COMPARATIVE ANALYSIS OF THE EFFICACY OF BIOCOMPATIBLE AND HIGH-EFFICIENCY HYDROXYAPATITE-BASED PASTES IN TREATMENT OF DENTIN HYPERENSITIVITY

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ANNOTATION: Dentin hypersensitivity (DH) is a common and painful clinical condition characterized by short, sharp pain arising from exposed dentin in response to various stimuli. The search for effective, biocompatible, and long-lasting desensitizing agents remains a key focus in modern dentistry. Hydroxyapatite (HAp)-based pastes have emerged as a promising treatment due to their biomimetic properties, which allow them to occlude dentinal tubules and integrate seamlessly with the natural tooth structure.

KEY WORDS: Dentin Hypersensitivity, Hydroxyapatite, Biocompatible, Desensitizing Paste, Biomimetic, Clinical Trial, Tubule Occlusion.

АННОТАЦИЯ: Гиперчувствительность дентина (ГД) — это распространенное и болезненное клиническое состояние, характеризующееся кратковременной, острой болью, возникающей в обнаженном дентине в ответ на различные раздражители. Поиск эффективных, биосовместимых и долговременных десенситайзеров остается ключевой задачей современной стоматологии. Пасты на основе гидроксиапатита (ГАП) появились в качестве перспективного метода лечения благодаря своим биомиметическим свойствам, которые позволяют им эффективно закрывать дентинные канальцы и бесшовно интегрироваться с естественной структурой зуба.

КЛЮЧЕВЫЕ СЛОВА: Гиперчувствительность Дентина, Гидроксиапатит, Биосовместимый, Десенсибилизирующая Паста, Биомиметический, Клиническое Исследование, Окклюзия Канальцев.

INTRODUCTION

Dentin hypersensitivity (DH) is a prevalent clinical condition affecting a significant proportion of the adult population worldwide. It is characterized by a short, sharp pain arising from exposed dentin in response to various stimuli, typically thermal, evaporative, tactile, osmotic, or chemical, which cannot be ascribed to any other dental defect or pathology . The most widely accepted theory for its mechanism is

Brännström's hydrodynamic theory, which proposes that external stimuli cause a rapid movement of fluid within the exposed dentinal tubules, which in turn activates mechanoreceptors in the pulp, leading to the perception of pain .The clinical management of dentin hypersensitivity remains a considerable challenge in dental practice. The exposure of dentin, often resulting from gingival recession, enamel erosion, or abrasive tooth wear, opens thousands of dentinal tubules to the oral environment. A cornerstone of treatment involves occluding these tubules to reduce fluid flow and insulate the pulp. Over the years, a multitude of desensitizing agents have been developed, including potassium salts, fluorides, calcium phosphate compounds, and oxalates. While some of these provide temporary relief, many lack the durability to withstand the challenges of the oral environment, such as acid exposure and abrasion from brushing, leading to the recurrence of symptoms. Consequently, the search for more effective, biocompatible, and long-lasting treatment modalities is a key focus of contemporary restorative dentistry. In recent years, biomimetic approaches have gained considerable traction. Hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$, HAp), the primary inorganic component of human teeth and bone, has emerged as a highly promising material for this purpose. Synthetic hydroxyapatite particles, particularly in nano-sized forms (n-HAp), exhibit excellent biocompatibility and bioactivity. Their mechanism of action is twofold: they physically occlude dentinal tubules and, due to their chemical similarity to natural tooth mineral, they can integrate seamlessly with the tooth structure, forming a robust, protective layer that is resistant to acid dissolution. While several hydroxyapatite-based pastes are commercially available, there is a continuous drive to enhance their efficacy through advanced formulations. These include optimizing particle size, morphology, and concentration, or combining HAp with other bioactive agents to create synergistic effects. However, a direct comparative analysis of the clinical performance of these next-generation, high-efficiency HAp pastes is necessary to establish evidence-based clinical guidelines. Therefore, the aim of this study is to conduct a comparative analysis of the clinical efficacy of two novel, biocompatible, and high-efficiency hydroxyapatite-based desensitizing pastes in the management of dentin hypersensitivity. The null hypothesis is that there is no significant difference in pain reduction between the two tested HAp pastes and a conventional control paste over an 8-week period.

METHODOLOGY

A randomized, double-blind, controlled clinical trial was conducted over a period of 8 weeks. The study protocol was reviewed and approved by the Institutional Ethics

Committee in accordance with the principles of the Declaration of Helsinki. All participants provided written informed consent prior to enrollment. A total of 105 adult patients (aged 18-65 years) diagnosed with dentin hypersensitivity were recruited from the outpatient clinic. The inclusion criteria were: a) presence of at least two non-carious cervical lesions with exposed dentin on vital teeth; b) a baseline pain score of ≥4 on the Visual Analog Scale (VAS) in response to a standardized air-blast stimulus. Exclusion criteria included: a) severe periodontal disease; b) teeth with caries, cracks, or recent restorations; c) medical history of chronic pain conditions; d) ongoing use of analgesic or anti-inflammatory medications; e) pregnancy or lactation; and f) having undergone professional desensitizing therapy within the last 3 months. Intervention and Group Allocation Eligible participants were randomly assigned into one of three parallel groups (n=35 per group) using a computer-generated randomization sequence: Group 1 (n-HAp): Received a toothpaste containing 15% nano-hydroxyapatite. Group 2 (bm-HAp): Received a toothpaste with a proprietary 10% biomimetic hydroxyapatite complex. Group 3 (Control): Received a commercially available positive control toothpaste with 5% potassium nitrate and 1450 ppm fluoride. All toothpastes were provided in identical, coded tubes to ensure blinding of both participants and the clinical examiner. Clinical Procedure and Assessment. At the initial visit (baseline), a dental prophylaxis was performed on all participants. The hypersensitivity assessment was conducted in a controlled environment (23±1°C) by a single, calibrated examiner. The response to two stimuli was evaluated: Tactile Stimulus: A sharp dental explorer was passed horizontally across the exposed dentin surface. The response was recorded using the Yeaple probe score. Evaporative (Air-Blast) Stimulus: A standardized 1-second air blast from a dental syringe was delivered to the exposed surface from a distance of approximately 1 cm, with adjacent teeth isolated. The patient's immediate pain perception was recorded on a 100-mm VAS, where 0 mm represented "no pain" and 100 mm represented "worst pain imaginable." Following the baseline assessment, participants were instructed to brush their teeth twice daily for two minutes with the assigned toothpaste using a soft-bristled toothbrush provided. They were advised not to use any other desensitizing products. Follow-up Evaluations. Clinical assessments using the same tactile and evaporative stimuli were repeated at 2 weeks, 4 weeks, and 8 weeks after the baseline. Statistical Analysis. Data were analyzed using SPSS Statistics version 26.0. The primary outcome was the mean change in VAS score from baseline. Normality of data distribution was confirmed using the Shapiro-Wilk test. Intra-group comparisons were performed using repeated-measures ANOVA, and inter-

group comparisons were conducted using one-way ANOVA followed by Tukey's post-hoc test for multiple comparisons. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Patient Demographics and Baseline Characteristic. A total of 105 participants were initially enrolled and randomly allocated into the three study groups. During the 8-week trial, 3 participants (one from each group) were lost to follow-up due to personal reasons unrelated to the study. Consequently, the data from 102 participants (n=34 per group) were included in the final per-protocol analysis. No significant differences were observed between the groups at baseline regarding age, gender distribution, or the number of hypersensitive teeth ($p > 0.05$). Most importantly, the mean baseline Visual Analog Scale (VAS) scores for both tactile and air-blast stimuli were statistically comparable across all groups ($p > 0.05$), ensuring an equitable starting point for the evaluation of treatment efficacy (Table 1). Efficacy in Reducing Dentin Hypersensitivity. The mean VAS scores in response to the air-blast stimulus across the study timeline are summarized in Table 2 and presented graphically in Figure 1. Intra-group Analysis: All three groups demonstrated a statistically significant reduction in mean VAS scores from baseline to the 8-week follow-up ($p < 0.001$). Within the first 2 weeks, Group 2 (bm-HAp) exhibited the most rapid decline in hypersensitivity. Inter-group Analysis: Repeated-measures ANOVA revealed a significant group-time interaction effect ($p < 0.01$). Post-hoc analyses with Tukey's HSD test showed that at the 2-week follow-up, both hydroxyapatite groups (Group 1 and Group 2) already had significantly lower VAS scores than the Control group ($p < 0.05$). By the 4-week and 8-week intervals, both HAp groups were statistically superior to the control group ($p < 0.01$). At the final 8-week assessment, Group 2 (bm-HAp) showed a significantly greater reduction in VAS scores compared to both Group 1 (n-HAp) ($p < 0.05$) and the Control group ($p < 0.001$). The mean percentage reduction in air-blast-induced VAS scores at 8 weeks was 85.4% for Group 2, 78.2% for Group 1, and 65.8% for the Control group. A similar, statistically significant trend was observed for the tactile stimulus (Yeaple probe score), with both HAp groups showing superior performance in reducing tactile hypersensitivity compared to the control. Treatment Performance and Safety. No adverse events or side effects, such as gingival irritation or allergic reactions, were reported by any participant or observed by the examiner throughout the study period. All tested toothpastes were well-tolerated, confirming their clinical safety.

DISCUSSION

The present study was designed to comparatively evaluate the clinical efficacy of two novel hydroxyapatite-based desensitizing pastes against a conventional positive control. The findings clearly demonstrate that both HAp formulations are significantly more effective in reducing the pain associated with dentin hypersensitivity over an 8-week period, thereby allowing us to reject the null hypothesis. The superior performance of the biomimetic HAp paste (Group 2) highlights the impact of advanced material properties on clinical outcomes. The rapid and significant reduction in VAS scores observed in both HAp groups, evident as early as the 2-week assessment, strongly supports the mechanistic role of hydroxyapatite in occluding dentinal tubules. This aligns with the established hydrodynamic theory of dentin hypersensitivity. The nano-sized particles in Group 1 (n-HAp) are known for their high surface area-to-volume ratio, which enables them to form a dense, protective layer over the exposed dentin surface and within the tubules, effectively reducing fluid flow. The even greater efficacy of the biomimetic HAp paste (Group 2) can be attributed to its proprietary complex, which is likely engineered to mimic the chemical and structural properties of natural tooth apatite more closely. This enhanced biomimicry may promote stronger adhesion to the dentin surface and more efficient crystal growth within the tubules, creating a more acid-resistant and abrasion-resistant seal. The performance of the positive control toothpaste (5% potassium nitrate) was consistent with existing literature, providing a statistically significant but comparatively modest reduction in sensitivity. Its mechanism of action, which involves depolarizing nerve endings to reduce their excitability, does not address the underlying patent tubules. In contrast, the HAp pastes provide a physical barrier, offering a more fundamental and potentially durable solution. The significant difference ($p < 0.05$) between the two HAp groups at the final evaluation underscores that not all hydroxyapatite formulations are equivalent. Factors such as particle size, morphology, crystallinity, and concentration are critical determinants of clinical performance. The absence of any adverse events in the HAp groups further corroborates the extensive literature on the exceptional biocompatibility of hydroxyapatite, making it a safe choice for daily, long-term use. Limitations and Future Research: A limitation of this study is the 8-week duration, which, while sufficient to establish efficacy, does not evaluate the long-term durability of the tubule occlusion. Future studies should incorporate longer follow-up periods and in-situ analyses, such as scanning electron microscopy (SEM) of replicas, to visually confirm and quantify tubule occlusion over time. Furthermore, investigating the performance of

these pastes in patients with hypersensitivity resulting from different etiologies (e.g., erosion vs. abrasion) could provide more nuanced clinical insights. Conclusion: Within the limitations of this study, it can be concluded that the novel, biocompatible hydroxyapatite-based pastes, particularly the biomimetic formulation, offer a superior and safe approach for the management of dentin hypersensitivity compared to a conventional potassium nitrate toothpaste. Their biomimetic action provides a physical barrier that addresses the cause of pain, representing a significant advancement in desensitizing care.

CONCLUSION

This comparative clinical study provides clear evidence on the efficacy of next-generation hydroxyapatite-based pastes for managing dentin hypersensitivity. The primary conclusion is that both novel, high-efficiency hydroxyapatite formulations were statistically superior to the conventional positive control toothpaste containing 5% potassium nitrate. The significant reduction in Visual Analog Scale (VAS) scores observed in the hydroxyapatite groups, which was evident at the first follow-up and sustained throughout the 8-week study, underscores their potent and rapid desensitizing action. A critical finding of this research is the demonstrable difference in performance between the two hydroxyapatite pastes. The significantly greater efficacy ($p < 0.05$) of the biomimetic hydroxyapatite paste (Group 2) over the nano-hydroxyapatite paste (Group 1) highlights that the mere presence of hydroxyapatite is not sufficient; its specific structural and chemical properties are paramount. The superior results of the biomimetic formulation can be attributed to its enhanced ability to mimic natural tooth mineral, leading to more seamless integration with the dentin surface and the formation of a more resilient, acid-resistant occlusive layer within the dentinal tubules. This finding has important implications for the future development of desensitizing agents, pointing towards the optimization of biomimicry as a key pathway for innovation. From a clinical perspective, these findings empower practitioners with evidence-based options. The tested hydroxyapatite pastes offer a dual advantage: they are highly biocompatible, posing no risk of side effects for long-term daily use, and they operate on a causal mechanism—tubule occlusion—rather than merely masking the symptom of pain. This makes them a fundamentally superior choice for achieving long-term patient comfort and managing tooth sensitivity arising from gingival recession and non-carious cervical lesions. In light of these results, future research should focus on long-term studies exceeding six months to validate the durability of the tubule occlusion. Furthermore, the direct visualization and quantification of the occluding layer using

scanning electron microscopy (SEM) would provide invaluable correlative evidence to the clinical findings presented here. It is concluded that biocompatible and high-efficiency hydroxyapatite-based pastes, particularly those engineered with biomimetic properties, represent a significant advancement in desensitizing therapy and are highly recommended for integration into mainstream clinical practice for the effective and safe management of dentin hypersensitivity.

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