid (erosion) challenge.
- Following a number of protocols, SMH measurements were used to assess remineralisation of lactic acid- and citric acid-softened enamel.

Results

- The novel toothpaste significantly inhibited enamel demineralisation following acid challenge compared with fluoride and non-fluoride controls ($P < 0.05$).
- The toothpaste also showed significant ($P < 0.05$) remineralisation of acid-softened enamel compared with controls.
- The addition of the novel dual-phase gel provided enhanced remineralisation of citric acid-softened enamel compared with fluoride and non-fluoride controls.

Conclusions

- Formulations containing CaSi, sodium phosphate salts and fluoride provide significant protection from lactic acid- or citric acid-induced demineralisation *in vitro*.
- The novel toothpaste significantly promoted remineralisation of acid-softened enamel compared with a sodium fluoride control and control toothpastes including fluoride.
- The application of the novel CaSi/phosphate fluoride dual-phase gel treatment further enhanced the remineralisation of citric acid-softened enamel lesions.

"Calcium silicate/phosphate fluoride toothpaste was shown under several different protocols to provide enamel demineralisation and remineralisation benefits versus control formulations and the calcium silicate/phosphate fluoride dual-phase gel was shown to provide additional in vitro *enamel remineralisation versus fluoride and non-fluoride control toothpastes."*

INTRODUCTION OF AN INTERPROXIMAL MINERALISATION MODEL TO MEASURE REMINERALISATION CAUSED BY NOVEL FORMULATIONS CONTAINING CALCIUM SILICATE, SODIUM PHOSPHATE SALTS AND FLUORIDE

Bodfel Jones S, Davies M, Chapman N, Willson R, Hornby K, Joiner A, West NX. J Dent 2014; 42 (Suppl. 1):S46–S52.

Introduction

- Enamel demineralisation, which occurs in both caries and erosion, leads to the degradation of the surface and sub-surface structures of teeth.
- In the early stages of erosion, saliva, which contains calcium and phosphate ions, can help remineralise acid-softened enamel; however, at later stages natural repair processes are insufficient to replace the lost tissue.
- As enamel at the cervicular and interproximal areas of the tooth is thin compared with the rest of the crown, the dentine is at particular risk of exposure if enamel is demineralised.
- To investigate interproximal de- and remineralisation processes, a new model was developed to recreate this interdental crevice environment.
- New toothpaste formulations containing calcium silicate (CaSi) and sodium phosphate combined with fluoride represent a novel approach to remineralising early stages of mineral loss.

Aim

- The aim of this study was to introduce a new interproximal mineralisation model to investigate the effectiveness of a novel CaSi/phosphate fluoridated toothpaste and dual-phase gel formulations to remineralise acid-softened enamel.

Methods

- Specimens were positioned opposite each other with an approximately 100 µm space between enamel surfaces to simulate an interproximal environment.
- Following acid challenge, Study 1 evaluated the remineralisation potential of a prototype CaSi/phosphate fluoride toothpaste formulation and Study 2 evaluated a novel CaSi/phosphate fluoride toothpaste and dual-phase gel formulation.

Results

- The novel mineralisation model was able to show increased remineralisation from CaSi/phosphate fluoride toothpaste over fluoridated formulations alone ($P < 0.05$).
- Combined application of the novel toothpaste and the dual-phase gel showed the greatest amount of remineralisation of acid-softened enamel, which was significantly greater than sodium fluoride and non-fluoride controls ($P < 0.05$).

Conclusions

- This study demonstrates that an interproximal mineralisation model can be used to differentiate between the remineralisation potential of toothpaste formulations containing fluoride and CaSi/phosphate plus fluoride.
- The remineralisation potential of a novel CaSi/phosphate fluoride toothpaste with a dual-phase gel formulation was greatest when the two formulations were used in combination.

"This study highlights the importance of designing erosion models that more closely simulate the clinical situation such as including interproximal areas because the effectiveness of oral care products to remineralise this area can be different to an open environment."

REMINERALISATION EFFECT OF A DUAL-PHASE CALCIUM SILICATE/PHOSPHATE GEL COMBINED WITH CALCIUM SILICATE/PHOSPHATE TOOTHPASTE ON ACID-CHALLENGED ENAMEL *IN SITU*

Joiner A, Schäfer F, Naeeni MM, Gupta AK, Zero DT. J Dent 2014; 42 (Suppl. 1):S53–S59.

Introduction

- The action of acid on enamel can give rise to enamel demineralisation, leading to the softening of the enamel structure that occurs in both the caries and erosion processes.
- Fluoride toothpastes have proven effective in reducing the incidence of caries and enamel mineral loss following acid erosion challenges.
- A new calcium silicate (CaSi) and sodium phosphate salts toothpaste containing fluoride has been developed to provide enhanced enamel health benefits.

Aim

- The aim of the study was to investigate if a treatment protocol based on a novel dual-phase gel system combined with a CaSi/phosphate fluoride toothpaste was able to remineralise acid-softened enamel to a greater extent than other toothpastes.

Methods

- Subjects wearing a partial denture loaded with demineralised enamel specimens used either the test regimen (dual-phase CaSi/phosphate gel system plus the CaSi/phosphate toothpaste) or one of the three controls (placebo gel system plus either CaSi/phosphate toothpaste, fluoride-only toothpaste or non-fluoride toothpaste) for 7 days.
- The gel systems were applied once per day for the first 3 days, during which time subjects also brushed with the corresponding toothpaste used in the conventional way, followed by 4 days of the toothpastes only.
- The outcome variables were indent length and Knoop hardness values.

Results

- The results showed a statistically significant ($P < 0.001$) re-hardening effect for all treatments compared with pre-treatment hardness.
- After *in situ* treatment, significantly greater hardening ($P < 0.05$) was found in the samples treated with CaSi/phosphate gel system plus CaSi/phosphate toothpaste compared with control groups.

Conclusions

- The study demonstrates that the novel dual-phase gel system combined with CaSi/phosphate fluoride toothpaste can re-harden acid-challenged tooth enamel to a significantly greater extent than a fluoride-only toothpaste.

"Applying a novel dual-phase gel system containing calcium silicate and phosphate, with 1450 ppm fluoride ion from sodium fluoride and sodium monofluorophosphate at equal proportions for three days and brushing with a toothpaste containing calcium silicate and sodium phosphate and 1450 ppm fluoride ion as sodium monofluorophosphate was able to re-harden acid-softened tooth enamel to a significantly greater extent than a normal fluoride toothpaste."

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