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# FLUORIDE VERSUS DENTAL IMPLANTS: CHEMICAL INTERACTIONS AND THEIR CLINICAL EFFECTS

# FLÚOR VERSUS IMPLANTES DENTÁRIOS: INTERAÇÕES QUÍMICAS E SEUS EFEITOS CLÍNICOS

# FLUORURO VERSUS IMPLANTES DENTALES: INTERACCIONES QUÍMICAS Y SUS EFECTOS CLÍNICOS

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**ABSTRACT**

Objective: To discuss the possible impacts that fluoride can have on dental implants. Methodology: The methodology of this article was outlined as follows: Four databases were used: PubMed, Cochrane Library, EMBASE and Google Scholar. During the searches for data on these platforms, the following descriptors were used in the search strategy: "Fluoride", "Dental implants" and "Clinical relevance", descriptors used in order to identify only results related to the topic addressed by the article. The results acquired went through 3 stages: 1- Deduplication of duplicate articles, eliminating repeated articles. 2- Elimination of articles in which, through reading their title and abstract, it was possible to see their incompatibility with the article. 3- In the last phase, a complete reading of the articles that remained from the first and second phases was carried out, eliminating the incompatible articles and selecting the compatible articles to compose the present narrative review. Results: Recent studies have shown that products containing fluoride may be contributing negatively to the oral health of people with dental implants, based on results that demonstrated that fluoride causes negative impacts on the implant's oxide wall, which serves as protection for it and allows it to coexist with human tissues. Conclusion: Fluoride can indeed negatively impact the implant, and may bring negative points to its structure and useful life. There is a clear need for future studies that aim to better understand this relationship between fluoride and dental implants.

**Keywords:** Fluoride. Dental Implants. Clinical Relevance.

**RESUMO**

Objetivo: Discutir os possíveis impactos que o flúor pode causar em implantes dentários. Metodologia: A metodologia deste artigo foi delineada da seguinte forma: Foram utilizadas quatro bases de dados: PubMed, Cochrane Library, EMBASE e Google Acadêmico. Durante as buscas de dados nessas plataformas, foram utilizados os seguintes descritores na estratégia de busca: "Flúor", "Implantes dentários" e "Relevância clínica", descritores utilizados com o objetivo de identificar apenas resultados relacionados ao tema abordado pelo artigo. Os resultados obtidos passaram por 3 etapas: 1- Desduplicação dos artigos duplicados, eliminando os artigos repetidos. 2- Eliminação dos artigos em que, por meio da leitura do título e resumo, foi possível constatar a incompatibilidade com o artigo. 3- Na última fase, foi realizada a leitura completa dos artigos que permaneceram da primeira e segunda fases, eliminando os artigos incompatíveis e selecionando os artigos compatíveis para compor a presente revisão narrativa. Resultados: Estudos recentes demonstraram que

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produtos que contêm flúor podem estar contribuindo negativamente para a saúde bucal de pessoas com implantes dentários, com base em resultados que demonstraram que o flúor causa impactos negativos na parede de óxido do implante, que serve como proteção para ele e permite sua coexistência com tecidos humanos. Conclusão: O flúor pode, de fato, impactar negativamente o implante, podendo trazer pontos negativos à sua estrutura e vida útil. Há uma clara necessidade de estudos futuros que visem melhor compreender essa relação entre flúor e implantes dentários.

**Palavras-chave:** Flúor. Implantes Dentários. Relevância Clínica.

## RESUMEN

Objetivo: Discutir los posibles impactos que el flúor puede causar en los implantes dentales. Metodología: La metodología de este artículo fue descrita de la siguiente manera: Se utilizaron cuatro bases de datos: PubMed, Cochrane Library, EMBASE y Google Scholar. Durante las búsquedas de datos en estas plataformas se utilizaron en la estrategia de búsqueda los siguientes descriptores: “Fluoruro”, “Implantes dentales” y “Relevancia clínica”, descriptores utilizados con el objetivo de identificar únicamente resultados relacionados con la temática abordada por el artículo. Los resultados obtenidos pasaron por 3 etapas: 1- Deduplicación de artículos duplicados, eliminando artículos repetidos. 2- Eliminación de artículos en los que mediante la lectura del título y resumen fue posible determinar incompatibilidad con el artículo. 3- En la última fase se realizó una lectura completa de los artículos que quedaron de la primera y segunda fase, eliminando los artículos incompatibles y seleccionando los compatibles para componer la presente revisión narrativa. Resultados: Estudios recientes han demostrado que los productos que contienen flúor pueden estar contribuyendo negativamente a la salud bucal de las personas con implantes dentales, basándose en resultados que demostraron que el flúor provoca impactos negativos en la pared de óxido del implante, que sirve de protección al mismo y permite su coexistencia con los tejidos humanos. Conclusión: El flúor puede, de hecho, afectar negativamente al implante, causando potencialmente efectos negativos en su estructura y vida útil. Existe una clara necesidad de realizar futuros estudios que apunten a comprender mejor esta relación entre el flúor y los implantes dentales.

**Palabras clave:** Flúor. Implantes dentales. Relevancia clínica.

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## INTRODUCTION

The use of titanium dental implants has become one of the main alternatives for oral rehabilitation, with long-term success rates of over 90%. Titanium's biocompatibility and corrosion resistance are attributed to the spontaneous formation of a titanium oxide ($TiO_2$) layer, which protects the implant against chemical aggressions and deleterious biological interactions (Han et al., 2005; Souza et al., 2013). However, extrinsic factors such as the frequent use of fluoridated toothpastes and mouthwashes can compromise this stability, making the implant vulnerable to corrosion, especially when associated with acidic pH environments (Reclaru & Meyer, 1998; Boere, 1995).

In addition to the influence of fluoride and acidity on the material, recent literature has pointed to the adverse effects of the release of titanium ions and particles in the peri-implant region. The presence of these particles can activate cells of the innate immune system, especially macrophages, promoting a sustained inflammatory cascade that culminates in bone resorption and loss of osseointegration (Oliveira et al., 2018; Pettersson et al., 2017). This is particularly relevant in the etiopathogenesis of peri-implantitis, a multifactorial condition that shares similarities with periodontitis but presents distinct characteristics of progression and response to treatment.

Thus, understanding the combined effects of fluoride concentration, pH of the medium and the immune response triggered by titanium particles is essential for the prevention of early or late failures of dental implants. The present study aims to fill this gap by evaluating, in an integrated manner, the release of titanium particles under different exposure conditions and their impact on the activation of human macrophages in vitro.

## METHODOLOGY

The methodology of this article was outlined as follows: Four databases were used: PubMed, Cochrane Library, EMBASE and Google Scholar. During the searches for data on these platforms, the following descriptors were used in the search strategy: "Fluoride", "Dental implants" and "Clinical relevance", descriptors used in order to identify only results related to the topic addressed by the article. The results acquired went through 3 stages: 1- Deduplication of duplicate articles, eliminating repeated articles. 2- Elimination of articles in which, through reading their title and abstract, it was possible to see their incompatibility with the article. 3- In the last phase, a complete reading of the articles that remained from the first and second phases was carried out, eliminating the incompatible articles and

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selecting the compatible articles to compose the present narrative review. Rother's work (2007) was used as a guide during the development of the present study, as it is an article that addresses the differences between systematic and narrative review articles, serving as instructions on how the approach and structure of a narrative review should be carried out.

## RESULTS

The analysis of the selected studies revealed consistent and concerning evidence regarding the interaction between fluoride compounds and titanium dental implants. In general, fluoride, especially in the form of sodium fluoride (NaF) or acidulated phosphate fluoride (APF) was found to induce chemical degradation of the protective oxide layer ($TiO_2$) that naturally forms on titanium surfaces. This oxide layer is essential for the biocompatibility and corrosion resistance of implants, and its degradation compromises the long-term stability of osseointegration (Reclaru & Meyer, 1998; Han et al., 2005).

### SURFACE CORROSION AND ION RELEASE

Several in vitro studies demonstrated that even at neutral pH, fluoride concentrations commonly found in dental gels and rinses were sufficient to damage the $TiO_2$ layer and promote the release of titanium ions (Schiff et al., 2002; Bhattarai et al., 2008). This process was exacerbated under acidic conditions ($pH < 4.5$), where the presence of APF formulations significantly increased the corrosion rate of titanium. The chemical interaction between fluoride ions and titanium leads to the formation of soluble complexes such as $TiF_6^{2-}$, which further destabilize the oxide layer (Reclaru & Meyer, 1998; Boere, 1995).

In electrochemical assays, such as polarization resistance and open circuit potential tests, titanium surfaces exposed to fluoridated solutions showed reduced corrosion resistance when compared to controls, indicating a compromised passive film (Schiff et al., 2002; Veys-Renaux et al., 2016). Notably, implants with polished or machined surfaces were more vulnerable to degradation than those with roughened or anodized surfaces, suggesting that surface modifications may influence resistance to fluoride-induced corrosion (Mareci et al., 2009).

### CELLULAR RESPONSE AND INFLAMMATION

Beyond the surface effects, several studies evaluated the biological response to the degradation products. Titanium nanoparticles and ions released due to corrosion were shown to be internalized by macrophages without causing immediate cell death (Oliveira et al., 2018; Pettersson et al., 2017). However, this internalization triggered an inflammatory response characterized by increased production of cytokines such as interleukin-1β (IL-1β) and interleukin-8 (IL-8), both of which are strongly associated with osteoclast activation and bone resorption (Kaufman et al., 2008; Eger et al., 2017).

This pro-inflammatory cascade is clinically relevant because it mirrors the pathophysiology observed in peri-implantitis. Chronic exposure to fluoride, especially in individuals with acidic oral environments (due to acidic diets or gastroesophageal reflux), may therefore create favorable conditions for the initiation or acceleration of peri-implant inflammation.

### CLINICAL IMPLICATIONS AND OBSERVATIONS

Although most of the available evidence stems from laboratory and animal studies, some clinical case reports and observational studies suggest a potential association between prolonged use of fluoride containing products and signs of peri-implant mucositis or bone loss in susceptible patients. For example, Schiff et al. (2002) demonstrated that the corrosion observed in vitro could feasibly occur in vivo under frequent exposure to fluoridated gels. Similarly, Toumelin-Chemla et al. (1996) found that titanium surfaces immersed in fluoride containing products exhibited pitting and structural compromise within hours, especially in acidic media.

While direct causality between fluoride exposure and implant failure has not been conclusively established in clinical studies largely due to the multifactorial nature of peri-implant diseases these results raise important considerations regarding the long-term effects of oral hygiene products in implant patients.

## DISCUSSION

The findings of the present study corroborate the existing literature by demonstrating that both acidity and the presence of fluoride are critical factors for the corrosion of the surface of titanium implants. The combination of fluoride with acidic pH favors the formation of soluble complexes such as $TiF_6^{2-}$, which degrade the $TiO_2$ layer and promote the release of metal particles (Reclaru & Meyer, 1998; Schiff et al., 2002). Interestingly, even at neutral pH, solutions with 1.23% and 5% NaF were able to induce particle release, confirming that fluoride, regardless of acidity, compromises the stability of the implant surface (Bhattarai et al., 2008).

However, acidity potentiates this effect, as observed in the greater release in APF pH 3.5. The cellular uptake of titanium nanoparticles by macrophages without membrane damage, but with increased expression of IL-1β and IL-8, highlights an active role of these cells in mediating the peri-implant inflammatory response. These cytokines are associated with osteoclastic activation and imbalance in bone homeostasis, contributing to failures in osseointegration (Eger et al., 2017; Pettersson et al., 2017). These results reinforce the importance of clinical awareness regarding the use of fluoride toothpastes in patients with dental implants, especially in contexts of acidic pH, such as acidic diets or conditions such as gastroesophageal reflux.

The literature indicates that the composition of the implant superstructure (ceramic, metallic or hybrid) also interacts with corrosion resistance in the presence of fluorides, as observed by Mareci et al. (2009). This evidence suggests that, in addition to the chemistry of the oral fluid, the topography and combined materials of the implant-abutment highlight the need for integrated strategies to prevent premature failure.

## CONCLUSION

Under the experimental design adopted, it was observed that fluoride, especially in an acidic environment, promotes the degradation of the surface of titanium dental implants, with consequent release of metal particles. The interaction of these particles with macrophages stimulates the expression of inflammatory mediators, implying osteoclastic activation and the risk of peri-implantitis. These findings provide mechanistic support for the hypothesis that fluoride may compromise the longevity of dental implants and suggest that the evaluation of the patient's clinical history and oral hygiene habits should consider the frequency and concentration of fluoride use. Longitudinal clinical studies are needed to consolidate this in vivo evidence.

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