| Table 1. Characteristics of the included articles (*in vitro* studies) | | | | | | | | |
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| **Author (Year)** | **Title** | | **Study aim** | **Outcome Measurement** | **Sample Size (SS), Follow-Up (FU)** | **Material(s) or Technology**  **(ies) Used** | **Active agent(s)** | **Primary results** |
| Poggio et al. (2017) | Preventive effects of different protective agents on dentin erosion: An in vitro investigation | To evaluate the preventive effects of different protective agents on dentin erosion caused by soft drinks | | Percent weight loss, SEM imaging | SS: 70 human dentin specimens; FU: 32 minutes total immersion in Coca-Cola | Remin Pro, MI Paste Plus, Tooth Mousse, Biorepair, Biorepair Plus, Regenerate | Hydroxyapatite, CPP-ACP, CPP-ACPF, zinc hydroxyapatite, calcium silicate, sodium phosphate, sodium monofluorophosphate (1450 ppm fluoride) | Biorepair and Regenerate significantly reduced dentin weight loss, showing greater resistance to acid erosion compared to other agents. Remin Pro and MI Paste Plus showed results similar to the control group, while Tooth Mousse and Biorepair Plus increased dentin demineralization |
| Altan et al. (2019) | Inhibition effects of different toothpastes on demineralisation of incipient enamel lesions | To Evaluate the inhibitory effects of different toothpastes on demineralisation of incipient enamel lesions using a toothbrush simulator | | Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDX) with weight percentage of mineral changes (Ca, P, Na, Si) | 50 Human enamel blocks (n=10 per group)  5 days pH cycling | Toothpaste with Arginine, Fluoride, CPP-ACP, and Bioactive Glass (NovaMin) | Arginine, Sodium Monofluorophosphate (Fluoride), CPP-ACP, Bioactive Glass (NovaMin) | All toothpaste groups showed a statistically significant increase in Ca and P compared to the control group (p < 0.05). CPP-ACP showed the highest increase in Ca and P. NovaMin increased Na and Si significantly |
| Vilhena et al.  (2020) | Biomimetic Mechanism of Action of Fluoridated  Toothpaste Containing Proprietary REFIX Technology  on the Remineralization and Repair of Demineralized  Dental Tissues: An in vitro Study | Characterize the mineral content and surface  and cross-sectional morphology of enamel and dentin tissues treated with a 1450 ppm  fluoride-containing toothpaste with REFIX technology. | | The surface and cross-sectional  micromorphology were assessed using scanning electron microscopy (SEM). The ele-  mental analyses (weight%) were determined with an energy-dispersive X-ray spectros-  copy (EDS). | Bovine enamel blocks  (n=5)  7 days of pH cycling | REFIX technology | Fluoride sodium, tetrasodium pyrophosphate | REFIX technology remineralized and repaired the surface enamel effectively.  Enamel with the toothpaste formed a silicon-enriched mineral layer on the enamel  surface.  The results were also consistent in the dentin, where the  dentinal tubules were progressively occluded until there was complete occlusion after  7 days. |
| Tomaz et al.  (2020) | Effects of 1450-ppm Fluoride-containing  Toothpastes Associated with Boosters on the Enamel  Remineralization and Surface Roughness after  Cariogenic Challenge | Investigated the remineralization potential of 1450  ppm, fluoride-containing toothpastes containing different active remineralization  agents after cariogenic challenge with pH cycling. | | Mean and percentage  of surface hardness recovery (% SHR) were calculated. Surface enamel roughness (Ra)  was also evaluated. The pH, %weight of particles, zeta potential, and polydispersity  index of toothpaste slurries were also evaluated. | Bovine enamel blocks  (n=8/ per group)  7 days of pH cycling | REFIX, NR-5,  Candida Professional, Colgate Total 12 Daily Repair, Bianco Pro Clinical, Elmex Sensitive | Sodium fluoride,  Tricalcium phosphate (β-TCP),  Sodium Monofuoro-phosphate, Oligopeptide-104,  Calcium glycerophosphate,  Triclosan, Arginine,  Tetrasodium pyrophosphate, Calcium silicate and  sodium phosphate | The  enamel subsurface was more effectively remineralized when treated with Bianco Pro Clinical, Elmex Sensitive,  and Refix. The surface roughness was higher when the demineralized third was treated  with Refix, and NR-5 and after the cariogenic challenge. |
| El-Damanhouryet al. (2021) | In Vitro Enamel Remineralization Efficacy of Calcium Silicate-Sodium Phosphate-Fluoride Salts versus NovaMin Bioactive Glass, Following Tooth Whitening | To evaluate the effect of in-office bleaching on enamel surface and compare the efficacy of Calcium Silicate-Sodium Phosphate-Fluoride (CS) and NovaMin bioactive glass (NM) in remineralizing bleached enamel | | Surface Microhardness (Knoop Hardness Number (KHN), Surface Roughness, SEM/EDX Elemental Analysis | 40 human premolars (n=10)  7 days pH cycling | Toothpaste with Novamin Bioactive Glass (NM), NR-5 (CS) and additional treatment with NR-5 boosting serum (CS+NR-5), | silica, calcium sodium phosphosilicate (Novamin), sodium monofluorophosphate  Calcium Silicate-Sodium Phosphate with Sodium Monofluorophosphate, hydrated silica (NR-5) | CS and CS+NR-5 showed superior remineralization compared to NM. All remineralization agents increased hardness and decreased surface roughness after bleaching, but NM had a significantly higher surface roughness. CS and CS+NR-5 were more effective in restoring hardness and smoothness. |
| Fernandes et al.  (2021) | Resistance against Erosive Challenge of Dental  Enamel Treated with 1,450-PPM Fluoride Toothpastes  Containing Different Biomimetic Compounds | This in vitro study aimed to characterize the superficial and subsurface  morphology of dental enamel treated with fluoridated gels containing different bio-  mimetic compounds after erosive challenge. | | The surface and cross-sectional micromorphology were assessed  using scanning electron microscope (SEM). The elemental analyses (weight percent-  age) were determined with an energy-dispersive X-ray spectroscopy (EDS). | Bovine enamel blocks  (n=5/ per group)  6 days of pH cycling | NR-5, REFIX, Novamin. | Fluoride sodium, triclosan, arginine, tetrasodium pyrophosphate  Sodium  monofuorophosphate, calcium silicate and  sodium phosphate  Calcium  sodium phosphosilicate 5% | Enamel treated with the product containing REFIX technology presented a  smoother surface morphology compared to the other treatments. The higher resis-  tance to the erosive challenge can be attributed to a silicon-enriched mineral layer  formed on the enamel induced by the REFIX-based toothpaste. |
| Rahman et al. (2021) | Effect of Calcium Silicate, Sodium Phosphate, and Fluoride on Dentinal Tubule Occlusion and Permeability in Comparison to Desensitizing Toothpaste: An In Vitro Study | To compare the efficacy of a calcium silicate-, sodium phosphate-, and fluoride-based (CSSPF)toothpaste in promoting dentinal tubule occlusion and reducing dentin permeability against other commercial desensitizing toothpastes | | Dye Percolation (DP%) test, SEM microphotographs, EDS elemental analysis | SS: 78 human dentin discs; FU: 7 days | Calcium silicate, sodium phosphate, fluoride (Regenerate Advanced); Bioactive Glass (NovaMin - Sensodyne Repair and Protect); Potassium Nitrate (Signal Sensitive Expert) | Sodium monofluorophosphate (1450 ppm fluoride), calcium silicate, trisodium phosphate, hydrated silica (Regenerate); Sodium monofluorophosphate (Sensodyne); Potassium nitrate, Sodium fluoride (Signal) | The Regenerate demonstrated the highest dentinal tubule occlusion and calcium deposition, significantly reducing dentin permeability. Novamin also showed effective tubule occlusion but with less calcium deposition compared to Regenerate. Signal Sensitive Expert, using potassium nitrate, showed effective tubule occlusion and permeability reduction, but was less effective overall compared to both Regenerate and Sensodyne in terms of calcium deposition and tubule occlusion. |
| Vilhena et al.  (2021) | Silicon-enriched hydroxyapatite formed induced by REFIX-based  toothpaste on the enamel surface | At characterizing the mineral content and filler particle morphology of a fluoridated  toothpaste containing REFIX technology and the mineral content and the morphology of the enamel surface treated  with this product. | | The surface morphology was assessed using scanning electron microscopy (SEM). The elemental analyses  were performed using an energy-dispersive X-ray spectrometer (EDS). | Bovine enamel blocks  (n=5)  7 days of pH cycling | REFIX technology | Fluoride sodium, tetrasodium pyrophosphate | Elemental  analysis of the toothpaste’s formulation demonstrated the presence of Si (silicon), Na (sodium), P (phosphorus), and  F (fluorine), among others. We also detected a mineral layer that had formed on the treated enamel surface; the layer  had a consistent uniform thickness of ~14 μm. |
| Fernandes et al.  (2022) | Efectiveness of fuoride-containing  toothpastes associated with diferent  technologies to remineralize enamel after pH  cycling: an in vitro study | To evaluate the efcacy of fuoride-containing toothpastes with diferent technologies to remineralize  artifcial caries lesions in enamel. | | Surface microhardness recovery (%SMHR) and the fuorescence recovery (ΔFRE) with quantitative light-induced fuores-  cence. The cross-sectional micromorphology of the enamel surface was also assessed using scanning electron micros-  copy. Elemental analyses (weight%) were determined with an energy-dispersive X-ray spectrometer (EDS). | Bovine enamel blocks  (n=12/ per group)  6 days of pH cycling | REFIX, NR-5,  and NOVAMIN. | Fluoride sodium, triclosan, arginine, tetrasodium pyrophosphate  Sodium  monofuorophosphate, calcium silicate and  sodium phosphate  Calcium  sodium phosphosilicate 5% | The Refix to recover the surface microhardness with a signifcantly lower mean of ΔFRE.  Only Refix was able to  promote the formation of a mineralized layer on the surface of enamel enriched with silicon on the surface. |
| Moras et al. (2023) | Regenerative Biomineralization Potential of Commercially Available Remineralizing Agents as a Preventive Treatment Approach for Tooth Erosion – An In Vitro Laser-Induced Breakdown Spectroscopy Analysis | |  | | --- | | To evaluate and compare the surface remineralization potential of SAP P11-4 (self-assembling peptide) and CSSP (calcium silicate plus sodium phosphate) on intact and demineralized enamel |  |  | | --- | |  | | | |  | | --- | | Laser-induced breakdown spectroscopy (LIBS) to measure changes in Ca and P levels |  |  | | --- | |  | | |  | | --- | | SS:32 human enamel samples (16 intact, 16 demineralized)  30 days pH cycling |  |  | | --- | |  | | |  | | --- | | SAP P11-4 (CURODONT™ PROTECT), CSSP (REGENERATE™ Enamel Science™ Advanced Toothpaste and Serum) |  |  | | --- | |  | | |  | | --- | | SAP P11-4, calcium silicate, sodium phosphate, fluoride |  |  | | --- | |  | | Both SAP P11-4 and CSSP significantly increased Ca and P levels in demineralized enamel. No significant difference in remineralization potential was observed between the two agents on intact and demineralized enamel. |
| Vilhena et al. (2023) | Regenerative and Protective Effects on Dental Tissues of a Fluoride–Silicon-Rich Toothpaste Associated with a Calcium Booster: An In Vitro Study | To characterize the regenerative and protective effects of a fluoride-silicon-rich toothpaste combined with a calcium booster on dental tissues | | SEM imaging, Energy-Dispersive X-ray Spectroscopy (EDS), Elemental analysis (weight %) | SS: 5 bovine enamel and 5 bovine dentin blocks;  FU: Immediate and after 5 days | Fluoride-silicon-rich toothpaste with calcium booster - REFIX technology | Sodium Fluoride (1450 ppm), Silicon-rich compounds, Calcium Carbonate, Tricalcium Phosphate | The treatment formed a mineralized layer on enamel and dentin surfaces. After 5 days, the enamel had a 4-5 µm layer and dentin had a 7 µm layer. The calcium and silicon signals increased after immediate treatment, showing significant remineralization and occlusion of dentin tubules. |
| Athanasiadou et al.  (2024) | Chemical and Ultrastructural Characterization of Dentin  Treated with Remineralizing Dentifrices | Investigate dentin chemical and ultrastructural changes upon exposure to remineralizing dentifrices. | | Atomic force microscopy (AFM),  scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX), transmission  electron microscopy (TEM) and selected area electron diffraction (SAED). | 12 human dentin blocks (n= 3 per group)  14 days of toothbrushing | REFIX, REFIX + Booster and Novamin | Fluoride sodium, tetrasodium pyrophosphate  Calcium | All evaluated dentifrices led to successful formation of hydroxyapatite and  increased dentin stiffness. |