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A randomised clinical trial to determine the abrasive effect of the tongue on human enamel loss with and without a prior erosive challenge

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ABSTRACT

Objectives: To investigate the abrasive effect of the tongue on human enamel loss with and without a prior dietary acid challenge in an in situ model.
Methods: A single centre, single blind, randomly allocated, split mouth, four treatment regimen, *in situ* study in healthy adult volunteers was undertaken. Twenty four subjects wore two lower intra-oral appliances each fitted with 4 human enamel samples 6 h/day for 15 days. The samples were treated with either 50 ml orange juice or water for 5 min *ex vivo* 4 x/day; prior to being licked or not licked with the subject's tongue for 60 s. There were 2 samples per group per subject. Surface loss was measured by contact profilometry.
Results: 23 subjects completed the study with no adverse events. The mean loss of enamel at 15 days was: 0.08 μm for water without licking, 0.10 μm with water and licking; 1.55 μm with orange juice alone, 3.65 μm with orange juice and licking. In the absence of erosive challenge, licking had no detectable effect on enamel loss $p = 0.28$. Without licking, orange juice had a highly significant effect on loss compared to water, $p < 0.001$. Erosive challenge followed by licking more than doubled the loss of enamel $p < 0.001$.
Conclusions: When enamel was exposed to orange juice prior to licking, tissue loss as a result of tongue abrasion of the eroded surface was increased, and double that of the erosive challenge alone. Licking enamel with the tongue had no perceptible effect on enamel loss in the absence of the erosive challenge.
Clinical significance: Enamel wear resulting from tongue abrasion on tooth surfaces softened by acid challenge, can be an unavoidable consequence of oral function. This may account for the pattern of erosive toothwear on palatal and occlusal tooth surfaces, reinforcing the importance of restricting the frequency of dietary acid challenge in susceptible individuals.

1. Introduction

Toothwear is the destruction of teeth over the course of a lifetime following exposure to a number of physical and chemical insults. Friction of exogenous material (abrasion), the effect of antagonistic teeth (attrition), forces incurred during tooth flexure (abfracation) and chemical dissolution (erosion) all contribute to various degrees [1]. Erosion, abrasion, and/or attrition rarely act alone, and often act synergistically, in the multifactorial aetiology of the condition [2]. Clinically, whilst the dominant origin of toothwear is often surmised, it is difficult to determine the part played by specific causative factors. Erosive toothwear has increased dramatically over the last couple of decades, particularly in the young adult populations and is of increasing importance for the long term health of the dentition [3].

Research has shown that when the enamel surface is challenged by acidic insult, loss of structural integrity occurs, rendering a softened tooth layer vulnerable to abrasive forces. This may cause further enamel substance loss [4]. Conversely, abrasive forces usually have no significant effect on sound tooth in an acid free environment [5], although individuals who brush

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more than twice a day with excessive force may suffer from abrasive toothwear and subsequent dentine hypersensitivity especially on the tooth that is brushed first and tends to be brushed for the longest [6]. One of the most destructive interactions in human toothwear, is the abrasion of erosively altered enamel [7]. Numerous studies assessing the effect of tooth brushing on eroded dental tissue indicate erosion is the dominant wear factor in toothwear, however the abrasivity of toothpaste will influence the degree of wear [8,9]. It is rare that other possible abrasive or frictional forces are considered to impact on erosive toothwear. It is known that the acid softened zone of enamel consist of bundles of crystals separated by large spaces [10] and is thus vulnerable to the slightest abrasive or frictional influence. It has therefore been postulated that friction from the oral soft tissue and the tongue in particular [11], may contribute to the site specificity of toothwear. It may also explain the predilection for tooth wear instead of tooth loss on the palatal aspect of the upper incisors where the tip of the tongue exerts pressure as well as the occlusal surfaces of lower first molars where the lateral borders of the tongue spread at rest [12,13].

Studies examining the abrasive effects of the tongue on toothwear are scarce. Gregg et al. [13] conducted a study *in vitro* demonstrating that enamel loss was significantly greater when acid challenge was followed by licking or ultrasonication than when acid challenge was followed by water immersion. This suggests that the tongue is exerting an abrasive effect on softened enamel. Vieira et al. [14] investigated *in vitro*, the disruption of acid softened enamel by simulated tongue friction. This methodology employed toothbrushes covered with chamois leather to replicate the tongue texture and abrasive force. Again this resulted in synergistic tooth tissue loss derived from erosion and abrasion compared which was significantly greater than that achieved by erosion alone.

The aim of this *in situ* study was to investigate the abrasive effect of the tongue on human enamel surface loss in combination with and without a prior erosive challenge on the enamel surface.

The research questions asked were:

(i) Does licking tooth enamel lead to loss of tooth tissue in the absence of acidic soft drinks?
(ii) Is the loss of tooth tissue caused by acidic soft drinks enhanced by licking?

The study hypothesis was that acidic soft drinks cause enamel tissue loss by erosion and additional enamel loss is incurred due to the abrasive effects of the tongue.

2. Materials and methods

2.1. Preparation of the enamel samples

Recently extracted, caries free, human third molar teeth donated from patients aged over 18 years of either gender were used for the enamel samples. Prior to donation, each patient signed an ethically approved informed consent form, allowing their teeth to be used for research purposes. To comply with UK law, human molars were sourced through an appropriately licensed and ethically approved Tissue Bank and were tracked and disposed of in compliance with Human Tissue Legislation.

Upon donation to the Tissue Bank, the teeth were soaked for at least 24 h in sodium dichloroisocyanurate (20,000 ppm available chlorine) solution, cleaned, roots sectioned from the crown and pulp removed, prior to soaking for a subsequent 24 h in sodium dichloroisocyanurate (20,000 ppm available chlorine) solution. The sections were then washed in distilled water and stored in the tooth tissue bank

Sections of enamel $4 \times 4 \times 2$ mm were cut from the buccal surface of the crown of the tooth and embedded in epoxy resin. The samples were placed in a stainless steel jig and polished with p600 silicon carbide paper using a lapping and polishing machine, followed by hand polishing with a slurry of p1200 grit silica powder on a glass slab and 0.3 μm alpha alumina powder on a felt cloth. The samples were finally placed in an ultrasonic bath containing deionised water to remove any powder debris.

2.2. Enamel sample measurement

Two baseline readings of each enamel sample were taken across an area to be exposed to the study treatment using a contact profilometer (Surftest SV-200®, Mitutoyo, UK). This area was demarcated on the epoxy resin surrounding the enamel sample and the specimen identified with a unique number on the reverse. The area to be treated was left exposed by placing PVC tape over the enamel surface either side of the demarcated area leaving an enamel window for treatment. The profilometer was calibrated daily on a reference block and has been validated to an accuracy of 0.042 μm for the measurement of step height enamel loss [15].

On Day 15, contact profilometry readings from the exposed area of enamel were recorded and tissue loss calculated. Prior to taking profilometric measurements, the samples were removed from the appliances and disinfected by soaking in a mixture of 0.5% chlorhexidine and 70% aqueous ethanol for a period of at least 20 min.

2.3. Study design

This was a single centre, single blind (blinded to the person responsible for performing the enamel sample analysis), randomly allocated, split mouth, four treatment regimen, one period, *in situ* study in healthy adult volunteers performed in a UK dental school. Favourable approval from an NHS Research Ethics Committee was obtained and the study was conducted to Good Clinical Practice guidelines as laid down by the Declaration of Helsinki. The primary objective of the study was to determine the loss of enamel tissue due to the abrasive influence of the tongue with and without prior exposure to orange juice over a 15 day period measured by contact profilometery.

2.4. Participant eligibility and randomisation

Participants aged 18 or over were invited to attend a screening visit, where those happy to take part in the study gave informed consent. Eligibility for inclusion in the study was determined following an oral soft tissue examination and evaluation of inclusion and exclusion criteria. Inclusion criteria included being in good general health and able to accommodate two lower intra-oral buccal appliances. Exclusion criteria included, susceptibility to acid regurgitation, orthodontic appliances, periodontal disease, caries, acidic medication, xerostomia and allergies to the study products.

A total of 24 subjects were enrolled in the study and custom made lower right and left buccal intra-oral appliances were constructed for all subjects, each fitted with four enamel samples (eight samples in total). Two study treatment regimens were applied per appliance and two specimens were used per regimen. Subjects were allocated a study number based on the order they were enrolled onto the study and were randomly allocated to 4 sequence groups, 6 participants per group, using a block randomisation scheme by study staff. The randomisation scheme dictated: right or left appliance samples being treated with either an acidic or water challenge regimen and; samples licked or not licked being either anteriorly or posteriorly placed in the appliance