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IMPACT OF ORAL HYGIENE PRODUCTS ON THE ORAL MICROBIOME AND SUSCEPTIBILITY TO THRUSH: A NARRATIVE REVIEW

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ARTICLE INFO	ABSTRACT
Keywords: Oral hygiene products, Periodontal disorders, Oral microbiome, Microbial diversity **Corresponding Author: Dr Hafiz Muhammad Bin Tahir Khan,** BDS, Dental College HITEC Institute of Medical Sciences Taxila CANTT, Email: mbt100000@gmail.com	By managing periodontal disorders, avoiding tooth cavities, and reducing bacterial loads, oral hygiene products are essential for preserving oral health. But there are concerns about how they may affect the delicate balance of the oral microbiome, which is a complex ecology of bacteria, fungus, and other microorganisms. The oral microbiota is essential for preserving homeostasis, promoting healthy digestion, and averting infections. Opportunistic infections, especially Candida albicans, the main cause of oral thrush, can proliferate as a result of disruptions brought on by dietary changes, antibiotics, or oral hygiene products. White lesions, inflammation, and discomfort are the hallmarks of thrush, which is most prevalent in immunocompromised people, the elderly, and newborns. This narrative review examines the connection between microbiome dynamics and oral hygiene products, with a particular emphasis on how these factors affect thrush susceptibility. While alcohol, chlorhexidine, and triclosan are efficient against dangerous bacteria, they can also accidentally diminish microbial diversity, which can lead to an overgrowth of Candida. On the other hand, substitutes like xylitol, essential oils, probiotics, and prebiotics exhibit microbiome-friendly qualities, specifically focusing on pathogenic microorganisms while maintaining microbial stability. There is also discussion of disruption mechanisms such pH change, reduced bacterial competition, and enhanced fungal adhesion. The study highlights the need of balanced dental hygiene habits, especially for vulnerable groups, and promotes the use of products that support the microbiome and less disruptive agents. Thrush and other fungal infections can be prevented by using these tactics to support microbial balance. Subsequent investigations ought to concentrate on the enduring consequences of oral hygiene products and novel formulations that maintain microbiome diversity and oral health.

INTRODUCTION

Oral hygiene products are vital for maintaining oral health because they reduce bacterial load, prevent tooth cavities, and treat gum disease.(1–3) However, since new research emphasizes the importance of microbial variety in infection prevention, the impact of these products on the delicate balance of the oral microbiome has lately been scrutinized.(2,4) The oral microbiome, a diverse community of bacteria, fungi, and other microorganisms, maintains the homeostasis of the mouth cavity in addition to aiding digestion and providing infection defense.(5,6) When this balance is disrupted, opportunistic infections such as *Candida albicans* can overgrow, causing oral thrush and other illnesses. (7–9)

Oral thrush, characterised by white spots, pain, and inflammation, is often associated with immunocompromised individuals, the elderly, and neonates.(8,10–12) However, it has been shown that some ingredients included in dental hygiene products, such as alcohol, chlorhexidine, and other antimicrobial agents, may upset the microbiota, leaving patients more susceptible to Candida overgrowth.(8,13,14) Since dental and medical professionals are increasingly advocating oral hygiene products, it is critical to understand the potential unintended repercussions of these products on the microbiome in order to prevent opportunistic infections.(15,16)

The investigation of the relationship between oral thrush susceptibility and different oral hygiene products is done in this review, which signifies how particular chemicals can change the dynamics of microbes in the oral cavity. This review provide information on how these products affect the oral microbiome also underline the value of maintaining a balanced oral hygiene routine and also offer suggestions for product usage that reduces the risk of infection while promoting microbiome health.

Oral Microbiome and Its Role in Health and Disease

Overview of the Oral Microbiome

The oral microbiome is a sustainable ecosystem that is home to a large number of microorganisms, including bacteria, fungi, viruses, and protozoa.(1,4) The oral and systematic health is supported by the essential functions of this complex microbial ecology.(14,17) By controlling pH, competitively excluding pathogens, and producing antimicrobial compounds, beneficial bacteria such as *Lactobacillus* species and *Streptococcus salivarius* provide protective functions.(18–23) These organisms work together to avoid infection, preserve the integrity of oral tissues, and establish a balanced condition known as microbial homeostasis.(22–24)

The delicate balance between potentially harmful and beneficial organisms in the oral cavity can be upset by a number of factors, including food, the use of antibiotics, and personal cleanliness habits.(6,25,26) The proliferation of opportunistic diseases can occur when helpful microorganisms are diminished. Specifically, when allowed to overgrow, the oral microbiome's fungal component—which is primarily represented by *Candida* species—can become troublesome.(7,17,27) Therefore, maintaining an environment where beneficial species flourish and successfully controlling pathogenic ones depends on the integrity of the oral microbiome.

Oral Thrush and *Candida* Species

Although other *Candida* species, like *C. glabrata* and *C. tropicalis*, may potentially be involved, *Candida albicans* is the main fungus species linked to oral thrush.(8,10,28) These fungi typically live innocuously with other microbes in the mouth cavity in tiny numbers. Candida's transformation from a benign, commensal organism to an invasive infection when the microbial balance is upset can also to formation of in Oral thrush.(3,29,30) White spots, redness, discomfort, and occasionally bleeding are the trademarks of this infection, which is particularly common in immunocompromised people, the elderly, and small children.(16,31–33)

Numerous variables, such as pH shifts, decreased salivary flow, weakened immunity, and microbial imbalances, contribute to Candida's transformation from a benign commensal to a pathogen.(24,27,34,35) By lowering bacterial populations and unintentionally fostering an environment that is conducive to *Candida* overgrowth, several oral hygiene products that include strong antimicrobial drugs may exacerbate this imbalance.(23,35–39) This change put focus on the significance of preserving microbial balance in order to avoid fungal illnesses such as oral thrush and shows the fine interactions within the oral microbiome.(10,16,39)

Microbiome Stability and Susceptibility to Infections

A stable oral microbiota is important for the body's first line of defense against pathogens.(1,31,40–42) By generating compounds that inhibit harmful organisms, promoting immunological modulation, and establishing a competitive environment that restricts the proliferation of pathogens, beneficial bacteria in the oral cavity aid in maintaining this stability.(12,43–45) Lactic acid, for example, is produced by some beneficial bacteria and lowers pH, making it less conducive to the growth of pathogenic microorganisms.(26,46)

However, the oral cavity is more prone to infections when stability is compromised. The use of antibiotics, dietary modifications, and even the regular use of some dental hygiene products can all throw off the microbial balance, which lowers the number of good bacteria and makes room for harmful organisms like *Candida*.(6,47–49) Because *Candida* species can take benefit of the lack of bacterial competition to establish themselves more aggressively within the oral cavity, such imbalances frequently leads to fungal overgrowth.(40,48–50)

Impact of Oral Hygiene Products on the Oral Microbiome

Types of Oral Hygiene Products

Proper use of oral hygiene products is important for maintaining cleanliness and avoiding dental problems like cavities and gum disease. The combination of active substances like xylitol, alcohol, chlorhexidine, essential oils, and fluoride are frequently present in products like Toothpaste, mouthwashes, and oral rinses.(51–53) Each of these elements has a different purpose, but they may also have an effect on the equilibrium and assembly of the oral microbiome. Well-known antibacterial components like alcohol and chlorhexidine, are efficient against bacteria that cause plaque but may be detrimental to the richness of the microbiome.(54–57) Essential oils are well known for their antibacterial and anti-inflammatory qualities and they are also present in natural or medicinal goods in frequent amount, which can help lower the bacterial load as well as compromise microbial stability. Fluoride which is a common ingredient in dental care products, is known for its ability to prevent cavities, while xylitol has antibacterial qualities which have ability to lower bacterial levels without seriously upsetting fungal species.(58–60)

It is crucial to understand how these components affect the oral microbiome since some products may unintentionally upset the fine balance between harmful and helpful organisms. The processes described below show how these products can upset the balance of micro-organisms, that might lead to the growth of opportunistic diseases like *Candida*.

Mechanisms of Disruption

1. **Antibacterial Agents**

   Alcohols are frequently found in oral hygiene products due to their potent antibacterial qualities, antibacterial compounds, along with triclosan, and chlorhexidine.(51–53,61,62) For instance, certain toothpastes contain triclosan because it can prevent gingivitis and plaque by attacking the membranes of bacteria. Nevertheless, triclosan and related substances eradicate beneficial bacterial populations that are essential for preserving microbial balance even though they are successful in decreasing dangerous bacteria.(53,58,61,62) It has been demonstrated that the broad-spectrum antibiotic chlorhexidine, which is present in many mouthwashes, dramatically lowers the number of germs in the oral cavity.(61,63,64) While this can help manage periodontal disease, it can also lead to an imbalance by eliminating bacterial rivals, which gives Candida species a chance to proliferate. Another powerful antibacterial, alcohol, is frequently found in mouthwashes to eradicate bacteria.(65,66) However, because of its broad-spectrum effects, alcohol can also decrease microbial diversity, which may allow Candida to grow in an environment where there are less bacterial inhibitors.(65–67)

2. **pH Alteration**

   The PH of mouth can be changed by the growth dynamics of the oral microbiome which is greatly impacted by oral hygiene products.(68–70) The stability of both bacterial and fungal populations is supported by a balanced oral pH, which is normally between 6.7 and 7.3.(35,71,72) However, goods that include a lot of alcohol or some acidic substances can lower the pH of the oral cavity, which makes it easier for Candida to develop.(34,68) Because bacterial populations are less competitive in acidic conditions, Candida species are known to flourish there. On the other hand, some items have the potential to increase pH to a point where microbial equilibrium is upset, which also creates an environment that is conducive to fungal development.(68,69) In addition to upsetting the natural equilibrium, this pH change may also favor pathogenic organisms like Candida that are tolerant of high pH, making people more vulnerable to oral thrush.

3. **Fluoride and Xylitol**

   Because it strengthens enamel and prevents cavities, fluoride is a well-known component of oral care products. Its advantages are well known, especially in terms of lowering dental decay.(51–53,60–62,73) However, fluoride has very little effect on fungus like *Candida* and its antimicrobial activities are mostly directed against cariogenic bacteria like *Streptococcus mutans*.(57,74,75) As a result, although while fluoride is usually seen as safe and beneficial for oral health, its selective action against bacteria may leave *Candida* species unharmed, especially when paired with other substances that alter the microbiome.(57,74)

Another unusual interaction with the microbiome is offered by xylitol, a sugar alcohol that is frequently added to oral care products. Through its bacteriostatic action, which stops bacteria from metabolizing it and generating acids, xylitol has been demonstrated to lower bacterial levels, particularly *Streptococcus mutans*.(57,75) Xylitol has not been demonstrated to have a major effect on fungal populations and is less likely to dramatically upset the microbial balance than fluoride and conventional antibacterial agents.(47,51,76,77) To fully understand its long-term effects more research is required on both bacterial and fungal species within the oral cavity, its selective antimicrobial action makes it a sort of microbiome-friendly choice.

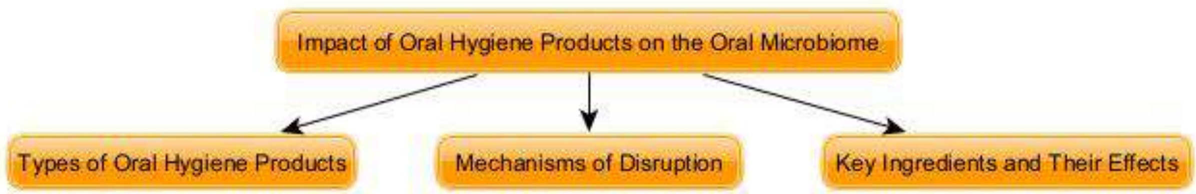

Figure 1"Conceptual Framework: Examining the Impact of Oral Hygiene Products on the Oral Microbiome through Product Types, Mechanisms of Disruption, and Key Ingredients."

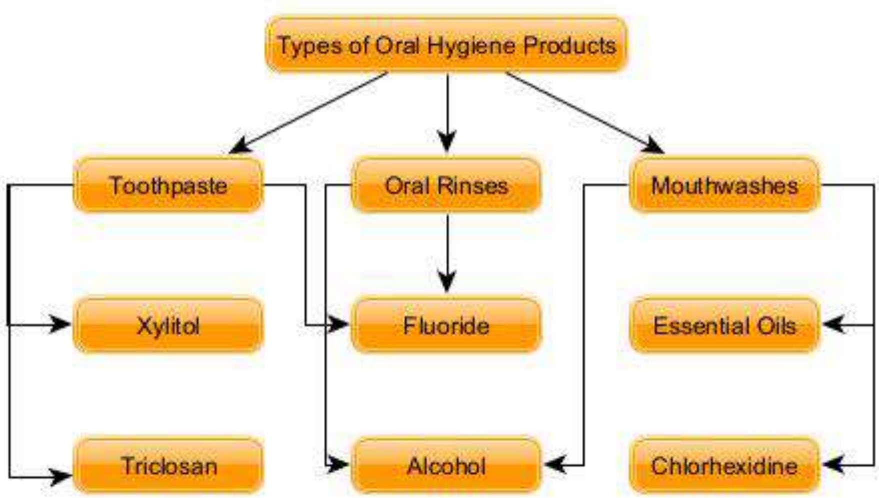

Figure 2 "Overview of oral hygiene products categorized by their active ingredients, including toothpaste, oral rinses, and mouthwashes."

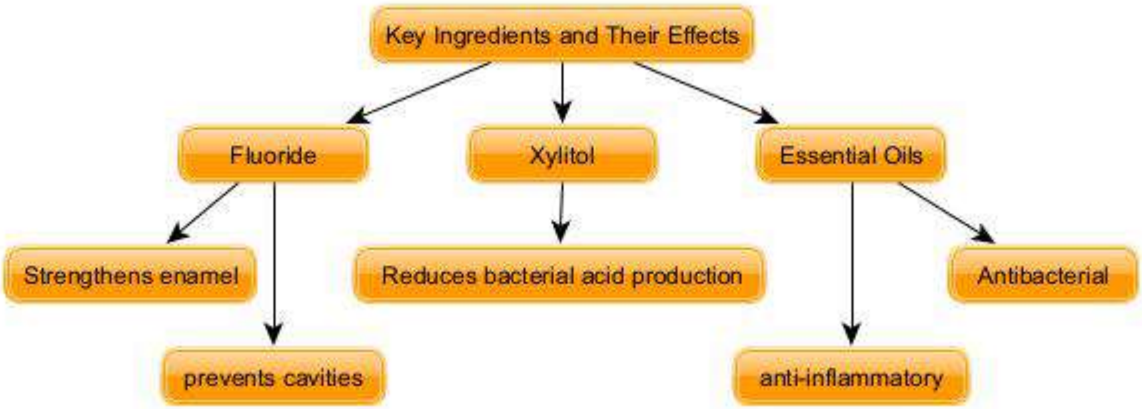

Figure 2"Key Ingredients in Oral Hygiene Products and Their Effects: A Breakdown of Fluoride, Xylitol, and Essential Oils on Oral Health."

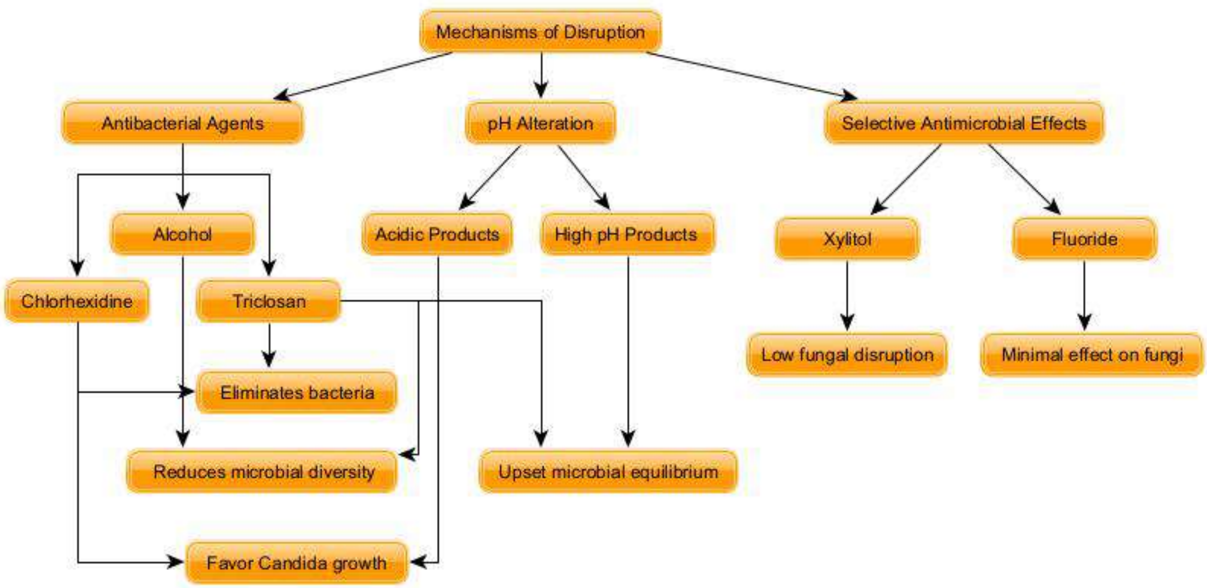

Figure 4 "Mechanisms by which oral hygiene products alter the oral microbiome, including antibacterial agents, pH changes, and selective antimicrobial effects."

Relationship Between Specific Ingredients and Susceptibility to Thrush

Alcohol-Based Mouthwashes

Alcohol based mouthwashes are commonly utilized because of their broad antibacterial impact and can target a variety of bacteria that cause gum disease and dental plaque. Bacterial cell walls are denaturated by alcohol, usually ethanol, which causes the bacteria to die quickly(78) But this potent antibacterial action can also affect good bacteria, upsetting the mouth cavity's natural microbial equilibrium.(67) Alcohol-based mouthwashes have been found to decrease bacterial diversity, which unintentionally fosters an environment that is conducive to the growth of *Candida* species, which prefer less competitive environments.(79) Alcohol can also dry up the mouth's mucosal surfaces, which could jeopardize the salivary film's ability to protect the microbial balance.(66,80) Regular use of alcohol-based mouthwashes is linked to an increased risk of oral thrush, particularly in users with compromised immune systems or pre-existing microbial imbalances, as a result of the dryness and bacterial depletion that foster *Candida* overgrowth.(81)

Chlorhexidine

Often used to treat periodontal disorders, chlorhexidine is a potent antiseptic that is found in many mouthwashes and is very effective at killing bacterial infections.(55,82) The diversity of bacteria in the oral cavity is significantly reduced as a result of its broad-spectrum antibacterial activity, which does not distinguish between good and dangerous bacteria.(54,83) According to studies, mouthwash containing chlorhexidine can change the composition of the microbiome by lowering bacterial populations that are essential for competitive exclusion, which inhibits the growth of fungi.(54) Additionally, studies indicate that chlorhexidine may have a direct effect on Candida species, occasionally increasing Candida adhesion to oral surfaces through changes in mucosal environment and mucosal proteins.(84,85) Candida may more easily colonize as a result of less bacterial competition and improved adherence, which increases vulnerability to thrush.(46,86) Although chlorhexidine is useful in treating some bacterial infections, its unexpected impact of encouraging *Candida* overgrowth emphasizes the need for cautious, brief use.(64,87)

Essential Oils

Because of their antibacterial, anti-inflammatory, and therapeutic qualities, essential oils including tea tree, eucalyptus, and clove are included to some mouthwashes.(88,89) By targeting bacteria through less disruptive processes to the entire diversity of microorganisms, these oils frequently function as a more natural substitute for alcohol and chlorhexidine.(90,91) For instance, compared to mouthwashes that contain alcohol or chlorhexidine, tea tree oil has broad-spectrum antibacterial activity but is less likely to significantly change the oral microbiome.(88,92) In addition to its well-known antifungal qualities, eucalyptus oil may also directly limit the growth of Candida, which could lower the risk of thrush.(93,94) However, depending on formulation and dose, essential oils have a variety of complex impacts on the microbiome.(95) High doses of essential oils have the potential to upset microbial equilibrium, even if they may promote a balanced mouth environment when utilized in moderation.(95) Therefore, the cautious usage of essential oils for regular oral hygiene may workout for their potential effectiveness in lowering the risk of thrush.(96)

Probiotics and Prebiotic-Based Products

The use of probiotics and prebiotics is a viable strategy for preserving a healthy oral microbiome without running the risk of upsetting the microbial balance.(97,98) While prebiotics operate as nutrients that promote the growth of helpful microbes already present in the mouth, probiotics provide beneficial bacteria that have the ability to outcompete pathogens.(50) According to studies, certain probiotic bacteria, like Bifidobacterium lactis and Lactobacillus rhamnosus, can prevent Candida colonization by generating antimicrobial chemicals and competing for attachment sites.(48,49) By preventing Candida from taking control, this competitive exclusion process lowers the incidence of oral thrush.(99,100) A healthy microbiome can also be supported by prebiotic components such as fructooligosaccharides and inulin, which selectively feed beneficial bacteria, encourage microbial diversity, and create an environment that is less favorable to fungal overgrowth.(101,102) Using probiotic and prebiotic-based products presents a viable and microbiome-friendly method of dental hygiene which also lessen thrush susceptibility while fostering long-term oral health.

Table 1: Relationship Between Specific Ingredients and Susceptibility to Thrush

Ingredient	Effect on Oral Microbiome	Impact on Candida and Thrush	Recommendation
Alcohol-Based Mouthwashes	Broad antibacterial effect, but reduces bacterial diversity by targeting both harmful and beneficial bacteria. Alcohol can dry the mucosal surfaces.	Increased risk of Candida overgrowth due to decreased bacterial competition and dry mouth environment. Particularly risky for those with weakened immune systems.	Use cautiously, especially for individuals with compromised immunity.
Chlorhexidine	Strong antibacterial action but reduces overall bacterial diversity, including beneficial bacteria essential for competitive exclusion.	May increase Candida adhesion to oral surfaces and promote Candida colonization, leading to thrush.	Caution is advised. Use for short periods, as it may encourage Candida growth.
Essential Oils (e.g., Tea Tree, Eucalyptus, Clove)	Antibacterial and anti-inflammatory properties with less disruptive effects on microbial diversity compared to alcohol and chlorhexidine.	Eucalyptus oil may directly limit Candida growth, while tea tree oil supports a balanced microbiome. However, high doses may disrupt the microbial balance.	Use in moderation to avoid imbalance; can reduce thrush risk if used carefully.
Probiotics and Prebiotics	Probiotics provide beneficial bacteria, while prebiotics support growth of beneficial microbes. They promote microbial diversity and create an environment less favorable to fungi.	Certain probiotics like *Bifidobacterium lactis* and *Lactobacillus rhamnosus* compete with Candida for attachment sites, preventing its colonization and reducing thrush risk.	Probiotic and prebiotic products are a microbiome-friendly and effective method for reducing thrush susceptibility.

Preventive Strategies and Best Practice

Balanced Product Use

Oral hygiene solutions that sustain a balance between micro biome preservation and effectiveness which is crucial for maintaining oral health while balancing micro biome stability.(103) The products that reduce or eliminate strong antimicrobials like alcohol and high-concentration chlorhexidine safeguard the good bacteria, that serve as the body's initial line of defense against infections.(103) People might use low-alcohol mouthwashes and moderate, fluoride-based toothpastes for everyday usage to maintain cleanliness without upsetting the microbial community.(103) Another useful tactic to prevent needless microbial disruption is to restrict the use of chlorhexidine and other strong antimicrobials to brief periods of time or as directed by a medical practitioner.(103) The promotion of a healthy oral environment through balanced product use lowers the risk of microbial imbalances and opportunistic diseases such as thrush.(79)

Alternative Ingredients and Innovations

In order to preserve the diversity of the microbiome, oral hygiene solutions have changed in recent years to incorporate softer substances and creative formulas.(52) For instance, xylitol-containing products have become more well-liked due to their capacity to suppress dangerous bacteria without appreciably altering beneficial populations.(76) Xylitol is a microbiome-friendly substitute for harsher chemicals since it can inhibit the growth of bacteria that cause plaque while mostly ignoring fungal populations.(76) Furthermore, products that contain moderate amounts of essential oils—like tea tree, eucalyptus, and clove oils—offer antibacterial properties without the wide-ranging effects of conventional antimicrobials.(104)

A noteworthy development in dental care is the use of probiotic and prebiotic-based products, which maintain microbial balance by supplying nutrients and good bacteria that promote a healthy microbiome.(50) Probiotic compositions containing Bifidobacterium and Lactobacillus strains have demonstrated the ability to compete with Candida and other harmful organisms.(105,106) Inulin and other prebiotic components promote the growth of good bacteria and make the environment less vulnerable to fungal overgrowth.(105,106) Adopting these substitute substances can be a proactive strategy to preserve the natural bacteria ecosystem and preserve dental health.(105,106)

Guidelines for At-Risk Populations

Elderly patients, people with weakened immune systems, or people on corticosteroids or antibiotics these are the people who are more susceptible to oral thrush, for these people specific oral hygiene measures can help lower the risk of microbial imbalance.(107) These people should steer clear of frequent usage of mouthwashes that contain alcohol or chlorhexidine and instead favor products that are kind to the microbiome.(67) Low-alcohol or alcohol-free rinses and fluoride-based toothpastes with modest antibacterial properties can provide good hygiene without causing undue microbial disruption.(67,79)

At risk groups may find it helpful to include probiotic or prebiotic oral care products in their daily routine to prevent fungal overgrowth and support beneficial bacteria.(50) Gently Brushing and flossing should be done as part of daily oral hygiene activities to maintain cleanliness without trading-off the microbial diversity.(50) Expert advice can assist people in customizing their oral hygiene routine therefore frequent dental examination is important to target certain risk factors, guaranteeing that microbiome health and hygiene are successfully maintained.(50)

Conclusion

Summary of Findings

The inseparable connection between oral hygiene products and the oral microbiome is highlighted in this narrative overview, this review also signifies how these products may affect an individual's susceptibility to oral thrush. Although these oral hygiene products are excellent in reducing dangerous bacteria, alcohol-based mouthwashes, chlorhexidine, and other essential oils can upset the delicate microbial balance in the mouth, which can lead to the formation of Candida. On the other hand products with softer components, like as probiotics, fluoride, and xylitol, seem to promote a balanced microbiota and are less likely to promote fungal dominance. This research highlights the importance of carefully choosing oral hygiene solutions, that preserve hygiene while reducing microbial disruption this solution is particularly for at-risk groups.

Future Directions

More investigation is required to study the correlation of various hygiene products with oral thrush and their long term effect on microbiome. Future research should concentrate on how regular antimicrobial agent usage may eventually lead to microbial imbalances and understanding their long term effect. Furthermore, studies on the efficacy and safety of replaceable components, such as probiotics and prebiotics, may offer important new perspectives on how to maintain microbiome diversity while promoting dental health. It would make it possible to more accurately customize product suggestions by looking into how individual differences, such as immunological state, age, and dietary habits, affect and how the microbiome reacts to oral hygiene products.

Clinical Implications

These findings underline the importance of dentists teaching their patients proper dental hygiene habits. It is feasible to avoid microbiome disruption and reduce the risk of illnesses such as oral thrush by advising patients not to overuse powerful antibiotics and promote the use of microbiome-friendly items. Practitioners can make a notable contribution to preserving not only oral hygiene but also the wellbeing of the oral microbial environment by providing customized suggestions based on each patient's particular requirements and risk factors. This would prevent opportunistic infections and will promot long-term dental health require this strategy.

Authors Contribution

1. **Dr Hafiz Muhammad Bin Tahir Khan**
   Author contribution: Conceptualization, study design, manuscript drafting, reviewing, editing, supervision, final approval, accountability
2. **Dr. M Omer Nasir Idrees**
   Author contribution: Drafting, study design, manuscript writing, proofreading, critical revisions, final approval, accountability
3. **Dr. Sarah Irfan**
   Author contribution: Drafting, writing significant sections of the manuscript, critical revisions, consistency check, final approval, accountability
4. **Dr. Hamna Rehman Chishti**
   Author contribution: Drafting, writing significant sections of the manuscript, critical revisions, consistency check, final approval, accountability

5. **Dr. Rameesha Tayyab**
   Author contribution: Conclusion writing, proofreading, manuscript preparation, critical revisions, final approval, accountability
6. **Dr. Nimra Naz Alam**
   Author contribution: Drafting, writing significant sections of the manuscript, proofreading, reviewing, critical revisions, final approval, accountability

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