Dental erosion and the role of saliva: a systematic review

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Abstract. – OBJECTIVE: This review evaluates the relationship between saliva and dental erosion. The acidic environment that can be established in the mouth leads to dental erosion. Acid pH, low salivary flow, systemic pathologies of patients, intake of acidic foods, and poor oral hygiene contribute to an oral environment that favors the development of dental erosion.

MATERIALS AND METHODS: A literature search was performed on PubMed, Scopus, and Web of Science databases to assess the role of saliva and dental erosion. The inclusion criteria for the search were: year of publication from January 1st, 2013, to March 1st, 2023, and English language.

RESULTS: A total of 3,597 articles covering our topic were found, of which 15 were selected for qualitative analysis.

CONCLUSIONS: Saliva protects against erosion by neutralizing and removing intrinsic and extrinsic acids, promoting the formation of an acquired protective film, and providing mineral substrates for remineralization by maintaining homeostasis in the digestive tract and oral cavity.

Key Words:
Saliva, Salivary pellicle, Low salivary flow, Acid pH, Enamel pellicle, Dental erosion, Tooth wear, Gastro-esophageal reflux, Pepsin.

Abbreviations

AP: acquired pellicle, BEWE: basic erosive wear examination, D: dentine, DE: dental erosion, DMFT: decayed, missing, and filled teeth, E: enamel, ETW: erosive tooth wear, FRAP: ferric-reducing antioxidant power, GSH: reduced glutathione, GERD: gastro-esophageal reflux disease, GerdQ: gastro-esophageal reflux disease questionnaire, LRP: laryngopharyngeal reflux, LSFR: low salivary flow rates, PEB: post-eruptive breakdown, PP: Human pepsin, SFR: Salivary flow rate, SHL: surface hardness loss, SISS: Schiff index sensitivity scale, VAS: Visual analogue scale.

Introduction

Dental erosion (DE) is the gradual and irreversible loss of dental enamel (E), the external coating of the tooth made of calcium mineral salts that serve as a barrier and protector for the dentin beneath, which is softer and more sensitive[1]. The dentine (D) dissolution process is more difficult than the E dissolution process because D contains a demineralized organic matrix that hinders ionic diffusion[2,3]. Dental erosion has been significantly more widespread in recent years, with apparent differences amongst different countries, regions, and age groups. Particularly among older age groups, DE is becoming more prevalent[4].

Etiopathogenesis and Risk Factors

Without requiring acids produced by bacteria, extrinsic or intrinsic acids acting on cells can cause DE. DE can be brought on by acidic chemicals that encounter teeth. Due to the critical pH of tooth E being around 5.5, any solution with a lower pH value could result in erosion, especially if contact is prolonged and repeated over time[5]. The lowering of pH within the oral cavity can be ascribed mainly to intrinsic causes and extrinsic causes (Figure 1). Examples of intrinsic causes include gastro-esophageal reflux disease (GERD), anorexia or bulimia-related vomiting, or other chronic gastrointestinal diseases. Extrinsic acids come from external sources like food (such as acidic liquids like fruit juices, isotonic drinks, and wine) and continuous usage of specific drugs[6-8].

As a result of persistent vomiting or reflux, stomach acid that enters the mouth is another etiological cause. Due to an irregularity in the diges-

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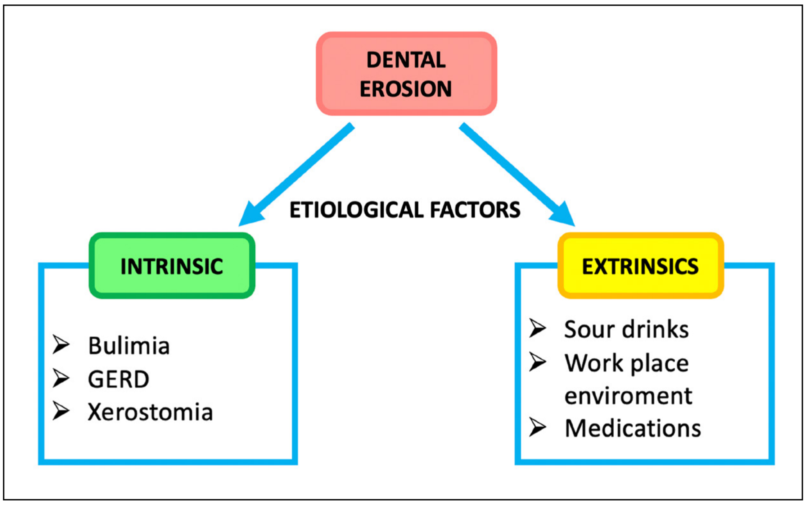

Figure 1. Etiological factors of dental erosion.

tive tract, reflux is the involuntary flow of gastric contents from the stomach into the mouth[9,10].

Therefore, if gastric acids act on dental hard tissues repeatedly over time, they promote a more rapid erosion process[11-13].

Additionally, how dietary acids are taken (sipping, sucking, using a drinking straw or not) affects the location and duration, leading to different erosion[14,15].

Because there is less saliva produced at night, acidic contact with the teeth can cause erosion[16].

For example, in addition to carious lesions, drinking acidic, sweet drinks – which some newborns do throughout the night from their bottles – can cause enormous erosive tooth structure destruction[17,18].

Basic Erosive Wear Examination

Basic Erosive Wear Examination (BEWE) score, which assigns the score 0 to a healthy tooth without erosions, 1 to a tooth with an initial loss of hard tissue, 2 to a tooth with hard tissue loss of less than 50% of the surface area and 3 when there is a loss of more than 50% of the superficial hard tissue (Table I)[19].

Saliva and Salivary Pellicle

The exocrine fluid known as saliva is clear and moderately acidic. Numerous electrolytes, such as potassium, magnesium, calcium, sodium, bicarbonate, and phosphates, as well as biological substances like immunoglobulins, mucins, enzymes, proteins, and nitrogenous products are found in saliva[20]. More than 99% of the substance in saliva is water. This biofluid's main functions include lubrication, antimicrobial activity, buffering, digestion, and tooth protection and removal. The fluids produced by the major and minor salivary glands, as well as the gingival crevicular fluid, are combined to form saliva[21]. Among the principal salivary glands are the paired parotid glands, which are situated adjacent to the maxillary first molars, as well as the submandibular and sublingual glands, which are on the floor of the mouth. Small saliva-producing glands can be found in the pharynx, lower lip, tongue, palate, and cheeks[22-24].

The acquired pellicle (AP) is made up of glycoproteins, proteins, lipids, and several enzymes[25,26]. It has been shown that this film can withstand relatively strong acid exposures, at least in terms of its fundamental structure. It is thought that this film prevents erosion by serving as a diffusion barrier or a membrane that allows certain types of acid to pass through while keeping the tooth surface out of direct contact with the acids[27-29].

Saliva and salivary pellicles defend against acid attacks, but if the threat is great enough, tooth tissue will be destroyed[30-32]. The salivary glands engage in various defensive mechanisms during an abrasive challenge, including neutralizing and buffering acids, producing the AP, and diluting and expelling an abrasive substance from the mouth[33-35].

Table I. BEWE Score.

Point	Criteria
0	No DE
1	Superficial loss of enamel
2	Hard tissue loss involving < 50% of the tooth surface
3	Hard tissue loss involving > 50% of the tooth surface

The critical pH is the pH at which a solution is just barely saturated concerning a specific solid, like E material[33,36]. In contrast, when the pH of the solution is above the critical pH, it is supersaturated, which increases the possibility of more minerals precipitating. When the pH of the solution is below the critical pH, it is undersaturated and can dissolve the solid. The critical pH is influenced by the target solid's solubility as well as the concentrations – or, more precisely, the activities – of the relevant mineral solution components[17,37,38].

Calcium, phosphate, and to a lesser extent, fluoride activity, are the principal critical constituents in tooth minerals because they regulate the level of saturation in the solution, which is what drives dissolution and precipitation[16,39]. If the erosive difficulty persists, E crystals in subsequent layers melt, causing a permanent loss of volume with a softer layer resting on top of the remaining tissue[40,41] (Figure 2).

Enamel

The body's toughest calcified matrix is E. Amelogenesis is the process of E development[42,43]. In the E space, ameloblasts synthesize E matrix proteins that are eventually degraded and removed by other ameloblasts through a process called proteolysis[44,45]. Ameloblasts carefully regulate the *de novo* hydroxyapatite-based inorganic material formation in the E area. The generated E has a distinct prismatic appearance and is composed of rods formed by individual ameloblasts that stretch from the dentin-E junction to the E surface, as well as interrod E, which surrounds the E rods[46-48].

Extracellular matrix proteins are assumed to have helped shape the final structure and give the E its distinctive morphological and biomechanical qualities. Traces of these proteins have been found in the fully formed (mature) E. 95 percent minerals, 1 percent organic material, and 2 to 4 percent water make up mature E[49-51].

The lesion in E mostly appears in the prism sheath regions, then the prism cores dissolve. In time, the interprismatic regions are also impacted[52].

Therefore, the purpose of this review is to analyze the aspects such as salivary composition and consequently its diagnostic value for certain diseases such as GERD.

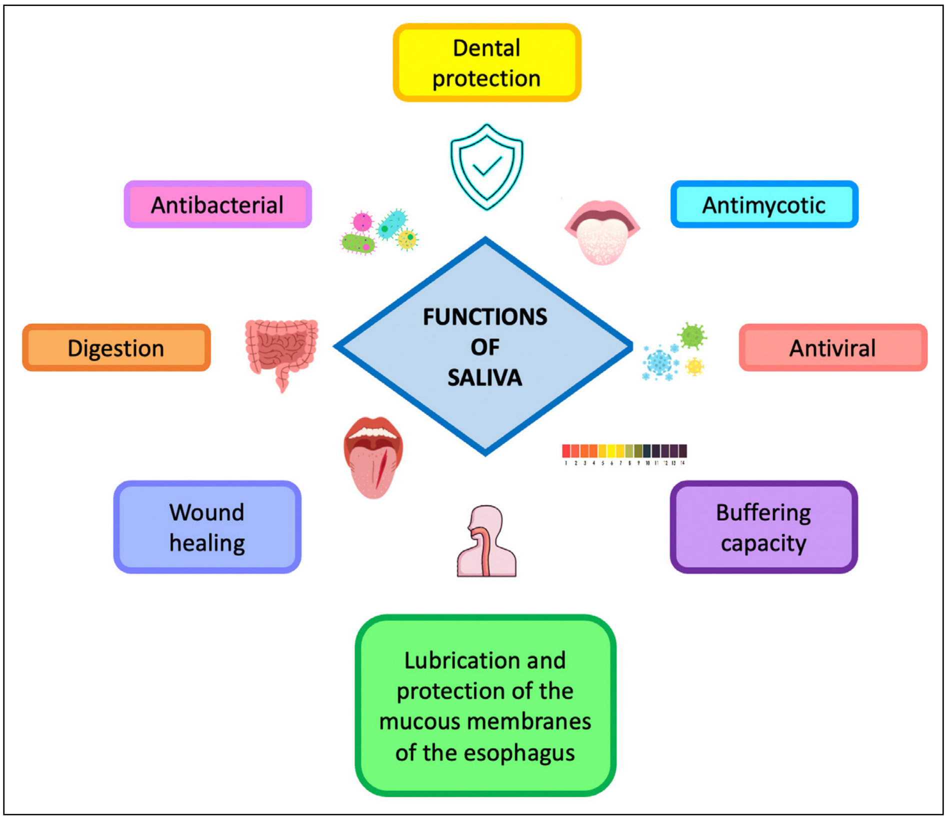

Figure 2. Summary of the main functions of saliva.

Materials and Methods

Protocol and Registration

This systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Search Processing

A search on PubMed, Scopus, and Web of Science was performed (Table II) to find papers that matched the topic of the relationship between saliva and DE, dating from 1 January 2013 to 1 March 2023. The search strategy used the Boolean keywords: "saliva" AND "dental erosion".

Inclusion Criteria

The following inclusion criteria were considered: (1) studies that investigated the relationship between saliva and DE, (2) randomized clinical trials, retrospective and observational studies, (3) English language, and (4) full-text.

Papers that did not match the above criteria were excluded.

The review was conducted using the PICOS criteria:

- Participants: children and adults were included.
- Interventions: the action of saliva
- Comparisons: factors that may influence salivary composition.
- Outcomes: role of saliva in dental tissue erosion.
- Study: randomized clinical trials, retrospective and observational studies on human teeth.

Exclusion Criteria

The exclusion criteria were as follow: (1) animal studies; (2) *in vitro* studies; (3) off-topic; (4) reviews, case reports, case series, letters or comments; (5) no English language.

Data Processing

Three reviewers (M.C., M.G. and I. P.) independently consulted the databases to collect the studies and rated their quality, based on selection criteria. The selected articles were downloaded into Zotero (version 6.0.15) (Bari, Italy). Any divergence between the three authors was settled by a discussion with a senior reviewer (F.I.).

Table II. BEWE Score.

Articles screening strategy	**KEYWORDS: A: saliva; B: dental erosion** **Boolean Indicators: A AND B** **Timespan: 2013-2023** **Electronic databases: PubMed; Scopus; WOS**

Results

Study Selection and Characteristics

The electronic database search identified a total of 3,597 articles (Scopus N = 2,741, PubMed N = 382, Web of Science N = 474), and no articles were included through the hand search[53-73].

After the deletion of duplicates, 2,792 studies were screened by evaluating the title and abstract, focusing on the association between the influence of saliva on DE.

2,776 articles did not meet the inclusion criteria (2,054 off-topic, 226 reviews, 496 animal studies), leading to 15 records[53-65-74,78] being selected. After eligibility, 15 records were selected for qualitative analysis. The selection process and the summary of selected records are shown in Figure 3 and **Supplementary Table I**, respectively.

Discussion

Saliva and Dental Erosion

A chemical-mechanical reaction that is mainly caused by non-bacteria acid aggression is ETW involves mineralized dental tissues, and is regarded as a complex and multifactorial oral health problem. ETW affecting only tooth E is observed in children, mostly in its early stages[66-68].

Intrinsic protection against ETW may rely on individual AP proteins in association with E substrate characteristics, including topography, tribology, and surface roughness. Some studies[57,69] proposed that saliva can vehicle proteins, e.g., statherin, more efficaciously on non-eroded areas than eroded ones.

The higher level of statherin, a calcium-binding protein, on uneroded tooth surfaces suggested that calcium and phosphorus ions were probably regulated around E crystals. Statherin was potentially an important facilitator against ETW and the protective effect of proteins in ETW was nullified by altered calcium homeostasis rather than an incapacity to neutralize or block the acid attack. In addition, a higher amount of total salivary protein was found in uneroded tooth surfaces than in eroded tooth surfaces of the same patients[57].

Salivary clinical and biochemical features of 48 children with and without ETW were evaluated by Shitsuka et al[53] through sialometry tests. Salivary

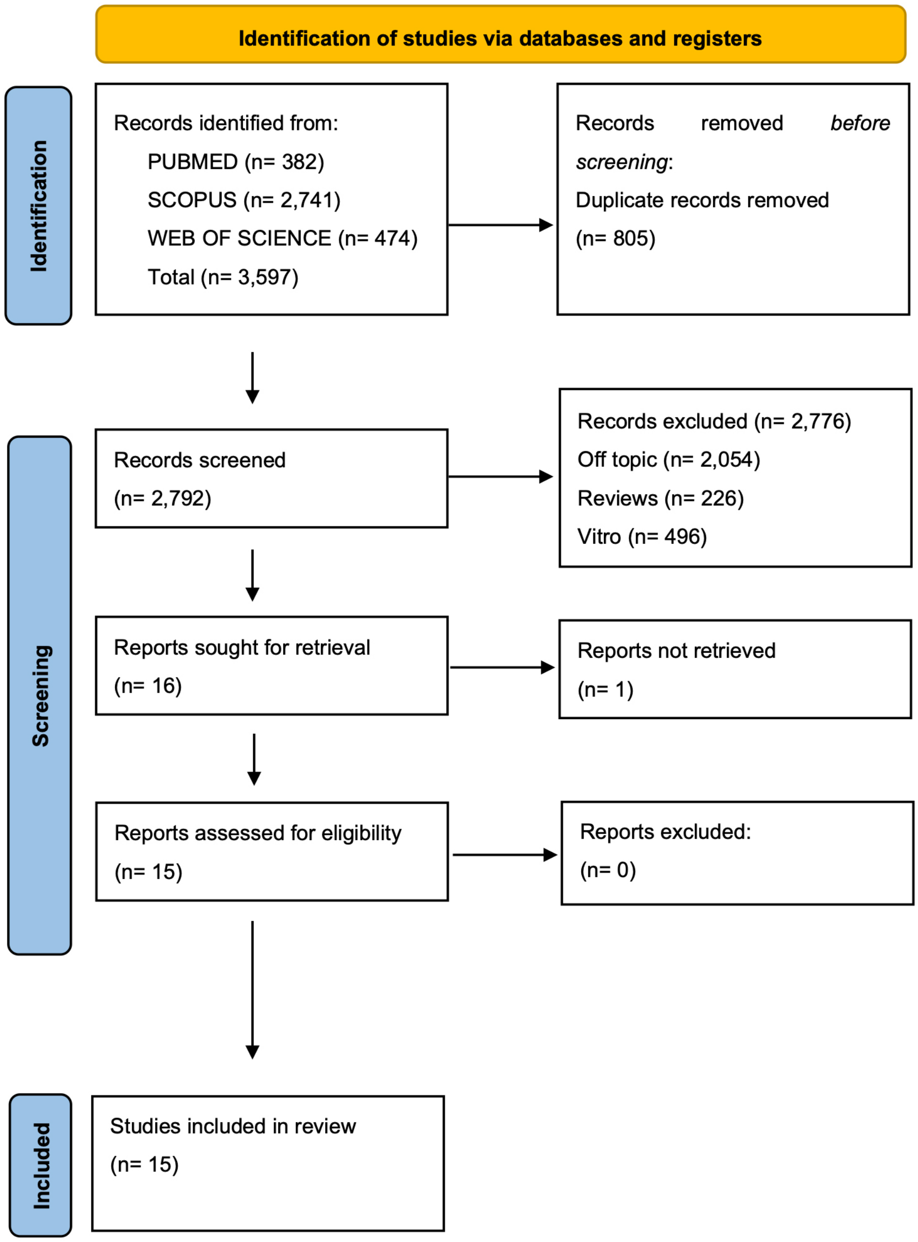

Figure 3. Literature search Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram and database search indicators.

flow rate (mL/min), pH, calcium (µg/mL), phosphorus (mg/mL), ferric-reducing antioxidant power (FRAP) (µmol Fe/min mL), uric acid (mg/dL), reduced glutathione (GSH) (mM), total buffering capacity (mL HCl 0.01N) were examined, and a statistically significant difference between groups was obtained only for the pH value ($p = 0.004$).

Low pH, moderately viscous saliva, and low salivary flow rates (LSFR) were substantially more frequent in children with molar hypomineralisation. They had considerably higher mean caries scores than the children without molar hypomineralisation, because the greater the hypomineralisation area, the more severe the carious lesion[54,70,71].

In comparison to teeth with merely opacities, teeth with a post-eruptive breakdown (PEB) had ten times as many dental carious lesions. It was connected with LSFR and moderately and highly acidic saliva[54,72].

Eating and drinking acid-containing products is a very common practice among people in many countries as the regular consumption of products. In the early phases of ETW, alterations of the E surface were hard to determine clinically[73].

Through dental impressions and a scanning electron microscope, Seong et al[74] observed the tooth surface before and after exposure to an acidic beverage with pH 2.57 for 30 minutes. They noted that E restoration had begun within 2 hours after acid exposure and had been completed after 24 hours.

Acid drinks with a lower pH favored erosion by initial etching of the surface, those with a greater titratable acidity retard salivary pH recovery, and the most surface hardness loss (SHL) was observed for the solution with lower pH and higher titratable acidities[55,75,76].

The impact of antiacid intake after multiple acid test challenges in subjects with and without DE was substantial in terms of the time required to regain baseline values of pH. In particular in the subjects with E erosion, was necessarily more time to resume baseline pH values, therefore maintaining a more basic pH[56].

GERD and Dental Erosion

Casciaro et al[58] sought to understand whether laryngopharyngeal reflux (LPR) was related to salivary changes and, therefore, to dental disease, because LPR is often considered a symptom of GERD. When compared to the control group, LPR patients had a higher incidence of dental problems, according to an intraoral examination. Additionally, patients in group A had statistically significant mean Schiff index sensitivity scale (SISS) and BEWE scores higher than those in group B. Although not statistically significant, subgroup A PEP -, which has lower salivary pepsin levels, had higher decayed, missing, and filled teeth (DMFT) values, reflecting inferior oral health. Although LPR-induced salivary alterations may be connected to DE and caries, pepsin does not appear to be directly related to DE. Saliva is one of the key factors in maintaining homeostasis in the digestive system and mouth cavity. In comparison to the control group, LPR patients had decreased SFR, and salivary buffering capacity.

Maniaci et al[61] also support a strong correlation between GERD and oral hard tissue lesions. Specifically, in their study, they went on to evaluate the diagnostic value of salivary pepsin in the diagnosis of GERD and the correlation between test-positive patients and oral lesions.

In support of these findings, there is also the study of Rajab and Zaidan[58]. In this study, the mean salivary pH for the GERD group was 6.95, while it was 7.11 for the control group. The mean salivary pH level in the GERD group was lower than in the healthy group. In comparison to the control group, the GERD group had lower salivary pH levels. The findings of this study revealed a significant ($p > 0.001$) increase in pepsin levels in the saliva of GERD patients as compared to the control group. In this study, negative correlations between DE and salivary volume and pH were found. The study's findings indicate that patients with GERD have significantly greater amounts of salivary pepsin than healthy people and a higher prevalence of DE.

Another interesting finding is reported in the paper of Mulic et al[63]; they discovered that certain protein profiles, including amylase and proteins with molecular weights under 1KDa, are present in young people with ETW. This shows that some salivary proteins, which may be produced from the proteolysis of hydroxyapatite-interactive human salivary proteins, protect against ETW.

The study by Picos et al[60] found a high prevalence of DE in both GERD patients and controls. Antacid usage, which is common among GERD patients, has been shown to be protective against DE.

The lower pH values in GERD patients confronted with the control group corroborated the greater risk of DE in this disease. DE was more prevalent and severe in participants with GERD than in non-GERD controls. BEWE scores and low salivary pH were associated. However, salivary buffering capacity was not. Patients with a BEWE of 10 or higher exhibited considerably lower buffering capacities than those with a lower BEWE score.

Martini et al[62] studied the proteomic profile of the AP in GERD patients with and without ETW. The findings showed significant differences in the protein profiles of the AP from participants with and without GERD and between those with GERD and controls. The proteomic profiles of the APs collected in the three groups were very varied, and many of the proteins identified were those that are frequently found in the AP and showed variation in expression.

The most significant information in this text is that many of the proteins found exclusively in patients with GERD and ETW are membrane proteins, suggesting that the gastric acids are lysing epithelial cells and that some of these proteins are secreted as active proteases and may alter the AP. These patients showed increased concentrations of proteins linked to lubrication and demineralization resistance. According to this study, Lysozyme C and Cathepsin G expression levels were lowest in patients with GERD and without ETW as compared to patients with GERD and ETW. As proteases break down the demineralized organic matrix, these proteins may be linked to slower rates of erosion and caries progression in dentin. Additionally, volunteers with GERD and without ETW had higher amounts of albumin and cystatins, which may help to protect against ETW.

Other Correlations

The quality of life of obese individuals was more unfavorably impacted by socioeconomic factors and oral disease, than normal-weight individuals. In obese individuals, salivary flow was low, and salivary pH was altered. Additionally, E wear was less represented in these individuals, and D wear was more represented[64,77].

Shitsuka et al[78] found that, in comparison to children without DE (1.180 ± 28), children with DE exhibited less biofilm (p = 0.0001), with a mean standard deviation of 0.760 ± 25. There was no variation in the salivary pH between the groups under investigation. Additionally, their data did not reveal a connection between saliva's ability to protect against acids.

Zwier et al[65] found that in patients who had ETW, the flow rate of unstimulated saliva was shown to be decreased. There were just two significant changes between the erosion group and the control group, both in saliva that wasn't stimulated. In participants with erosion, the flow rate of unstimulated saliva was considerably reduced (p = 0.016). Subjects with erosion had significantly higher chloride concentrations in their unstimulated saliva (p = 0.019). The amount of total protein in stimulated saliva showed a non-significant (p = 0.072) trend. Protein levels in erosion-affected participants were lower (0.3 g/l) than in the control group (0.4 g/l).

Conclusions

Saliva protects against erosion by neutralizing and removing both intrinsic and extrinsic acids, promoting the formation of an AP, and providing mineral substrates for remineralization. Saliva is one of the key factors in maintaining homeostasis of the digestive tract and oral cavity patients with GERD have reduced salivary flow, and it is this salivary flow with reduced salivary buffering capacity that may be a factor risk for DE.

Also, in GERD patients, there are differences in salivary composition, they have higher amounts of salivary pepsin which results in a higher predisposition to DE.

Authors' Contributions

Conceptualization, A.D.I., A.M.I., G.M., F.P., (A.P.-Assunta Patano), I.P. and M.G.; methodology, G.D., (A.P.-Andrea Palermo) and M.C., software, F.C.T., (A.P.-Assunta Patano), M.G., F.I. and G.D.; validation, (A.P.-Assunta Patano), M.G., G.M., (A.P.-Andrea Palermo), F.I. and G.D.; formal analysis, F.I., G.M., A.P., A.M.I., I.P., M.G., E.M. and G.D.; resources, A.D.I., A.M.I., G.M., M.G. and (A.P.-Assunta Patano); data curation, G.M., I.P., M.G., F.I., and G.D.; writing–original draft preparation, A.D.I., A.M.I., I.P., M.G., F.I., E.M. and G.D.; writing–review and editing, (A.P.-Assunta Patano), G.M., F.C.T., (A.P.-Andrea Palermo) and F.I.; visualization, G.P., C.D.P., G.L., F.I., (A.P.-Assunta Patano), V.S. and I.R.B.; supervision, A.D.I., A.M.I., G.M., F.I. and G.D.; project administration, M.G., F.I. and G.D. All authors have read and agreed to the published version of the manuscript.

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Ethics Approval

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Informed Consent

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Data Availability

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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