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The journal invites manuscripts from dental and other allied health sciences. It publishes manuscripts under categories of Original Research, Review and Case Reports.

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PRESIDENT'S MESSAGE

Dear Members,

It gives me immense pleasure to present Volume 8, Issue 2 of JIDAK, the official scientific journal of the Indian Dental Association, Kochi Branch.

A scientific journal is much more than a collection of articles, it is a reflection of the academic strength, clinical excellence, and intellectual spirit of our fraternity. Through JIDAK, we continue to foster a culture of learning, evidence-based practice, and the dissemination of quality scientific knowledge among dental professionals.

I extend my heartfelt congratulations and appreciation to our dedicated Editorial Team for their tireless efforts, commitment, and meticulous work in bringing out yet another excellent issue. My sincere gratitude also goes to all the contributors, authors, reviewers, and academicians whose valuable submissions enrich this journal and make it a meaningful academic resource.

As dentistry continues to evolve rapidly, platforms such as JIDAK play a pivotal role in keeping us updated, inspiring research, and encouraging the exchange of innovative ideas and clinical experiences. The continued success of this journal stands as a testament to our branch's commitment towards promoting quality education and lifelong professional development.

I encourage all our members to make the most of this issue, enjoy an enriching read, and actively contribute to future editions with their research, case reports, and scientific insights. Together, let us continue to strengthen the academic legacy of IDA Kochi and uphold the highest standards of dental education and scientific excellence.

Wishing JIDAK many more milestones in its journey of knowledge sharing and academic advancement.

Dr. Meera Gopalakrishnan
President, IDA Kochi

SECRETARY'S MESSAGE

Dear Members,

It gives me immense pleasure to extend my warm greetings to the editorial team of the Journal of the Indian Dental Association, Kochi Branch, on the release of this edition. I extend my sincere appreciation to Dr. Pooja Latti, Chief Editor, whose vision and unwavering commitment have been instrumental in timely publication of our journal. My congratulations also go to Dr. Surya Suprabhan, Assistant Editor, and the entire team for their meticulous efforts in bringing together scholarly work that reflects both scientific flavor and clinical relevance.

In an era where dentistry is evolving at an unprecedented pace, the Indian Dental Association continues to remain the trusted voice of the profession. Through advocacy, continuing professional development, ethical guidance, and support for practitioners, the Association plays a pivotal role in strengthening dental practice across the country. Likewise, this journal remains an invaluable resource for our members by bridging research with clinical practice, encouraging evidence-based decision-making, and providing a platform for the exchange of ideas, innovations, and experiences that enhance patient care.

May the Journal continue to serve as a beacon of knowledge and a source of inspiration for dental professionals across our community.

Dr. Vivek Narayan
Hon. Secretary, IDA Kochi Branch

CHIEF EDITOR'S MESSAGE

It gives me immense pleasure to welcome you to the second issue of the Journal of the Indian Dental Association, Kochi Branch for the period April–July.

In keeping with the spirit of continuous learning and scientific advancement, this issue presents a diverse collection of scholarly contributions that reflect both emerging trends and evolving technologies in dentistry.

Our original research article explores Google Trends Analysis of Oral and Perioral Piercings, Tooth Jewellery, and Oral Tattoos in India. As social media and digital platforms increasingly influence patient choices, understanding these trends can help dental professionals anticipate patient concerns and provide evidence-based guidance.

The review section features a range of thought-provoking topics. An article on Robotics in Dentistry examines how automation and intelligent systems are reshaping clinical practice, enhancing precision, and opening new frontiers in patient care. Another review discusses the intricate relationship between Hormones and Oral Health, highlighting the impact of hormonal fluctuations across different life stages and their relevance to oral disease management. Readers will also find an informative update on Toothbrushes, tracing their evolution and examining current innovations that contribute to effective oral hygiene. Additionally, the review on Digital Pathology in Oral Diagnosis provides a comprehensive overview of how digital technologies are transforming diagnostic workflows, improving efficiency, and supporting precision healthcare.

Complementing these academic discussions is a clinically significant case report on Herpes Zoster Affecting the Trigeminal Nerve, which underscores the importance of timely diagnosis and multidisciplinary management in preventing complications and ensuring optimal patient outcomes.

The articles presented in this issue exemplify this commitment and contribute meaningfully to the advancement of dental knowledge and practice.

I extend my sincere appreciation to all authors, reviewers, editorial board members, and contributors whose dedication and expertise have made this publication possible. I also thank our readers for their continued support and engagement with the journal.

I hope this issue proves informative, inspiring, and beneficial in your academic and clinical pursuits.

Happy reading!

Dr. Pooja Latti
Chief Editor, JIDAK

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EDITORIAL

NAVIGATING THE DIGITAL DIVIDE - EDUCATIONAL AWARENESS VS. UNETHICAL ADVERTISING

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Dental practice in Kerala and particularly in a health-conscious hub like Kochi has changed dramatically over the last two decades. Gone are the days when a practice grew solely because of word-of-mouth referrals and generational family loyalty. Today, most patients learn about dental care through their smartphones. Before they step into a clinic, they have likely scrolled through Instagram, watched YouTube shorts, or read Google reviews. In this fast-moving digital age, having an online presence is no longer optional for practice growth. However, this shift has brought **a major professional challenge: Where do we draw the line between honest patient awareness and unethical advertising?**

As members of the Indian Dental Association (IDA) Kochi Branch, we must talk openly about this issue. We need to understand the regulations, clear up common misconceptions, and protect ourselves from serious medico-legal risks.

The Reality of Modern Dental Practice

Starting and running a dental practice today is tough. There is a high concentration of skilled dental surgeons. Rising setup costs, expensive technology, high clinic rents, and intense competition put immense financial pressure on both young practitioners and established clinics. In this environment, wanting to be visible is completely natural. Patients are actively looking for information online, and if ethical dentists remain silent, the void is rapidly filled by corporate chains, unregulated aligner companies, and sometimes, practitioners who prioritize profit over protocol.

Therefore, having a digital presence is not inherently unethical. Creating awareness about oral health, explaining complex procedures, and demystifying dental anxiety are noble endeavors that serve the public interest. The ethical breach occurs not in the medium of communication, but in its message and intent.

The Anchor: DCI's 2014 Code of Ethics

To find our bearings, we must return to our regulatory anchor. The DCI Revised Dentists (Code of Ethics) Regulations, 2014[1], provides an unequivocal framework regarding how a dentist may present themselves to the public.

Under Chapter 6 ("Unethical Acts"), Section 6.1 explicitly states that **a dentist shall not solicit patients directly or indirectly**[1]. The regulations strictly ban using advertisements in newspapers, leaflets, TV, or social media to invite personal attention, claim superiority over colleagues, or advertise specific treatments.

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The guideline allows simple, factual public notices in only a few situations:

- Opening a new clinic.
- Changing clinic location or address.
- Resuming practice after a long absence.
- Changing the type of practice.

The core principle of the 2014 guidelines is simple: Healthcare is a trust-based relationship, not a retail business. When we treat dental treatments like discounted items on a shopping site, we lower the dignity of our profession. As we step into the era where the National Dental Commission[2] replaces the erstwhile Dental Council of India, we can rest assured that these core principles will remain the same.

Awareness vs. Advertising: Understanding the Difference

How do you know if your social media video is ethical education or illegal advertising? Ask yourself one question: Who gets the primary benefit from this video?

- **Awareness benefits the patient.** It gives the public unbiased information so they can make healthy decisions.
- **Advertising benefits the dentist.** It focuses on pulling patients into a specific clinic using claims, discounts, or hype.

Simple Rule of Thumb:

Ethical: A video explaining how clear aligners gently move teeth, discussing the importance of compliance, and advising patients to consult a qualified dentist/ orthodontist for expert guidance.

Unethical: A video stating, "Get your perfect smile in 3 months! Book now for 50% off your aligner scan. Offer valid only for the first 10 patients!"

The Slippery Slope of Unethical Practices

Unfortunately, driven by the pressure to stand out, some practitioners resort to blatant retail marketing tactics[3,4]. Some of these practices[5,6] outlined below not only violate the DCI Code of Ethics but also cheapen the entire profession in the eyes of the public.

1. **Announcing Discounts and "Freebies"** Offering "Festive Discounts," "Monsoon Offers on Scaling," or "Buy One Get One Free" bleaching treatments treats medical procedures like consumer goods. Healthcare pricing should be based on the cost of materials, the time invested, and the skill of the operator none of which go on "sale" during a holiday. Furthermore, advertising "Free Consultations" with the hidden

Comparing Ethical Awareness and Unethical Advertising

FEATURE	ETHICAL PATIENT AWARENESS	UNETHICAL ADVERTISING
MAIN FOCUS	Disease, prevention, and general treatment options.	The dentist's awards, clinic luxury, or self proclaimed fame.
PROMISES	Realistic outcomes and potential risks.	Absolute claims (e.g., "100% Painless," "Lifetime Guarantee").
FINANCIAL TACTICS	Standard, transparent fee discussion in person.	Public discounts, "Free Consultations," or holiday offers.
TONE	Professional, factual, and informative.	High-pressure sales, dramatic music, and theatrical claims.

intent of upselling expensive treatments is a deceptive practice that betrays patient trust.

2. **Before-and-After Manipulation** While clinical photographs are vital for documentation and case discussions among peers, their use in public marketing is fraught with ethical peril. Posting before-and-after photos without explicit, written, and informed consent from the patient is a gross violation of patient confidentiality. Furthermore, using deceptive lighting, favorable angles, or digital editing tools to enhance the "after" photo is fraudulent.
3. **Self-Aggrandizement and Comparative Claims** Claiming to be a "Pioneer," "World-Renowned," or "The Only Expert in Town" is grossly unethical. Denigrating colleagues or claiming exclusive mastery over a standard dental procedure is explicitly prohibited by DCI guidelines.
4. **Organizing a "Free Dental Screening Camp"** directly under the commercial banner of a private clinic is widely recognized by regulatory bodies as a disguised lead-generation tool. When a clinic uses a camp to distribute promotional flyers, hand out discount vouchers, or lure patients back to their private operatory, it crosses the line into direct commercial solicitation a clear ethical breach.

The Medico-Legal Trap of Over-Promising

Unethical advertising does more than harm your reputation it exposes you to severe legal trouble under consumer and civil law. Under medical law, a doctor is judged by the 'Bolam Standard'. This principle states that a dentist is not negligent if they perform treatment with the ordinary skill and care expected of a reasonable professional[7]. The law accepts that biological complications can happen even with the best care. However, when someone advertises claims like "100% Success Rate," "Permanent Fix," or "Guaranteed Painless," the legal nature of the service is altered.

- There is a shift from a duty of care to a breach of promise or contract.
- If an implant fails or a crown fractures down the line, the patient can take your advertisement to the Consumer Disputes Redressal Commission.
- The consumer court will view your advertisement as a written guarantee.

Moving Forward Together

As members of the IDA Kochi Branch, we do not need to avoid social media or community outreach. In fact, our patients need accurate, science-based information now more than ever.

We can use our digital platforms to share knowledge, demonstrate high infection control standards, and build long-term trust. When doing community service, let us funnel our efforts through the Community Dental Health wing of our association.

Before you post your next video or plan your next community drive, ask yourself four quick questions:

1. *Is this activity teaching the public, or is it trying to solicit private clients?*
2. *Am I making promises that biological science cannot guarantee?*
3. *Does this follow ethical guidelines and directives?*
4. *Am I doing outreach independently under a private banner, or ethically through the IDA CDH wing?*

A Commendable Stand - and the Imperative of Self-Regulation

The proactive vigilance demonstrated by both the Kerala Dental Council (KDC) and the Indian Dental Association in recent times deserve sincere appreciation. From issuing firm public notices against commercialized media campaigns and non-recognized degrees to curbing predatory clinical camps, their steadfast efforts have sent an unequivocal message: our professional integrity is not up for sale.

However, as individuals, we must realize a fundamental truth: **regulating oneself from within is far more honorable and far safer than constantly searching for loopholes in the existing framework.** When we spend energy looking for legal technicalities to justify a sensationalist video or a commercial discount, we

chip away at the foundation of trust that binds the doctor-patient relationship. True practice growth is not built on short-term discount campaigns, private commercial camps, or dramatic social media stunts. It is built in the operatory through clinical skill, honest communication, and ethical care.

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ORIGINAL ARTICLE

INFODEMIOLOGICAL EVALUATION OF INTEREST IN ORAL BODY ART: A GOOGLE TRENDS ANALYSIS OF ORAL AND PERIORAL PIERCINGS, TOOTH JEWELLERY, AND ORAL TATTOOS IN INDIA (2015–2024)

ABSTRACT

Background: Oral and perioral cosmetic modifications, including lip, tongue, and cheek piercings, tooth jewellery, and oral tattoos, have gained popularity among adolescents and young adults. These practices are associated with several oral health complications, yet population-level surveillance data remain limited. Infodemiology tools such as Google Trends provide insights into public interest and health-related behaviors through internet search patterns. The aim of the study was to analyze temporal and seasonal trends in online search interest related to oral and perioral cosmetic modifications in India using Google Trends.

Methods: A retrospective infodemiological study was conducted using Google Trends data for India between January 2015 and December 2024. Search terms included "tongue piercing," "lip piercing," "cheek piercing," "tooth jewellery," and "oral tattoo." Relative search volume (RSV) data were extracted and analyzed using descriptive statistics, linear regression trend analysis, and seasonal pattern evaluation. The slope of search interest over time and coefficient of determination (R^2) were calculated to assess growth trends.

Results: Tongue piercing demonstrated the highest growth trend (slope/year = 1.077; $R^2 = 0.0566$), followed by lip piercing (slope/year = 0.862; $R^2 = 0.0350$) and tooth jewellery (slope/year = 0.768; $R^2 = 0.0412$). Cheek piercing and oral tattoo searches showed relatively low trends with minimal variation.

Conclusions: The findings indicate increasing online interest in oral cosmetic modifications in India, particularly tongue and lip piercings. Dental professionals should be aware of these emerging trends and emphasize public awareness regarding potential oral health risks.

Keywords: Infodemiology; Google Trends; Oral piercing; Tooth jewellery; Oral tattoo; Dental public health.

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INTRODUCTION

Oral and perioral piercings and tattoos represent forms of body modification that have experienced fluctuating trends in popularity across different cultures and time periods. Once associated with ritualistic practices, expressions of social status, or cultural identity in various ancient societies, these practices have evolved into forms of personal expression, fashion statements, and declarations of individuality in contemporary society.[1]

Oral and perioral piercings involve the insertion of piercings into the oral cavity, such as the tongue, lip, cheek, frenulum, etc. Oral piercings have been associated with different religious, cultural, tribal, and marital practices in different parts of the world throughout history. For example, in southern India, religious practices involve piercing the tongue as an act of penance. In Mali, tribal practices involve piercing the lips and inserting large wooden or clay plates into them. Across different periods, oral piercings have been known to signify different things, ranging from royalty to negative emotions, from purity to spirituality.[2]

In the latter part of the 20th century (1970s-1980s), tattoos and body piercings underwent a transformation in public perception, shifting from associations with religious beliefs to being seen as acts of rebellion and markers of negative behaviors. A common stereotype during this period linked individuals with such body modifications to problems like drug use, smoking, alcohol abuse, anger issues, and aggression, an image partly propagated by the heavily tattooed and pierced adherents of the Punk movement. However, contemporary society has largely moved away from this stereotype, now recognizing tattooing and piercing as valid art forms, with body adornment using jewelry being primarily motivated by aesthetic preferences and self-expression.[3] In modern times, oral piercings are often synonymous with fashion and the punk movement.

The rise and popularity of oral and perioral piercings are associated with peer pressure, media exposure, and the need for individualism and are commonly seen in young adults. Due to this increased interest, healthcare professionals, especially dentists, must be aware of the risks and complications associated with them.[4] Given the increasing popularity and potential health implications of oral and perioral piercings and tattoos, analyzing public interest and trends related to these practices can provide valuable insights for healthcare professionals and public health authorities.

Healthcare research in the Big Data era is being advanced by new tools that utilize internet search data, a form of Big Data, to uncover significant patterns in disease and population behavior.[5] Notably, Google has emerged as the primary choice for individuals seeking information about their oral health concerns. Google Trends is a product of Google, that has been used to assess the popularity of queries searched on Google. This is a valuable infodemiology tool and analyzes the popularity of search queries over time and across different geographical regions.6 Google Trends has been utilized in various health-related studies to explore public interest in diseases, mental health, and health behaviors.

Given the increasing popularity and potential health implications of oral and perioral piercings and tattoos, analysing public interest and trends related to these practices can provide valuable insights for healthcare professionals and public health authorities. This study utilizes Google Trends to examine the interest in lip, tongue, and cheek piercings in India over the last ten years, providing a digital epidemiology perspective.

METHODOLOGY

Study Design and Data Source

This quantitative, retrospective infodemiological study utilized publicly available Google Trends data to analyze search interest in oral and perioral piercings, specifically lip, tongue, and cheek piercings, within India between January 1, 2015, and October 1, 2025. Google Trends indexes the relative search volume (RSV) of user queries across time and geography. RSV values represent normalized search interest ranging from 0 to 100, with 100 indicating the maximum search frequency within the queried time frame and region.

Keyword Selection

The selection of search terms was guided by existing literature on oral piercing practices[2,7]

and observed semantic variations among Indian internet users. The primary keywords were “lip piercing,” “tongue piercing,” “cheek piercing.”, Tooth Jewellery," and "Oral Tattoo" Only Web Search data were included, excluding verticals such as Google Images, News, or YouTube, to ensure consistent behavioral representation of general search interest.

Data Extraction

Extracted data were exported as CSV files and consolidated into a unified dataset for time-series processing.

Data Analysis

CSV data were merged and analyzed. Descriptive statistics were calculated, and temporal trends were visualized using line graphs. No inferential statistics were applied due to the descriptive scope of the study.

Ethical Considerations

All data used were publicly available through Google Trends’ open-access interface, devoid of personal identifiers or user-specific metadata. The study adhered to the ethical principles for digital epidemiological research. Ethical approval was obtained from the Institutional Ethics Committee.

RESULTS

Table 1 shows the average Relative Search Volume (RSV) of Selected Oral Cosmetic Modification Queries in India (2015–2024Google Trends analysis revealed varying levels of search interest for oral and peri-oral cosmetic modifications in India between 2015 and 2024. Among the evaluated search terms, tongue piercing and lip piercing consistently demonstrated the highest search interest throughout the study period. Search interest for tongue piercing increased steadily from 2017 onwards, reaching peak values during 2020–2021 and again in 2023. Lip piercing searches followed a similar pattern, with periodic spikes possibly associated with social media trends and fashion cycles. Search interest for tooth jewellery showed intermittent increases, particularly between 2018 and 2023, reflecting growing demand for cosmetic dental enhancements. Conversely, cheek piercing and oral tattoo que-

Table 1: Average Relative Search Volume (RSV) of Selected Oral Cosmetic Modification Queries in India (2015–2024)

Year	Tongue Piercing	Lip Piercing	Tooth Jewellery	Cheek Piercing	Oral Tattoo
2015	32	28	15	10	6
2016	34	29	17	11	7
2017	38	32	18	12	7
2018	41	35	21	12	8
2019	45	39	24	13	8
2020	48	42	26	14	9
2021	50	44	28	15	9
2022	46	41	30	14	9
2023	52	47	31	16	10
2024	49	45	29	15	9

Values represent average annual relative search volume (RSV) derived from Google Trends.

ries showed relatively low and inconsistent search volumes throughout the study period. Overall, the data suggest an increasing public curiosity and awareness regarding oral piercings and cosmetic oral modifications in India over the past decade.

Table 2 and Figure 1 shows the Google Trends Relative Search Interest Trend Indicators for Oral and Perioral Cosmetic Modifications in India (2015–2024). The Google Trends analysis demonstrated distinct variations in online search interest related to oral and perioral cosmetic modifications in India between 2015 and 2024.

Among the evaluated search terms, tongue piercing showed the highest growth trend, with a slope of 1.077 per year, indicating a steady increase in online interest over the study period. Lip piercing demonstrated the second highest growth trend (0.862 per year), reflecting its widespread popularity as a visible facial modification. Search interest for tooth jewellery also showed a moderate upward trend (0.768 per year). In contrast, cheek piercing and oral tattoo searches exhibited relatively small slopes and low R^2 values, indicating limited and inconsistent search activity in India.

Table 2. Google Trends Relative Search Interest Trend Indicators for Oral and Perioral Cosmetic Modifications in India (2015–2024)

Search Term	Slope per Month	Slope per Year	Intercept	R^2
Tongue piercing	0.090	1.077	26.766	0.0566
Lip piercing	0.072	0.862	-1.883	0.0350
Tooth jewellery	0.064	0.768	5.214	0.0412
Cheek piercing	0.025	0.304	-0.675	0.0093
Oral tattoo	0.018	0.216	2.987	0.0078

Slope values represent the linear trend in Relative Search Volume (RSV) over time derived from Google Trends data for India (2015–2024).

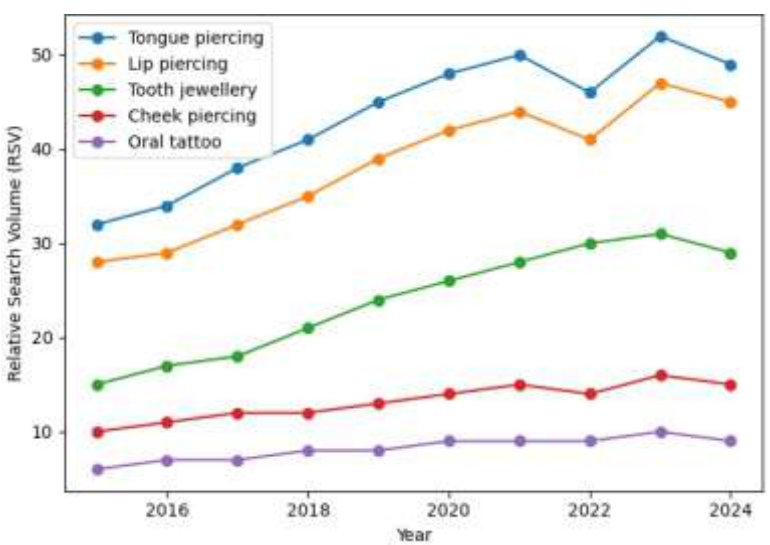

Figure 1:
Google Trends Relative Search Interest for Oral and Perioral Cosmetic Modifications in India (2015–2024)

DISCUSSION

The present study utilized data from Google Trends to evaluate temporal patterns in public interest regarding oral and perioral cosmetic modifications in India.

The analysis demonstrated a gradual increase in search interest for several practices, particularly tongue piercing and lip piercing, over the past decade. These findings reflect the growing influence of global fashion trends, social media exposure, and increased acceptance of body modification practices among younger populations.

Among the analyzed terms, tongue piercing demonstrated the highest positive trend. This observation aligns with earlier epidemiological reports indicating that tongue piercing is one of the most common intraoral body modification practices worldwide.[8,9] Previous clinical studies have documented that tongue piercings are associated with several oral complications, including enamel fractures, gingival recession, periodontal attachment loss, and increased plaque accumulation around jewellery components.[3,7,10] Campbell et al. reported that individuals with tongue piercings exhibited significantly greater periodontal attachment loss compared with non-pierced individuals.[11] Similarly, Ziebolz et al. observed increased gingival trauma and tooth wear associated with long-term tongue piercing use.[12] The growing online interest identified in the present study may therefore represent an emerging oral health concern that warrants increased professional awareness and preventive education.

Lip piercing was the second most prominent search term identified in this study. Lip piercings are often perceived as a less invasive alternative to intraoral piercings; however, several studies have reported associated complications.[1-3,7,13] De Moor et al. described cases of gingival recession and enamel abrasion caused by repeated contact between lip jewellery and the labial surfaces of anterior teeth.[14] Kapferer et al. further reported that lip piercings may contribute to localized periodontal damage in the mandibular anterior region.[15] The increasing online interest in lip piercings observed in this study may therefore highlight the need for dental practitioners to provide appropriate counseling regarding potential oral health risks.

Tooth jewellery also demonstrated a moderate increase in search interest over time. Cosmetic dental adornments have become increasingly popular due to the rising demand for minimally invasive aesthetic procedures. Unlike oral piercings, tooth jewellery typically involves the temporary bonding of decorative crystals or metallic ornaments to enamel surfaces.[16-18] Although generally considered safe when performed under professional supervision, improper placement or inadequate oral hygiene may contribute to plaque retention and increased risk of dental caries. The increase in online searches related to tooth jewellery may therefore reflect broader trends in cosmetic dentistry and the growing emphasis on dental aesthetics.

In contrast to tongue and lip piercings, cheek piercing and oral tattoo searches remained relatively low throughout the study period. These practices may be less popular due to their invasive nature and the potential for complications such as infection, scarring, and nerve damage. Oral tattoos, which involve pigmentation of mucosal tissues, are relatively uncommon and have received limited attention in dental literature.[19,20] The relatively low search interest observed in the present study suggests that these practices remain niche forms of body modification within the Indian context.

The present study also highlights the utility of infodemiological approaches in dental public health research. The concept of infodemiology, introduced by Eysenbach, refers to the analysis of information patterns on the internet to monitor public health trends. Digital platforms have become primary sources of health information for many individuals, and search engine data can provide valuable insights into emerging behaviors and concerns.[5,6] Several studies have demonstrated the usefulness of Google Trends in monitoring public interest in oral health topics such as orthodontic treatments, oral cancer awareness etc.[21,22] The findings of the present

study extend this approach to the domain of oral cosmetic modifications, an area that has received limited attention in infodemiological research.

Public Health Significance

From a dental public health perspective, the increasing popularity of oral cosmetic modifications underscores the importance of patient education and preventive strategies. Dental practitioners should be prepared to counsel patients regarding the potential risks associated with oral piercings and cosmetic dental adornments. Educational initiatives targeting adolescents and young adults may help reduce complications associated with unsafe body modification practices.

Overall, the findings of the present study suggest that digital surveillance tools can serve as valuable adjuncts to traditional epidemiological methods. Monitoring online search behavior may help identify emerging trends in oral health practices and guide the development of targeted public health interventions.

Limitations

Despite providing valuable insights into public interest, the present study has several limitations inherent to Google Trends–based infodemiology research. First, Google Trends provides relative search volume (RSV) rather than absolute search counts, which limits the ability to quantify the exact number of searches performed. Second, the analysis captures only internet search behavior, which may not fully represent the actual prevalence of oral piercings, tooth jewellery, or oral tattoos in the population. Individuals without internet access or those using other search engines may not be represented. Third, search queries are influenced by media coverage, social media trends, and cultural events, which may temporarily inflate search interest without reflecting long-term behavioral changes. Fourth, Google Trends allows analysis only of selected keywords, and variations in spelling, language, or colloquial terminology may influence search results. Finally, the analysis was restricted to India, and therefore the findings cannot be generalized to other countries with different cultural practices and aesthetic preferences. Despite these limitations, Google Trends provides a useful real-time tool for monitoring public interest and emerging trends in oral health–related behaviors, offering valuable insights for dental public health planning and preventive strategies.

CONCLUSIONS

The present infodemiological study demonstrated increasing online interest in oral cosmetic modifications in India, particularly tongue piercing and lip piercing. Tooth jewellery also exhibited moderate growth in search popularity, while cheek piercing and oral tattoo searches remained relatively low.

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REVIEW ARTICLE

ROBOTICS IN DENTISTRY

ABSTRACT

The field of dentistry is improvised by the introduction of robotics in every aspect. Robots were innovated as a part of industry revolution and they were a part of supportive hands with human work forces. Patient care, treatment efficiency and precision everything has changed to an ascending graph. Advances in robotics has helped the dentist with diagnosis and treatment planning with precision. Nowadays more hospitals and dental clinics are incorporating the robotic systems into their practices thereby improving the quality of treatment. The applications of robotics in each field of dentistry including prosthodontics, implantology, orthodontics, surgery have been discussed in the article. Robotic assisted surgeries, bracket placement, crown fabrication, root canal procedures etc. showcase the potential of robotics in transforming various aspects of dentistry. The conventional dentistry has been upgraded to a highly precise one with improved patient outcomes and increased efficiency is the main advantage of robotics. At the same time high cost and need for additional training to effectively use robotic systems are the challenges and limitations highlighted.

Key words: Robotics, dentistry, robot assisted system.

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INTRODUCTION

We are witnessing a new world of computerization that affects the way we live, learn, work, travel, and more. Robots are devices that accomplish computer-programmed and automated manual tasks. Robotics is a field of reprogrammable, multifunctional, multipurpose, and multitalented systems that intelligently linking sensing into action.[1] Robots were innovated as a part of industry revolution and they were a part of supportive hands with human work forces.[2]

Robotics is a branch of technology that is peculiar in the design, construction, operation, and application of robots, as well as computer systems for its control, sensory feedback, and information processing.[3]

Robots are machines that perform automatic manual tasks programmed by computers. Robots usually exhibit consistently high performance, economic relevance, and increasingly serve as smart assistants and co-workers in many public areas. There is a high demand for improving healthcare efficiency and quantity while standardizing the current methods. Robots may mitigate human resources for more important tasks, such as interacting with patients or other functionalities that require high cognitive skills.[3]

HISTORY

Karel carpel invented the term "Robot".[4] The Programmable Universal Machine (PUMA 200, Westinghouse Electric, Pittsburg, PA, USA) was the first robot to be used in medicine over 25 years later. Its aim was to align the needle during neurosurgical biopsies. In 2000, the USA Food and Drug Administration (FDA) licensed the first robotic system for performing laparoscopic surgery in a doctor-robot setup.[1] The pioneering work conducted at the National Aeronautics and Space Administration (NASA) labeled the origin of robot-assisted surgery.[5] The use of robotics in medicine has depicted more and more attention. Macro-, micro-, and biomedical robots are the three main classes of medical robots.[4] The medical robotics industry has recently switched its focus to autonomous robotic technology, which is capable of performing a procedure without constant control or active monitoring by a human. In addition, remote-controlled injectable medical microrobots have been developed for the delivery of cytotoxic agents to cancer cells.[5]

The application of robots in dentistry has been established much later than in medicine. The introduction of new technologies like digitalization and intellectualization in dentistry is critical to replacing manual operations and improving work efficiency.[6] Dentistry provides multiple opportunities for robotic automation and assistive technologies to enhance the quality of dental care. A study at Oxford University found that the responsibilities of dental hygienists and dental assistants were more likely to be computerized than those of dentists. Jenkins recognized the need for a robotic dental secretary in 1967, and several robotic applications in dentistry have since become a reality.[5]

Aside from serving as dental assistants, robots in conjunction with 3D navigation can be used for invasive dental procedures, including tooth preparation and autonomous dental implant placement. Robotic systems can also play a role in education. Training dental students with the support of full-body robotics, haptic interface technology, and advanced simulation can teach basic learning needs before interaction with real patients.[5]

Applications of Robotics in Dentistry

Robotics have been used in various fields of dentistry. Advances in robotics has helped the den-

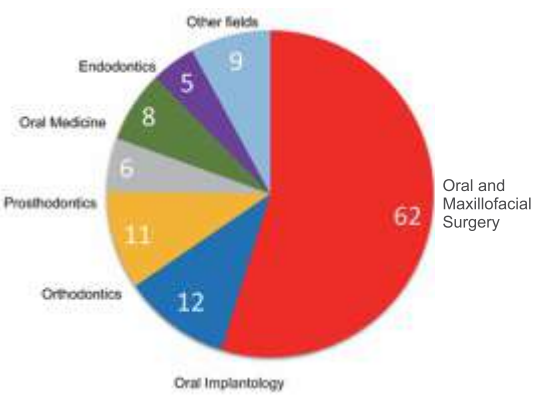

Figure 1: Number of articles related to the applications of robots for treatments in different dental specialties.[6]

tist with diagnosis and treatment planning with precision.

IMPLANTOLOGY

Dental implant robotic system continuously enhances software modules and optimizes operating procedures to become more intelligent, more flexible and easier to learn and use.[7]

Boesecke et al initiated the first dental implant placement using robot guidance in 2002.[1]

The architecture of dental implant robotics primarily constitutes the hardware utilized for surgical data acquisition and surgical execution. (figure 2) Data acquisition includes perceiving, identifying, and understanding the surroundings and information required for task execution through encoders, tactile sensors, force sensors, and vision systems. Real-time information obtained also comprises the robot's surrounding environment, object positions, shapes, sizes, surface features, and other relevant information. The perception system aids the robot in comprehending its working environment and facilitates corresponding decision-making as well as actions.[7]

Robotic assistant dental implant surgery comprises three steps: (figure number 3)

1. Preoperative planning

For preoperative planning, it is mandatory to obtain digital intraoral casts and CBCT data from the patient, which are then imported into preoperative planning software for 3D reconstruction and implant placement planning. For single or multiple tooth gaps using implant robotic systems (except Yakebot), a universal registration device (such as the U-shaped tube) must be worn on the patients' missing tooth site using a silicone impression material preoperatively to obtain CBCT data for registration. The software performs virtual placement of implant positions depending on prosthetic and biological principles of implant surgery, taking into account the bone quality of the edentulous implant site to direct the drilling sequence, insertion depth of each drill, speed, and feed rate. For single or multiple tooth implants accomplished using Yakebot, there is no need for preoperative CBCT imaging with markers.[7]

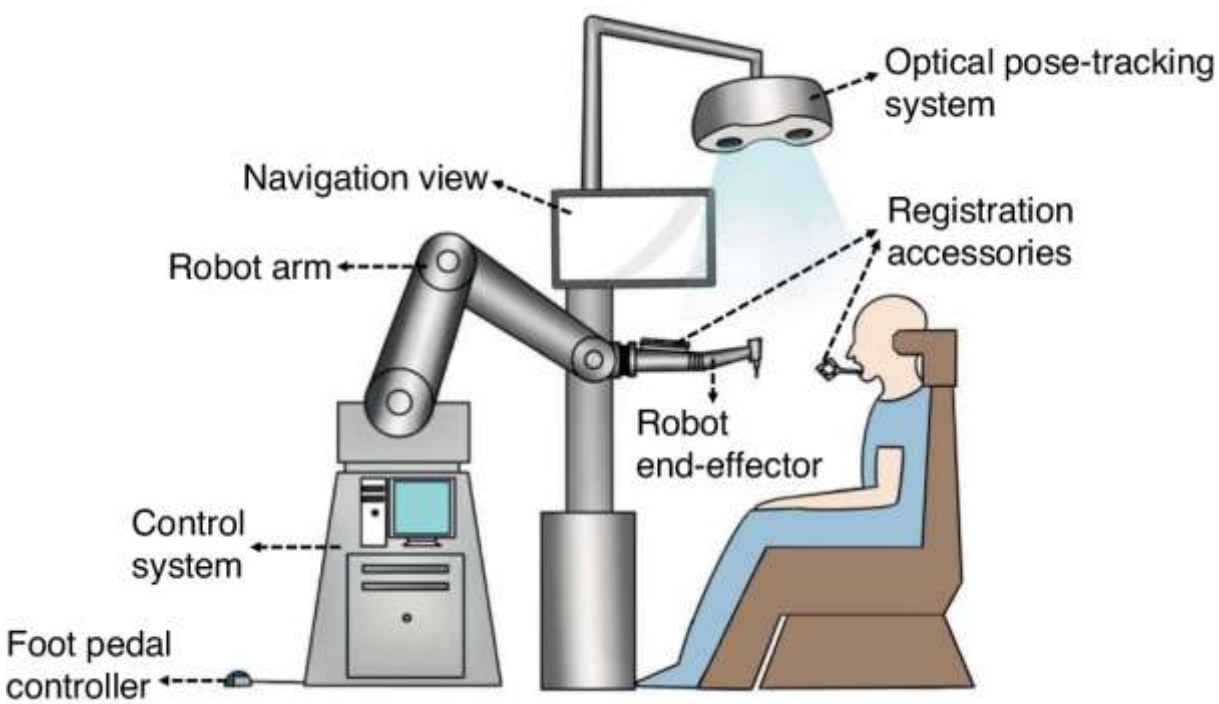

Figure 2. Architecture of dental implant robotics.[7]

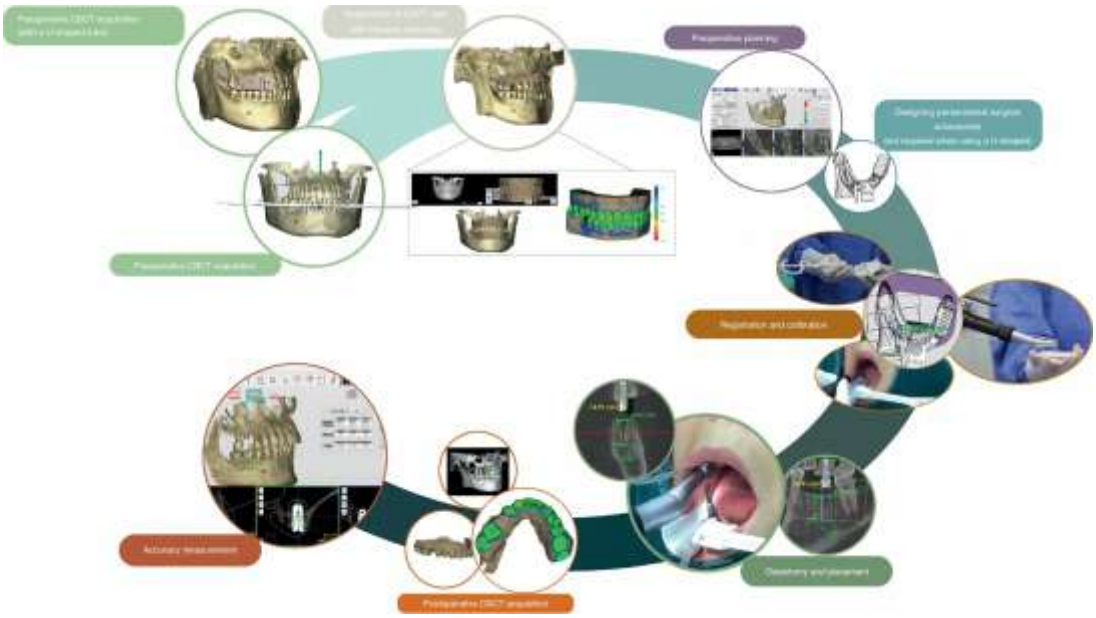

Figure 3. Clinical workflow of robotic-assisted dental implant placement.[7]

2. Intraoperative phase

The first step in the intraoperative phase is preoperative registration and calibration. For Yakebot, the end-effector marker was set up on the robotic arm, and the spatial positions were recorded using an optical tracker. The calibration plate with the positioning points was then gathered into the implant handpiece for drill tip calibration. Then, the registration probe is placed in the registration holes of the jaw positioning plate in turn for spatial registration of the jaw marker and jaw. With Yakebot, the entire surgery is performed under the surgeon's supervision, and instant instructions are sent in response to possible emergencies via foot pedal.[7]

3. Postoperative phase

The postoperative phase focus at post operative CBCT acquisition and accuracy measurement.[7]

A 3-DOF (Degrees of freedom) robotic system with a stereo camera was developed. This system can recognize and control the dental handpiece, ensuring that implants are placed in accordance with the preoperative protocol. The computer automatically applied the planned surgical process to ensure the right cutting site and applied the right amount of force.[8]

ORTHODONTICS

Diagnosis and treatment planning can be performed in orthodontics by the interpretation of radiographs and photographs by intraoral scanners and cameras, which work on the principles of AI. This eliminates the need for making patient impressions as well as several laboratory steps that are usually followed. Tooth movement and final treatment outcomes can be anticipated using algorithms and statistical analyses.[2]

The SureSmile orthodontic arch wire (OAW) bending robot, which is part of the robotic system for bending orthodontic arches, is arranged on a table or other surface that provides support. SureSmile uses a robotic system to individualize fixed orthodontic appliances and state-of-the-art 3D computer and imaging techniques for diagnosis and treatment planning. Similarly, "LAMDA (Lingual Archwire Manufacturing and Design Aid)" comprises a heater that can raise the temperature of a nickel-titanium archwire to 600°F and bend it within 6 min.[9]

Butscher et al. combined other medical equipment with an orthodontic archwire bending robot to carry out the complete process, from data collection to 3D imaging and automatic archwire bending. The arch wire-bending robot was initiated in 1994[6].

Van der Meer et al. make use of a robot called FMU 2.7 (Airedale Springs, West Yorkshire, UK), a machine for coiling and forming wire, for arch wire bending.

Robots used to bend orthodontic arch wires are inexpensive, have a straightforward design, and can bend a variety of arch wire types. This reduces the doctor's labor intensity, avoids the fatigue fracture of the archwire caused by frequent bending, and enhances the effectiveness of the treatment.[1]

A robot called AcceleDent (OrthoAccel Technologies Inc., Bellaire, TX, USA) was established to aid in orthodontic treatment. This novel micro-pulse vibration robotic system applies cyclic forces to move teeth faster through accelerated bone remodelling and decrease the discomfort associated with orthodontics.[6]

PROSTHODONTICS

Robotics have been used for tooth preparation and arrangement.

Tooth Preparation

The establishment of robots used to prepare and arrange teeth has been the main focus of recent research. Preparation of a tooth for crowns and bridges is a daily task for the dentist. Dentists must simultaneously strive to meet precise tooth preparation standards as well as prevent trauma to the delicate tissues within the small oral cavity.[1] The idea of a robotic arm that are used for tooth preparation or preparation support for the dentist seems tempting and sensible.[2]

LaserBot is a microrobot device that was developed in 2013 in order to accomplish clinical tooth-crown preparation.[1]

Yuan et al. introduced a robotic system for tooth preparation. The results showed improved performance compared to the clinician's crown preparation using the average repetition ability of the robotic system.[4]

Tooth Arrangement

Zhang et al. introduced a robotic system for tooth arrange in complete dentures. The first robotic system was established in 2001 using Visual C++ and RAPL robot languages. In 2011, a multi-manipulator tooth-arrangement robot was initiated for manufacturing complete dentures.[6]

The manufacturing of complete dentures is performed with the help of this teeth arrangement robot. In addition, it adjusts each tooth's position on the screen by viewing 3D virtual teeth in that format.[4]

A single manipulator robotic system introduced by CRS robots manufactured in Canada was used for the fabrication of complete denture prosthesis through six degrees of freedom (DOF). The three-dimensional virtual tooth arrangement software of the robot utilizes patients mandibular arch parameters to create patients' medical history data, expert-drawn jaw, and dental arch curves.[8]

ENDODONTICS

An endo microrobot was introduced to enhance the accuracy of endodontic treatment and provide high-quality root canal treatment. This performs automatic drilling, cleaning and shaping and three-dimensional filling of the root canal system. Research is still ongoing for the invention of new designs and manufacturing of microsensors and accurators.[10]

Figure 4. Endodontic microrobot[4]

In the endodontic specialty, a robot called OMIN PHANTOM with a virtual reality simulator has been introduced to help operators efficiently train in endodontic procedures. Robots can also help endodontists prepare the cavity

by running the drill with more precision and smoothness, thereby reducing iatrogenic damage. Toosi et al in 2014 developed a HAPTIC REALITY VIRTUAL SIMULATOR for root canal treatment. The benefit of the system is that the operator can clean the internal surface of the root canal using a simulated K file.[10]

Simon et al. introduced the first mechatronic system to assist dentists in handling dental drills. Nelson et al. developed a novel tool vending machine for providing root canal instruments during surgery, which is preprogrammed to automatically select and deliver surgical instruments according to the surgeon's needs, thereby acting as a surgical assistant. Hwang et al developed catalytic antimicrobial robots that can kill, degrade, and remove biofilms precisely, efficiently, and controllably.[6]

ORAL AND MAXILLOFACIAL SURGERY

Oral and maxillofacial robotic surgery has emerged as an optimistic treatment option, particularly for oropharyngeal carcinoma. The da Vinci system was recommended by the US Food and Drug Administration in 2009 for the transoral treatment of certain malignant and all non-malignant oropharyngeal lesions, including those situated at the base of the tongue and larynx. Additionally, robotic surgery is carried out in the upper aerodigestive tract, which is accessible through the mouth. With its stereoscopic vision, multiarticulated instruments, and robotic arms, transoral robotic surgery slightly invades the oropharynx. Transoral robotic surgery has been widely used for the surgical treatment of obstructive sleep apnea and pathological conditions. A high degree of accuracy was illustrated by the preprogrammed osteotomies performed by a robot (KUKA, Augsburg, Germany) in experiments on free fibula flap mandibular reconstruction. A robotic system has also been introduced to aid in repositioning bone segments during orthognathic surgery. Robots for specialized procedures in oral and maxillofacial surgery, such as velopharyngeal surgery, are also being developed. In a nutshell, robots are primarily used in oral and maxillofacial surgery for two tasks: acquiring and reconstructing preoperative 3D image data of the oral and maxillofacial region, analyzing lesion characteristics, and creating a targeted operation plan and precisely segmenting, reshaping, displacing, and fixing the craniofacial bone in line with the surgical plan.[1]

AI-powered artificial eyes, for example, can allow patients to see without surgery, while voice-activated smart reading glasses can help the visually impaired read text and recognize faces. AI has also been implemented in tissue engineering to create skin replacements for wound healing purposes. Artificial skin grafts can be used as long-term skin replacements or transient wound dressings. They are primarily used to supply oxygen, avoid dehydration, encourage healing, as well as guard against infections.[8]

PAEDIATRIC DENTISTRY

Based on the principles of attentional capacity theory, distracting stimuli need to be stronger than pain stimulus to attract children's attention.[11] These are a few applications of robotics in pediatric dentistry:

- **Distraction and Entertainment:** Robots can engage children with interactive storytelling, games, and other entertaining activities, effectively redirecting their attention from dental procedures. This helps relieve anxiety and discomfort, making the overall experience more pleasant for young patients.[11]
- **Patient Education:** Humanoid robots can be programmed to be modified to individual preferences and needs, tailoring their interactions based on factors such as age, language, and cultural background. They can act as educational tools, teaching children about oral hygiene practices and the importance of dental care in a fun and engaging manner, promoting positive attitudes toward oral health along with encouraging healthy habits from a young age.[11]
- **Customized Treatment Planning:** Based on patient assessments and data analysis, Humanoid Robots can assist dental professionals in creating personalized treatment plans customized to the individual needs of

each child. These plans may comprise recommendations for preventive care, restorative treatments, orthodontic interventions, or behavioral management strategies.

- Interactive Waiting Room Experience: Humanoid robots can conduct initial assessments of Pediatric patients by engaging in interactive conversations along with gathering relevant information about their dental history, oral health habits, and any specific concerns or preferences they may have. Using artificial intelligence algorithms, the collected data can be interpreted to identify patterns, trends, and potential risk factors, helping to develop a comprehensive understanding of each child's dental needs.[11]

PUBLIC HEALTH DENTISTRY

In dental public health, in 2004, a robot using Lego Mindstorms was developed to guide elementary school students to brush their teeth correctly.

Yasemin et al. designed a human-robot interaction scenario for children aged 4 to 10 years to improve their experience in a clinical environment by reducing pain and anxiety during dental treatments.

Sakaeda et al. developed an automatic teeth-cleaning mouthpiece robot comprising of an eccentric cam, a wiper with sponges, and a rounded guide railto aid the elderly and handicapped in brushing their teeth. The robot was enhanced to achieve a higher plaque removal rate.

Kasimoglu et al. developed a humanoid robot that can reduce anxiety in children during dental treatments and improve their behaviours.

In 2015, Zhang introduced an integrated system for dental treatment that consisted of a console, robot, chair device, and navigation system. Dentists can control the robotic arm at the console to perform various oral and dental treatments under the guidance of the navigation system. The team later proposed a novel self-service robotic system for the early diagnosis of oral diseases along with routine maintenance of oral hygiene.[6]

TEMPROMANDIBULAR JOINT DISORDERS

The Waseda Asahi Oral-rehabilitation Robot No.1 (WAO1) is an oral rehabilitation robot introduced by Waseda University in Japan. consists of a headrest-equipped body, two arms with six degrees of freedom and plungers, a control box, a computer, and an automated massage trajectory generation system with virtual compliance control. The robotic apparatus massages the patient's face by pressing or rubbing a plunger whose action is automatically controlled by a computer. The first robot designed to massage a patient's facial tissues, masticatory muscles (masseter and temporalis), and oral structures such as the parotid gland and duct, is the WAO1. It can be used to treat dry mouth and TMJ disorders.

Speech robots were developed in 2005 at a university in the Canadian province. Two 3-DOF parallel manipulators operate the two TMJs, one at each end of the jaw. The aim is to examine how jaw movements impact our ability to receive and understand facial communication.[8]

GNATHOLOGY

Waseda Yamanashi designed a master-slave system to facilitate training of mouth opening. Jaw movements can be recreated using robotic articulators with or without the assistance of jaw movement-tracking sensors. A full veneer crown was designed in an experiment on the working cast of a single patient using a robotic articulator.[8]

Advantages

The use of robots in dentistry increases precision, reproducibility, and dependability. Robots may also improve healthcare, increase the effectiveness of transportation, and offer greater flexibility to engage in creative activities by taking on the load of physically taxing or repetitive work.[12]

Robotic guidance in dental implant surgery offers several advantages. Robotic systems can excel in the accuracy achieved even by expert clinicians and would have even greater accuracy gains compared to average dental practitioners.[13]

Nanorobotic probes are primarily used for disease monitoring, evaluation, and treatment, and they can detect and activate neuroelectric impulses in the body.[14]

Medical robots are commonly used in surgery, diagnosis, and rehabilitation. They allow precise and minimally invasive operations, thus minimizing patient trauma and pain, shortening hospitalization, speeding recovery, and reducing the need for reoperations and blood transfusions. In addition, medical robots can minimize radiation exposure for both surgeons and patients.[7]

Limitations

It is an acknowledged fact that innovations come with new challenges. Likewise, Robotics has limitations.[1] Adopting robotic technology is a powerful prospect, but it is not without challenges. The hesitation to adopt new technology could be due to the barriers to entry both the upfront cost and the time it takes to learn how to use it. As with any new technology, initial adopters face decisions on resources related to cost, personnel, physical space and the learning curve. Making an investment in a large capital piece of equipment require a careful decision-making process. Practices also need to consider the learning curve for the dentist and staff. The dentist placing the implants with the Yomi robot needs to coordinate with trusted team members to complete a case. Robotic systems are complicated and require skill to operate and function properly.[4]

Future Perspectives

Robotics holds promise for applications in dentistry over implant surgery. Orthognathic surgery, endodontics, prosthetics, restorative dentistry, and other fields could all be reshaped by the emergence of robotic technology. However, witnessing the transformation of robotics in dentistry will take time. Before robotic technology can become the standard of care in dentistry, more research is required. "Ongoing research will expand the scope of this technology into other areas of dentistry that require keen attention to anatomical features and extreme precision in application, such as endodontics and other jaw surgeries; however, robotics is possible for all areas of dentistry, as we will see in its continuing evolution," said Dr. Talib. Even though research has demonstrated the efficacy of robotic technology, it still needs to be made available in terms of price. Dentists also have to be willing to accept the change.[15]

CONCLUSION

The entire generation is approaching a novel age of robotics. Dentistry is also being converted into Robotic Dentistry. Robotics are used in dentistry to improve human activity and overcome the shortcomings of manual labor, enabling more accurate and refined movements than human hands. However, there is considerable scope for improvement in terms of further simplification, flexibility of robotic surgical procedures, and systematic education. Robotics in the field of dentistry has the potential to alter the quality of dental health in just a few years. However, the future of dentistry remains unknown because of the advancement of new technologies. We believe that in the near future, robots will change the existing dental treatment model and guide new directions for further advancements.

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REVIEW ARTICLE

DIGITAL PATHOLOGY IN ORAL DIAGNOSIS: CURRENT TRENDS AND APPLICATIONS

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ABSTRACT

Digital pathology has emerged as a transformative advancement in oral diagnostic practice by improving image analysis, remote consultation, workflow efficiency, and data management. Conventional histopathological examination remains the gold standard for oral diagnosis; however, limitations such as observer variability, delayed consultation, and difficulties in slide storage have encouraged the development of digital technologies. Recent advances in whole-slide imaging, telepathology, and artificial intelligence have expanded the role of digital pathology in oral healthcare. Applications include oral squamous cell carcinoma, oral potentially malignant disorders, salivary gland lesions, odontogenic lesions, oral cytology, and telepathology. Artificial intelligence-assisted systems improve diagnostic precision through automated image analysis, predictive modelling, and workflow optimization. Despite its advantages, digital pathology faces challenges including high infrastructure cost, data storage requirements, technical limitations, and concerns regarding privacy and standardization.

Keywords: Digital pathology, Oral diagnosis, Telepathology, Whole-slide imaging, Artificial intelligence, Oral cancer.

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INTRODUCTION

Oral pathology is an essential branch of dentistry that deals with the diagnosis and study of diseases affecting the oral and maxillofacial region. Histopathological examination remains the gold standard for diagnosing oral lesions because it provides detailed information regarding tissue architecture, cellular morphology, and pathological alterations.[1] Accurate diagnosis is crucial for effective treatment planning, prognosis assessment, and long-term patient management.

Traditionally, oral pathological diagnosis depends on microscopic examination of stained tissue sections mounted on glass slides. Although conventional microscopy has been highly effective for decades, several limitations have become increasingly evident in modern healthcare systems. Diagnostic interpretation may vary among pathologists because of subjective assessment, leading to interobserver variability. Physical slides may deteriorate with time, become damaged during transport, or be misplaced during storage. Consultation with specialists often requires physical transfer of slides, resulting in delays in diagnosis and treatment.[1,2]

Advances in information technology and digital imaging have led to the development of digital pathology, which has transformed the practice of pathology worldwide. [2] Digital pathology involves the acquisition, storage, sharing, and interpretation of histopath ological information in digital form. The introduction of whole-slide imaging (WSI) systems has enabled the conversion of conventional glass slides into high-resolution digital images that closely resemble microscopic views.[3,4]

Digital pathology has become increasingly important in oral and maxillofacial pathology because it improves accessibility, facilitates teleconsultation, enhances teaching methods, and supports research activities. Oral cancer and oral potentially malignant disorders represent major global health concerns, particularly in developing countries where tobacco use and betel quid chewing are common. Early diagnosis significantly improves patient survival; therefore, technologies that enhance diagnostic precision are of great clinical importance.[4,5]

Artificial intelligence (AI), machine learning, and deep learning technologies have further expanded the applications of digital pathology.[3] AI-assisted systems can analyze histopathological images, detect abnormal cellular patterns, grade dysplasia, and predict prognosis with increasing accuracy. These technologies support oral pathologists by reducing workload and improving diagnostic consistency.[6,7]

Despite its advantages, digital pathology also faces several limitations including high equipment costs, large data storage requirements, technical challenges, legal concerns, and the need for standardization. Nevertheless, continued advancements in imaging technology and computational analysis are expected to make digital pathology an integral component of precision oral medicine.[8,9]

This review article aims to discuss the principles, applications, advantages, limitations, and future perspectives of digital pathology in oral diagnosis.

Principles of Digital Pathology

Digital pathology is the process of converting conventional glass histopathological slides into high-resolution digital images that can be viewed, analyzed, stored, and shared electronically.[4] It combines pathology with digital imaging, computer technology, telecommunications, and artificial intelligence to improve diagnostic efficiency and accessibility.[10] The core component of digital pathology is whole-slide imaging, in which stained tissue sections are scanned using specialized scanners to produce detailed digital images that closely resemble conventional microscopic views.[11,12] These images can then be examined using image-viewing software on a computer screen.

A digital pathology system typically includes whole-slide scanners, image management software, digital storage systems, telepathology platforms, and artificial intelligence-assisted tools.[4] Whole-slide scanners digitize tissue sections with high

image quality, while image management software enables viewing, annotation, measurement, and comparison of images efficiently. Since digital slides generate large image files, advanced storage systems are required for proper archiving and retrieval.10 Telepathology platforms facilitate remote consultation and case sharing among pathologists through internet-based systems.[13] In addition, AI-assisted tools support automated image analysis, pattern recognition, and prognostic assessment.[5]

Digital pathology may be classified into static telepathology, dynamic telepathology, and whole-slide imaging telepathology. Static telepathology involves transmission of selected microscopic images for consultation, whereas dynamic telepathology enables real-time remote control of microscopes. Whole-slide imaging telepathology allows complete digital scanning and comprehensive evaluation of tissue sections.[14] Overall, digital pathology has significantly improved workflow efficiency, remote accessibility, and diagnostic collaboration in oral pathology practice.[15]

Whole-slide Imaging in Oral Pathology

Whole-slide imaging is considered the foundation of modern digital pathology.[10] It allows the entire histopathological slide to be scanned and digitized at high resolution. The resulting image can be viewed on computer monitors with magnification capabilities similar to conventional microscopy.

In oral pathology, whole-slide imaging has numerous clinical and educational applications. Oral lesions often require detailed evaluation of epithelial dysplasia, stromal invasion, inflammatory changes, and cellular morphology. High-resolution digital slides permit accurate visualization of these microscopic features.

Whole-slide imaging offers several advantages compared to traditional microscopy:[10,11]

- Improved slide preservation
- Rapid retrieval of archived cases
- Easier sharing for consultation
- Reduced risk of slide damage
- Enhanced teaching capabilities
- Integration with image analysis software

Whole-slide imaging is particularly useful in diagnosing oral squamous cell carcinoma and oral potentially malignant disorders where accurate grading of dysplasia is essential.

Digital slides can also be integrated with patient records, thereby improving workflow efficiency and clinical documentation.

Telepathology in Oral Diagnosis

Telepathology refers to the practice of pathology using telecommunications technology for remote diagnosis, consultation, and education.[11] It has become an important application of digital pathology, especially in regions with limited access to oral pathologists.

Telepathology enables oral pathologists to evaluate digital slides remotely without physically transporting glass slides. This is particularly beneficial for rural healthcare centers and institutions lacking specialized diagnostic services.

Applications of Telepathology

Telepathology has become an important component of digital pathology by enabling remote diagnosis, consultation, education, and research collaboration.[11] Complex oral lesions often require expert opinion, and telepathology allows specialists from different geographic regions to review digital slides and provide diagnostic consultation without physically transporting glass slides.[13] Digital pathology systems are also useful during intraoperative consultations, particularly for rapid frozen section diagnosis during surgical procedures.[15]

Applications Of Digital Pathology in Oral Diagnosis

1. Oral Squamous Cell Carcinoma

Oral squamous cell carcinoma (OSCC) is one of the most common malignant tumors affecting the oral cavity.[5] Early diagnosis plays a critical role in improving patient survival and treatment outcomes. Digital pathology has demonstrated significant applications in the detection, grading, and prognostic evaluation of OSCC.[2] AI-assisted image analysis systems can identify

abnormal epithelial architecture, nuclear pleomorphism, mitotic activity, and invasive tumor patterns with improved consistency and reproducibility.8 Quantitative image analysis also assists in evaluating biomarkers and tumor microenvironment characteristics that may influence prognosis and treatment planning.[12]

Digital pathology further enhances interdisciplinary communication among oral pathologists, oncologists, surgeons, and radiologists by facilitating rapid sharing of histopathological data and remote consultation in difficult cases.[15]

2. **Oral Potentially Malignant Disorders**

Oral potentially malignant disorders (OPMDs), including leukoplakia, erythroplakia, oral submucous fibrosis, and oral lichen planus, possess varying risks of malignant transformation.[6] Histopath ological evaluation of epithelial dysplasia remains essential for assessing this risk. Digital pathology enables accurate visualization, quantitative assessment, and documentation of dysplastic features. AI-based systems can assist in grading epithelial dysplasia by analyzing nuclear morphology, cellular arrangement, and architectural abnormalities with greater objectivity.[5] Early identification of dysplastic changes supports timely intervention and improves prognosis.[6]

3. **Salivary Gland Lesions**

Salivary gland tumors are histologically diverse and often present diagnostic challenges because of overlapping microscopic features. Digital pathology and telepathology facilitate consultation among specialists for difficult or rare salivary gland lesions. Digital image analysis also supports evaluation of immunohistochemical markers used in salivary gland pathology, thereby improving diagnostic accuracy.[4]

4. **Odontogenic Cysts and Tumors**

Digital pathology improves documentation, visualization, and long-term archiving of odontogenic lesions such as ameloblastoma, odontogenic keratocyst, dentigerous cyst, and calcifying odontogenic cysts. Whole-slide imaging allows detailed evaluation of histopathological characteristics and preservation of rare cases for educational and research purposes.[10]

5. **Infectious and Inflammatory Lesions**

Digital pathology assists in the diagnosis of fungal infections, granulomatous diseases, and inflammatory lesions affecting the oral cavity by enabling enhanced visualization and image analysis. AI-assisted systems may further improve identification of pathological changes in inflammatory conditions.[3]

6. **Forensic Odontology**

Digital imaging systems have applications in forensic odontology by facilitating documentation, storage, and comparison of histopathological findings for medico-legal investigations and forensic analysis.[16]

7. **Oral Cytology**

Digital cytology combined with artificial intelligence-assisted analysis has demonstrated promising potential in screening oral mucosal lesions and detecting early malignant transformation.[7]Automated image analysis may improve the sensitivity and efficiency of oral cancer screening programs.[8]

Artificial Intelligence in Digital Oral Pathology

Artificial intelligence (AI) has emerged as one of the most significant advancements in digital pathology and has greatly influenced modern oral diagnostic practice.[5] AI systems use computational algorithms to analyze large datasets, recognize complex histopathological patterns, and assist in diagnostic decision-making.[3] The integration of AI into digital pathology improves diagnostic accuracy, efficiency, reproducibility, and workflow management in oral pathology laboratories.

Machine Learning

Machine learning is a branch of artificial intelligence in which computer systems are trained using large datasets to identify

patterns, learn from previous data, and make predictions. In oral pathology, machine learning algorithms assist in detecting dysplastic and malignant lesions by analyzing cellular and architectural changes in histopathological images.[3] These systems can support early diagnosis and reduce interobserver variability during microscopic interpretation.

Deep Learning

Deep learning is an advanced subset of machine learning that utilizes multilayer neural networks for automated image analysis. Convolutional neural networks (CNNs) are widely used in digital pathology because of their ability to analyze histopathological images with high precision and accuracy.[8] Deep learning models have demonstrated promising applications in oral pathology, particularly in oral cancer detection, epithelial dysplasia grading, prognostic prediction, identification of metastatic patterns, and quantitative image analysis.[5]

Applications of Artificial Intelligence in Oral Pathology

1. **Automated Image Analysis**

   AI-assisted systems can automatically analyze digital slides and identify suspicious pathological areas, thereby assisting oral pathologists during microscopic examination.[12]

2. **Tumor Detection**

   Deep learning algorithms help detect malignant cells, invasion patterns, and tumor margins with improved consistency and reproducibility.[8]

3. **Dysplasia Grading**

   Artificial intelligence improves the grading of epithelial dysplasia by reducing subjective interpretation and enhancing diagnostic consistency among pathologists.[6]

4. **Prognostic Prediction**

   AI-based predictive models can estimate disease progression, recurrence risk, and patient survival outcomes using histopathological and clinical data.[12]

5. **Workflow Optimization**

   AI systems contribute to workflow efficiency by prioritizing abnormal cases, automating repetitive tasks, and reducing the workload of oral pathologists.[5]

Despite these advantages, artificial intelligence cannot replace the role of oral pathologists. Human expertise remains essential for final diagnosis, interpretation of microscopic findings, clinical correlation, and treatment planning.[3] Furthermore, several challenges remain associated with AI implementation, including algorithm bias, lack of standardization, limited training datasets, regulatory concerns, and ethical issues related to patient privacy and data security.[5]

Role of Digital Pathology in Research

Digital pathology has expanded opportunities for oral pathology research.[12] Large digital databases allow researchers to analyze histopathological patterns quantitatively.

Applications in research include:[12]

- Biomarker analysis
- Morphometric studies
- AI algorithm development
- Tumor microenvironment analysis
- Molecular pathology integration
- Multi-institutional collaborative studies

Digital slides facilitate data sharing and improve reproducibility in scientific investigations.

Advantages of Digital Pathology

- Rapid sharing of digital slides for expert consultation.[13]
- Improved access to pathology services through telepathology.[14]
- Efficient storage, retrieval, and archiving of histopathological data.[10]
- Reduced risk of slide loss or physical damage.[10]
- Enhanced collaboration among oral pathologists and other specialists.[13]
- Improved workflow efficiency and laboratory productivity.[15]

- Integration with artificial intelligence for image analysis and decision support.[5]
- Preservation of rare cases for research and future reference.[10]

Limitations and Challenges

- High cost of scanners, software, and digital infrastructure.[14]
- Large storage requirements for whole-slide images.[10]
- Variations in image quality and scanning artifacts.[11]
- Requirement for specialized training and technical expertise.[14]
- Lack of standardization among platforms and image formats.[11]
- Concerns regarding patient privacy, cybersecurity, and data sharing.[5]
- Regulatory and validation issues related to AI-assisted diagnosis.[5]
- Dependence on reliable internet connectivity for telepathology services.[14]

Future Perspectives

The future of digital pathology in oral diagnosis appears highly promising because continuous technological advancements are expected to improve diagnostic precision, workflow efficiency, and patient care.[9] Artificial intelligence-integrated diagnostic systems are likely to become an important component of future pathology workflows by supporting automated screening, predictive analytics, and decision-making processes.[5]

Integration of digital pathology with molecular diagnostics, genomics, and biomarker analysis may further contribute to the development of precision oral medicine and personalized treatment planning.[9] Cloud-based pathology platforms are also expected to improve accessibility, digital storage, and collaborative consultation among healthcare professionals across different geographic regions.[10]

Advanced artificial intelligence algorithms may facilitate automated identification of dysplastic and malignant lesions with improved sensitivity and specificity.[8] Combining histopathological imaging with molecular diagnostic techniques may enhance prognostic assessment and early disease detection.[12] Expansion of telepathology networks may further improve access to oral healthcare services in rural and underserved communities.[11]

Future developments may also include three-dimensional histopathological imaging systems and advanced visualization technologies for improved tissue assessment. In dental education, virtual reality and augmented reality technologies may provide more interactive and immersive learning experiences for students and trainees.[7] As digital technologies continue to evolve, digital pathology is expected to become an integral component of routine oral diagnostic practice and precision healthcare.[15]

CONCLUSION

Digital pathology has revolutionized oral diagnostic practice through advancements in whole-slide imaging, telepathology, digital image analysis, and artificial intelligence. These technologies have improved diagnostic efficiency, accessibility, workflow management, and diagnostic collaboration.

Applications in oral squamous cell carcinoma, oral potentially malignant disorders, salivary gland pathology and odontogenic lesions demonstrate the growing importance of digital pathology in oral healthcare. Artificial intelligence-assisted systems have further enhanced diagnostic support by improving image analysis, predictive modelling, and workflow optimization.

Despite challenges related to cost, data storage, technical limitations, and ethical concerns, continued advancements in digital technology are expected to overcome many existing barriers. Integration of digital pathology with molecular diagnostics, cloud computing, and precision medicine will likely transform future oral healthcare.

Digital pathology represents a major step toward modern, efficient, and patient-centered oral diagnosis. Continued research, technological innovation, and standardization are essential for maximizing its clinical and educational potential.

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REVIEW ARTICLE

ROLE OF HORMONES IN ORAL HEALTH

ABSTRACT

Hormones play a vital role in maintaining oral health by influencing the gums, bone, and salivary glands. Fluctuations in hormones especially estrogen and progesterone can increase blood flow to the gum tissues, making them more sensitive, swollen, and prone to bleeding. These changes are often seen during puberty, menstruation, pregnancy, and menopause, leading to conditions such as gingivitis or gum inflammation. Estrogen also helps maintain bone density in the jaw, so decreased levels during menopause may contribute to bone loss and tooth mobility. Other hormones, such as cortisol (released during stress), can weaken the immune response and increase the risk of periodontal disease, while insulin imbalances in diabetes can lead to gum infections and delayed healing. Thus, hormonal balance is essential for good oral health.

Key words: Hormones, oral health, gingivitis, periodontitis.

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INTRODUCTION

Oral health is constantly shaped by the cross-talk between behavioral, biological, and social forces. There is a considerable difference between the oral health needs of women and men. Hormones are integral biochemical messengers that regulate numerous physiological processes within the human body. Hormonal fluctuations in women such as puberty, menses, pregnancy, and menopause are said to have a strong influence on oral health. During menopause, women undergo a series of biological and endocrine changes, especially in their sex steroid hormone production, affecting their overall health.[1] One of the primary hormones that influence oral health is estrogen. Fluctuations in estrogen can lead to increased gingival blood flow and changes in the connective tissues of the gums, making them more susceptible to inflammation and periodontal disease. This literature review is centred on the effect of various hormones and their fluctuations on patients' oral health. Diseases of the mouth itself are the most common reasons for pain and discomfort in the mouth. However, there are certain situations where oral symptoms are caused as a result of systemic diseases[1].

Some of the hormones that affect the oral health of a person include :

- Progesterone
- Estrogen
- Growth hormone
- Thyroid hormone
- Parathyroid hormone

Effect of Estrogen and Progesterone

Estrogen is predominantly produced by the ovaries in women, and a small amount is also produced by the adrenal gland and the fat cells. It reduces the reaction of T-lymphocytes, thus leading to an increased occurrence of gingival inflammations, without favoring dental plaque formation. Estrogen also stimulates the proliferation of fibroblasts and the synthesis and maturation of tissues composing the gingiva. Progesterone is released by the corpus luteum, placenta, and adrenal cortex. It expands vascular beds, increasing their permeability. Progesterone impedes the synthesis of collagen present in the periodontal ligaments. As a result, their potential to repair reduces, as does the number of their fibers. An increase in the level of progesterone accelerates the metabolic decomposition of folic acid required for growth, development, and proliferation of the cells. Estrogen and progesterone receptors are also located in other periodontal components, namely, the gingiva and the periodontal ligaments, so they exert a range of effects on tissues in the periodontium.[2]

1. Gingivitis

a) **Puberty:** The period of maturation into adulthood, associated with changes in physical appearance and behaviour and a major increase in the secretions of the sex steroid hormones. During puberty, gingivitis is often observed to increase, followed by remission. Puberty gingivitis is clinically characterized by exuberant inflammation and gingival overgrowth, which may be associated with gingival bleeding. Significant gingival inflammatory changes have been documented, and these changes are aggravated by an imbalance in the sex hormones. Mühlemann presented a "gingivitis intermenstrualis" which was characterized by bright red hemorrhagic lesions of the interdental papilla developed prior to the menstrual period. Increased levels of gingival crevicular fluid are found during the menstrual period of women with pre-existing gingivitis. Additionally, inflammatory cytokines like interleukin 1β (IL-1β) levels were also reported to have significant changes, i.e., a steady increase in GCF IL-1β from the day of menstruation to the peak progesterone day.[3]

b) **Pregnancy:** The levels of estrogen and progesterone are at a peak during pregnancy. During this period gingivitis, pregnancy granuloma, periodontitis, and dental caries are some of the common findings. Pregnancy gingivitis begins to appear in 2nd month and last till 8th month with maximum effect seen between first and second month. Pregnancy periodontitis is characterised by tooth mobility and

increased probing depth, which may result from oedema or hyperplastic changes of the gingiva. A gingival lesion seen during the 1st and 2nd trimester of pregnancy is an epulis gravidarum characterised by a red, raw, raspberry-like appearance and tends to bleed easily. Histologically resembles pyogenic granuloma, they regress or become fibrotic mass postpartum.

Figure 1. Intraoral image at the time of admission, showing a granuloma-like mass with irregular surface and bleeding[4].

The etiology of pregnancy tumors is not known, although the influence of sex pregnancy hormones is quite clear. It occurs mainly during the pregnancy but also has been associated with contraceptive pills. One third of the cases may occur due to a trauma. Another important etiologic factor is improper oral hygiene leading to chronic gingivitis[5].

c) **Menopause:** Menopause marks the end of the reproductive period when menstrual cycles cease by reduced secretion of the ovarian hormones, such as, estrogen and progesterone. It is characterised by dry and shiny oral mucosa and gingiva. The gingiva which may appear abnormally pale or bright red with a tendency to bleed easily. More commonly reported gingival changes seen in women of this age are desquamative in nature, characterized by a smooth, polished gingival surface and a mottled appearance. The lowered levels of estrogen may result in postmenopausal osteoporosis. Reduction in bone density and strength leads to clinical attachment loss and tooth loss[3].

d) **Oral contraceptives:** Oral contraceptives are commonly used by women of reproductive age group. They are used as chemical birth control, treating hormonal imbalance and menstrual disorders. Currently, 3 types of oral contraceptive pills are broadly prescribed: combined estrogen-progesterone, progesterone-only, and continuous or extended-use pills. The most commonly prescribed pill is the combined hormonal pill with estrogen and progesterone. Progesterone is the hormone that prevents pregnancy, and the estrogen component controls menstrual bleeding.

Consistent use of low dose oral contraceptives may lead to gingivitis or hyperplastic gingivitis. Along with the effect on the gingiva, a stimulatory effect on bone metabolism was also identified. This effect, especially with long term use of oral contraceptives, is evidenced by decreasing serum levels of bone biomarkers like alkaline phosphatase and higher mean bone mineral density. This suggests that women on long-term oral contraceptives tend to have a lower risk of osteoporosis.[3]

2. Halitosis

Levels of Volatile Sulfur Compounds (VSC) increased by 2.2-fold in the ovulation phase compared to the follicular phase in individuals with periodontitis. The effect of the menstrual cycle on halitosis can be attributed to direct and indirect effects. A direct effect is defined as effects on halitosis that are directly related to the menstrual cycle and hormonal changes, while indirect effects are defined as effects on halitosis due to modifying variables such as microbiota saliva and stress.[6]

3. Xerostomia

Xerostomia is common among older people. It is more prevalent in postmenopausal women on medication and is quite common even in those without disease or drug usage often related to lowered salivary flow rates[7]. Decreased salivary flow during menopause results from blocking of salivary gland func-

tion, which may be due to physiological changes associated with age and/or hormones, as demonstrated by the detection of sex hormone receptors in the oral mucosa and salivary glands[8].

4. Lichen Planus (LP)

The word Lichen Planus (from Greek: leichen - lichen; planus-flat) is a chronic disease affecting both hairy and non-hairy skin, mucous membranes and nails[9]. OLP is more prevalent in premenopausal women and is associated with gonadotropin, estrogen and progesterone fluctuations. The increase in FSH and LH during menopausal status is due to the feedback cycle of estrogen and progesterone reduction. These hormonal changes may participate in the etiopathogenesis of OLP[10].

5. Dental Caries

Dental caries is a multifactorial microbial disease of the tooth and is one of the most common health problems[11]. Postmenopausal women have lower flow rates of saliva than menstruating women. Saliva acts as a defense mechanism for prevention of caries and reduced salivary flow can encourage oral microbial colonization thus affecting the dental health[12]. The saliva acts as a buffer, which prevents the demineralisation of the tooth. Women in postmenopausal period experience xerostomia due to lowered estrogen levels, which can affect the quality and quantity of saliva. This leads to an increased risk of dental caries.

Effect of Growth Hormone

Growth hormone (GH) is a critical regulator of the growth process in children. It is secreted by the pituitary gland, mainly during physiological night sleep. GH exerts its function mainly by promoting insulin-like growth factor I (IGF-I) secretion, acting within the GH-IGF-I signaling axis[13]. The GH secretion is stimulated by Ca+ ions and inhibited by calcium channel blocker. Growth hormone secretion is under dual hypothalamic regulation by the stimulatory peptide, GHRH,' and the inhibitory peptide, somatostatin[14]. GHD children showed abnormal craniofacial morphology with reduced mandibular dimensions, with a resulting tendency towards Angle's Class II occlusion, which affected up to 31% of patients. Dental age is delayed in GHD patients by about 1 to 2 years. Moreover, the risk of dental caries in children with GHD decreases with increasing levels of vitamin D[13]. Vitamin D plays an integral part in maintaining serum calcium concentration. Higher vitamin D3 concentrations and vitamin D supplementation reduces the intensity of active caries in children with GHD. This suggests that caries may constitute a symptom of vitamin D deficiency[15].

Effect of Thyroid Hormone

Thyroid hormones play an important role in the regulation of physiologic processes. Thyroid dysfunction is the second most common glandular disorder of the endocrine system and is increasingly prevalent among women. Thyroid disease can lead to an imbalance in the homeostasis of the body and affect the healing capacity of tissues[16].

Childhood hypothyroidism, known as cretinism, is characterized by thick lips, a large protruding tongue (macroglossia), malocclusion, and delayed eruption of teeth. Thickening of the lips and macroglossia is due to increased accumulation of subcutaneous mucopoly saccharides (ie, glycosaminoglycans) caused by a decrease in the degradation of these substances. The long-term effects of severe hypothyroidism on craniofacial growth and dental development have also included impaction of the mandibular second molars. This seems to be caused by a dissociation of ramus growth combined with a failure of normal resorption of the internal aspect of the ramus, resulting in insufficient space for proper eruption of these teeth[17].

In hypothyroidism, delayed wound healing occurs due to the decreased metabolic activity of the fibroblasts. Delayed wound healing may be associated with an increased risk for infection due to the longer exposure of the unhealed tissue to pathogenic organisms manifesting clinically with increased gingival bleeding[17]. Patients with hypothyroidism have increased subcutaneous mucopolysaccharides due to a decrease in the degradation of these

substances[16]. Excess subcutaneous mucopolysaccharides may decrease the ability of small blood vessels to constrict and may result in increased bleeding from infiltrated tissues, including the mucosa and skin[17].

Effect of Parathyroid Hormone

Parathyroid hormone and calcitonin are the main hormones that play an important role in bone remodelling. Parathyroid hormone increases the concentration of blood calcium by increasing bone remodelling and reducing calcium clearance by the kidneys.

The effect of hyperparathydoidism is more significant in oral cavity than hypopara thyroidism. Intraoral manifestations include:

- Obliteration of pulp chamber by pulp stone,
- Alterations in dental eruption,
- loosening and drifting of teeth,
- Malocclusions, spacing of teeth,
- Partial loss of lamina dura, periodontal ligament widening.
- Teeth may become sensitive to percussion and mastication or appear as floating teeth.
- Other findings include a delay or cessation of dental development, brown tumors, generalized bone rarefication of jaw, soft tissue calcifications and caries.

Hypercalcemia may result in sialolithiasis mandibular tori. Additionally, the patient may complain of vague jaw bone pain[18].

Figure 2: Intraoral view showing expansion of right side mandibular arch with indentation of teeth.[19]

Figure 3: Intraoral view showing expansion of complete maxilla.[19]

Hypoparathyroidism is characterised by enamel hypoplasia, microdontia, delayed eruption and multiple unerupted teeth. Hence, proper maintenance of parathyroid hormone levels are important.

Clinical Implications

Oral hygiene has a supportive role. Dental care integrated into prenatal programs can prevent the deterioration of oral health in pregnant women[20]. As women transition through menopause, hormonal fluctuations continue to influence periodontal health. The decline in oestrogen levels may contribute to changes in oral tissues, potentially leading to increased susceptibility to periodontal disease. Understanding these cyclic variations is essential for tailored oral-health care, emphasising the importance of regular dental check-ups and preventive measures.

Women using oral contraceptives should be given instructions to maintain proper oral hygiene. Women should give their bodies time to adapt to the hormones, reduce stress, eat anti-inflammatory food, stay hydrated, and get enough sleep. The diet should contain sufficient amounts of calcium. Vitamin D levels should be kept in check as it plays an important role in bone metabolism.

CONCLUSION

Hormones influence oral health by directly affecting the oral tissues, as well as affecting a multitude of other body systems that, in turn, produce effects in the oral cavity. Oral discomfort like dry mouth, altered taste, and burning sensation are the common and chief com-

plaints among menopausal women in dental clinics. Dentists should conduct a thorough examination of the oral cavity and rule out other systemic diseases before arriving at any definitive diagnosis related to hormonal changes.[1] Continued interdisciplinary collaboration and patient education remain essential in mitigating hormone-related oral health risks and promoting overall systemic well-being.

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REVIEW ARTICLE

EVOLUTION OF TOOTHBRUSHES: MODERN APPROACHES TO MECHANICAL PLAQUE CONTROL

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ABSTRACT

The evolution of toothbrushes reflects a continuous progression from ancient natural aids like chewing sticks and miswak to highly sophisticated digital health systems. This article examines the historical transition from traditional oral hygiene practices to modern mechanical plaque control, emphasizing the shift toward synthetic nylon filaments and the transformative impact of powered toothbrushing. Recent technological advancements have integrated mechanical cleaning with Artificial Intelligence (AI), smart sensors, and digital monitoring to create a data-driven, personalized health experience.

The review explores various classifications of toothbrushes based on mode of action, bristle hardness, and design innovations. It highlights the clinical efficacy of oscillating-rotating, sonic, and ultrasonic systems in reducing plaque and gingival inflammation compared to manual brushes. Furthermore, the article discusses specialized innovations such as U-shaped automatic designs, ionic and light-based technologies, and suction toothbrushes for hospitalized, critically ill patients. Advanced features like real-time feedback via smartphone applications, pressure sensors, and augmented reality games for children significantly improve patient compliance and technique. As the dental field moves toward more sustainable, eco-friendly materials and autonomous robotic systems, mechanical plaque control is evolving into a proactive, real-time diagnostic tool for monitoring oral health conditions and detecting issues like caries or calculus. Ultimately, these innovations aim to provide superior cleaning outcomes across diverse populations, ensuring more effective long-term dental health maintenance through precision, user-centered design, and comprehensive home monitoring.

Key Words: Mechanical Plaque Control, Artificial Intelligence (AI), Toothbrush Innovation, Oral Hygiene, Smart Technology.

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INTRODUCTION

The development of toothbrushes reflects the continuous progress of oral hygiene practices throughout human history. In ancient times, people relied on natural materials such as chewing sticks, plant fibers and frayed twigs to clean their teeth and maintain oral health. Among these traditional aids, miswak obtained from Salvadora persica became widely recognized because of its cleansing and antimicrobial effects.[1]

During the twentieth century, toothbrushes experienced major technological improvements. Natural bristles were eventually replaced with nylon filaments because they were more hygienic, durable, and flexible. Researchers and manufacturers subsequently focussed on improving toothbrush efficiency through changes in bristle arrangement, brush head size, filament texture, and handle design to achieve better plaque control and patient comfort.[2]

The introduction of powered toothbrushes further transformed mechanical plaque removal methods. Over time, powered brushes evolved into oscillating-rotating, sonic, and ultrasonic systems that enhanced cleaning effectiveness. Several systematic reviews have reported that powered toothbrushes can provide greater reduction of plaque accumulation and gingival inflammation when compared with conventional manual toothbrushes.[3] In recent years, attention has also shifted toward environmentally sustainable toothbrushes, including biodegradable and eco-friendly alternatives aimed at reducing plastic waste while maintaining oral hygiene effectiveness.[2]

Historical evaluation of toothbrushes

The history of toothbrushes illustrates the continuous development of oral hygiene methods from simple traditional practices to advanced preventive dental devices. In ancient civilizations, various natural materials such as chewing sticks, fibrous roots, feathers, and twigs were commonly used for cleaning teeth and maintaining oral hygiene. Miswak, prepared from Salvadora persica, became one of the most recognized traditional oral hygiene tools because of its cleansing action and antimicrobial activity.[1]

Figure 1. Neem sticks[18]

Figure 2. Miswak[18]

Further improvements in toothbrush design were observed during the twentieth century with the introduction of synthetic nylon filaments. Nylon bristles replaced animal hairs because they provided better flexibility, durability, and hygiene. Subsequent developments concentrated on enhancing brushing efficiency through modifications in bristle arrangement, brush head configuration, filament texture, and handle design to improve plaque control and gingival health.[2]

The introduction of powered toothbrushes marked another significant phase in toothbrush evolution. These devices later progressed into oscillating-rotating, sonic, and ultrasonic toothbrush systems intended to enhance

mechanical plaque removal. Evidence from systematic reviews indicates that powered toothbrushes may offer superior plaque reduction and gingivitis control compared with conventional manual toothbrushes.[3]

In recent years, greater attention has also been directed toward environmentally sustainable toothbrushes, including biodegradable and eco-friendly alternatives developed to minimize environmental impact while maintaining oral hygiene effectiveness.[2]

Principles of Mechanical Plaque Control

1. **Physical disruption of dental plaque**

   Mechanical plaque control is based on the principle that plaque biofilm must be physically disrupted and removed from tooth surfaces because it adheres firmly and cannot be eliminated effectively by rinsing alone.[4]

2. **Regular and consistent plaque removal**

   Since dental plaque reforms continuously, routine and consistent cleaning is necessary to limit biofilm maturation and reduce the risk of gingival inflammation and periodontal disease.[4,5]

3. **Toothbrushing as the primary method**

   Toothbrushing serves as the main method for supragingival plaque removal and should be performed with appropriate technique to clean all accessible tooth surfaces effectively.[5]

4. **Interdental cleaning for inaccessible areas**

   Brushing alone may not adequately clean proximal tooth surfaces; therefore, interdental aids such as floss or interdental brushes are recommended to remove plaque from spaces between teeth.[5,6]

5. **Correct technique over excessive force**

   Effective plaque control depends more on proper brushing movements, angulation, and coverage than on applying excessive pressure, which may traumatize soft tissues.[5]

6. **Individualized plaque-control measures**

   Mechanical plaque-control methods should be selected according to patient-specific factors such as manual dexterity, oral condition, periodontal status, or appliances.[5]

7. **Adjunctive role of chemical plaque control**

   Mouth rinses and antimicrobial agents may support plaque reduction, but they should be used as supplementary measures rather than replacements for mechanical plaque removal.[7]

8. **Professional maintenance and reinforcement**

   Professional plaque removal combined with oral hygiene instruction can reinforce self-performed plaque control and support gingival health.[4]

Classification of Toothbrushes

1. According to mode of action[2]

Toothbrushes are classified based on how they function into

- manual toothbrushes (depends on hand movement)
- powered/electric toothbrushes (uses automated motion such as oscillating, sonic, or ultrasonic action for plaque removal) .

Figure 3. Manual and Powered tooth brush[2]

2. According to bristle hardness[8]

Based on filament stiffness, toothbrushes are classified as

- extra-soft
- soft
- medium
- hard

Figure 4. Bristle hardness (soft, medium, hard)[8]

3. According to bristle arrangement/design[8]

This classification is based on the organization of bristles, including

- flat trim
- multilevel
- crisscross
- tapered
- zigzag designs

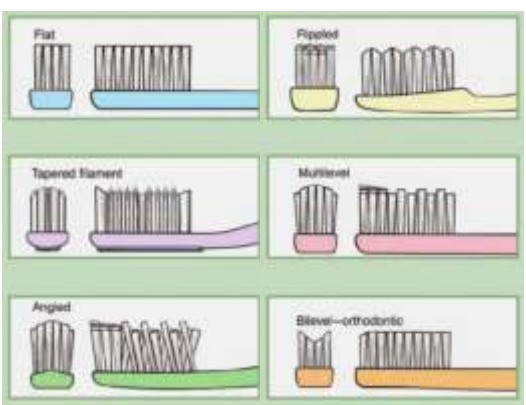

Figure 5. Bristle arrangement / design[8]

4. According to head size[8]

Toothbrushes may be grouped into

- small,
- medium
- large head designs

selected according to oral cavity size, patient age, and access to posterior teeth.

5. According to tuft arrangement[9]

According to tuft placement, toothbrushes are classified as

- single-tuft
- multi-tuft
- end-tuft toothbrushes

End-tuft designs are especially useful for cleaning around orthodontic appliances, implants, and difficult-to-reach surfaces.

Figure 6. Single-tuft24, Multi-tuft24, End-tuft Toothbrushes[25]

6. According to special purpose/use[9]

Some toothbrushes are developed for specific purposes, including

- orthodontic
- paediatric
- post-surgical
- denture
- interdental toothbrushes.

7. According to technology in powered brushes[2,10]

Powered toothbrushes may further be classified as

- oscillating-rotating,
- sonic,
- ultrasonic,
- smart toothbrushes .

8. According to material/design innovation[10,11]

Modern toothbrushes may also be classified according to material and design, including

- nylon-bristle,
- silicone, and
- eco-friendly bamboo toothbrushes.

Recent Advancements in Toothbrush Technology

Toothbrush technology has evolved significantly from conventional manual toothbrushes to highly advanced powered and intelligent systems designed to improve plaque control, gingival health, patient compliance, and personalized oral hygiene care. Modern advancements combine mechanical cleaning systems, artificial intelligence (AI), smart sensors, robotics, and digital monitoring technologies to enhance oral healthcare outcomes [10,12].

Powered Toothbrushes

One of the earliest and most significant advancements in toothbrush technology is the development of powered toothbrushes, including oscillating-rotating, sonic, and ultrasonic toothbrushes. Oscillating-rotating toothbrushes use circular rotating and pulsating motions to remove plaque more effectively than manual toothbrushes. Studies have shown that these toothbrushes significantly reduce plaque accumulation and gingivitis.[12]

Sonic toothbrushes produce high-frequency vibrations, usually between 24,000 and 40,000 strokes per minute, creating dynamic fluid movement that helps clean areas beyond direct bristle contact. Ultrasonic toothbrushes further advance this technology by using ultrasonic waves to disrupt bacterial biofilm and improve plaque removal with minimal mechanical action.[13]

Modern electric toothbrushes such as the Oral-B iO system incorporate magnetic drive technology and micro-vibrations to improve cleaning precision and user comfort. Pressure sensors in these brushes alert users when excessive brushing force is applied, helping prevent tooth abrasion and gingival trauma.[12]

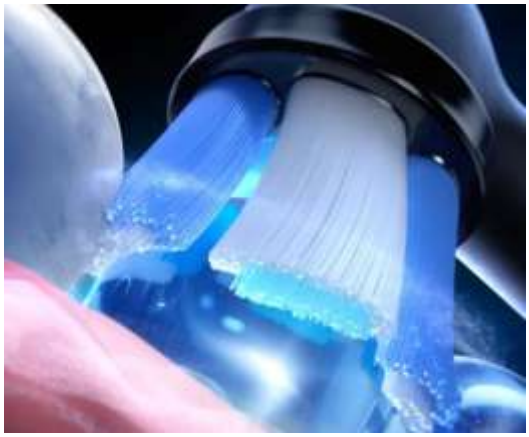

Figure 7. Oral-B iO System[19]

Smart Toothbrushes and Artificial Intelligence

Recent years have witnessed rapid growth in AI-powered smart toothbrushes integrated with Bluetooth connectivity, motion sensors, smartphone applications, and machine learning systems. These smart toothbrushes can monitor brushing duration, brushing pressure, brushing location, tooth surfaces cleaned, brushing angle, and brushing posture in real time.

AI-assisted toothbrushes use technologies such as artificial neural networks (ANN), convolutional neural networks (CNN), and long short-term memory (LSTM) models to analyse brushing patterns and provide personalized oral hygiene guidance. Motion sensors and nine-axis inertial sensors detect brushing movements and synchronize data with

smartphone applications through Bluetooth technology.[10]

Smart toothbrush systems such as Oral-B Genius, Colgate Hum, Plaqless Pro, and Ara toothbrushes provide live feedback and coaching to improve brushing techniques.14 These applications can identify missed areas, track oral hygiene habits, and encourage better brushing compliance.

Figure 8. Oral-B Genius[19]

Figure 9. Plaqless Pro[20]

Studies demonstrated that intelligent toothbrush systems connected to mobile applications significantly reduced plaque scores and improved supportive periodontal care outcomes. AI-assisted home monitoring and counselling also improved periodontal treatment outcomes, including reductions in plaque index and periodontal pocket depth.

Figure 10. Hum by Colgate[21]

Smart Toothbrushes for Children

Several advancements specifically target paediatric oral healthcare. AI-based smart toothbrushes such as Colgate Magik, Hum Kids by Colgate, FunDee toothbrush systems, and Blu smart toothbrushes use interactive technologies to motivate children and improve brushing habits.

These systems often incorporate augmented reality (AR), gaming features, avatars, and animated guidance to make brushing more engaging for children. Some smart toothbrushes use the "m-Teeth model," which detects plaque and evaluates brushing strokes more effectively than conventional monitoring systems .

Smartwatch-integrated toothbrushes have also been developed for children. These systems synchronize toothbrushes with wearable devices to detect brushing direction, brushing posture, and hand movements using magnetic sensors and motion tracking technologies .

Research has shown that AI-assisted toothbrushes linked with smartphone applications help children learn proper brushing techniques and improve oral hygiene compliance.[10]

U-Shaped and Automatic Toothbrushes

U-shaped and Y-shaped automatic toothbrushes represent another important innova-

Figure 10. Sonic Brush® V5[22]

tion in toothbrush technology. These devices contain silicone bristles arranged in a horseshoe or mouthpiece design that simultaneously clean multiple tooth surfaces .

These toothbrushes are particularly beneficial for children, elderly individuals, and patients with limited manual dexterity because they reduce brushing time and simplify brushing techniques.

Some U-shaped toothbrushes are designed to mimic the Bass brushing technique by placing bristles at a 45-degree angle to the gingival margin .

Clinical studies have shown that U-shaped toothbrushes significantly reduce plaque accumulation in preschool children when compared with conventional toothbrushes.[15]

Ionic Toothbrushes

Ionic toothbrushes represent another technological advancement aimed at reducing plaque adherence. These toothbrushes alter the polarity between the tooth surface and plaque, thereby reducing plaque attachment to teeth. Unlike traditional toothbrushes that rely mainly on mechanical action, ionic toothbrushes attempt to improve plaque removal through electrochemical mechanisms.[18]

Laser and LED Toothbrushes[23]

Laser toothbrushes and LED toothbrushes incorporate light-based technologies into oral hygiene devices. Laser toothbrushes are primarily designed to manage dentinal hypersensitivity and reduce gingival inflammation, while LED toothbrushes may provide antimicrobial and anti-inflammatory effects.

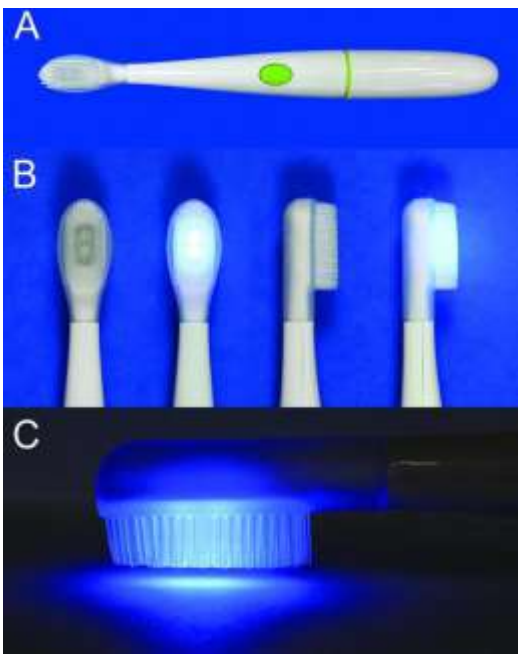

Figure 11. Photographs of a blue light-emitting toothbrush: (A) general view, (B) toothbrush heads in off and on modes, (C) exposure of LED light with 2-mm distance from the surface[23]

Although promising, these technologies still require additional long-term clinical studies to establish their effectiveness and safety.

Suction Toothbrushes and Specialized Toothbrushes

Suction toothbrushes have been developed for hospitalized, critically ill, and physically dependent patients. These systems combine brushing with suction mechanisms to remove debris, saliva, and secretions while reducing aspiration risk.[13]

Specialized toothbrushes are also available for individuals with disabilities and intellectual impairments. AI-assisted toothbrush systems have shown improved oral hygiene outcomes among individuals with intellectual disabilities compared to traditional educational methods.[10]

Toothbrushes with Sensing and Diagnostic Technologies

Recent research has explored toothbrushes capable of detecting oral diseases and monitoring oral conditions. AI-assisted sensing technologies such as ToMoBrush use acoustic signals generated during brushing to detect dental caries, calculus, and food impaction.

Other systems combine toothbrushes with smartphone-based intraoral imaging technologies that allow users to self-monitor oral conditions and receive professional feedback remotely.[16]

Robotic and Microrobotic Tooth Cleaning Systems

Emerging technologies include robotic and microrobotic plaque-removal systems capable of autonomously cleaning tooth surfaces and removing dental biofilm. These systems aim to improve oral hygiene among individuals with limited manual dexterity and may represent future directions in oral healthcare technology.[10]

Plaque Simulation and Research Technologies

Advanced plaque simulation technologies are also being developed to evaluate toothbrush effectiveness and plaque-removal efficiency . Research has investigated multiple artificial plaque simulation methods including ink, varnish, calcium phosphate coatings, occlusal sprays, and artificial plaque suspensions.

Although no current simulation system fully reproduces the characteristics of natural oral biofilm, these models are valuable for evaluating toothbrush performance and mechanical plaque removal methods.[17]

CONCLUSION

Innovation in toothbrush technology has transformed oral hygiene from a basic manual task into a data-driven, personalized health experience. The integration of AI, motion sensors, and diagnostic tools allows for more precise plaque removal and improved user techniques. While traditional manual and electric brushes remain effective, emerging specialized designs such as suction brushes for hospital care and autonomous robotic systems expand the accessibility of oral health. As the field moves toward more sustainable materials and smart monitoring, the future of mechanical plaque control lies in technologies that not only clean teeth more efficiently but also actively monitor oral health conditions in real-time, ensuring a more proactive approach to dental care.

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CASE REPORT

A RARE CASE REPORT OF HERPES ZOSTER AFFECTING ALL THREE TRIGEMINAL DIVISIONS WITH ORAL MANIFESTATIONS

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ABSTRACT

Herpes zoster is a viral infection caused by reactivation of latent varicella-zoster virus and commonly affects elderly individuals. Trigeminal nerve involvement is a recognized manifestation, while simultaneous involvement of multiple divisions is relatively uncommon. This report describes a case of herpes zoster involving the ophthalmic, maxillary and mandibular divisions of the trigeminal nerve in a 70-year-old male patient. Clinically, the patient presented with unilateral facial and oral lesions involving the labial mucosa, buccal mucosa, gingiva and palate. A clinical diagnosis of multidivisional trigeminal herpes zoster was established based on the history and clinical findings. The patient was managed with antiviral therapy, antibiotics and supportive care, resulting in progressive healing and satisfactory resolution of the lesions during follow-up. This case highlights the importance of recognizing the oral manifestations of herpes zoster and emphasizes the role of early diagnosis and timely management in achieving favourable clinical outcomes.

Keywords: Herpes zoster, Trigeminal nerve, Oral manifestations, Antiviral therapy, Acyclovir.

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INTRODUCTION

Herpes zoster (HZ) is a viral infection caused by reactivation of latent varicella-zoster virus (VZV) within sensory ganglia following primary varicella infection. It is characterized by painful unilateral vesicular eruptions distributed along the affected dermatome and is more commonly encountered in elderly individuals due to age-related decline in cell-mediated Immunity.[1] The incidence of herpes zoster has been reported to increase with advancing age, with a substantial disease burden observed among older adults worldwide.[2]

Trigeminal nerve involvement is a well-recognized manifestation of herpes zoster, with the ophthalmic division being the most frequently affected branch.[3] Multidivisional trigeminal herpes zoster is an uncommon clinical presentation. Although involvement of the maxillary and mandibular divisions has been documented, simultaneous involvement of the ophthalmic, maxillary and mandibular divisions is exceedingly rare, with only approximately five to six documented cases reported in the literature.[4] Oral manifestations may occur when the maxillary and mandibular divisions are involved and can present as unilateral vesicular and ulcerative lesions involving the lips, palate, gingiva and buccal mucosa.[5]

Simultaneous involvement of multiple divisions of the trigeminal nerve is uncommon and may pose a diagnostic challenge to dental practitioners.6 Early diagnosis and prompt antiviral therapy play a crucial role in reducing disease severity and promoting healing.[7]

CASE REPORT

A 70-year-old male patient reported to the Department of Oral Medicine and Radiology with a chief complaint of pain and swelling on the left side of the face and lips for five days. The patient was apparently asymptomatic prior to the onset of the illness, following which he developed pain over the left side of the face. The pain was gradual in onset, dull aching in nature, moderate in intensity and continuous, aggravated during the morning hours and relieved on medication, with a Visual Analog Scale (VAS) score of [5]. Subsequently, the patient noticed swelling involving the left side of the face, which was gradual in onset and progressively increased in size from a peanut-sized swelling to its present size. The patient gave a history of applying Vicks ointment once over the affected area three days prior to presentation, following which the swelling became more noticeable. He also reported a history of fever of one day's duration, which was gradual in onset, continuous and moderate in intensity. No history of bleeding, pus discharge, recurrence of swelling, difficulty in mouth opening, chewing or swallowing, or weight loss was elicited.

Figure 1 (A – H) : First visit – Initial presentation

A. Extra oral frontal view showing unilateral vesicular and crusted lesions involving the left side of the face

B. Extra oral lateral view showing unilateral vesicular and crusted lesions involving the left side of the face

C. Lesion on the left buccal mucosa

D. Lesions on the left unilateral palate

E. Lesion on labial mucosa

F. Lesion on the Floor of the mouth

G. Lesion on the left side of gingiva

H. Lesion over the left pinna

The patient's medical, dental and family histories were non-contributory.

On extraoral examination, facial asymmetry was evident due to diffuse swelling involving the left middle and lower third of the face. Multiple unilateral freshly ruptured vesicular lesions with yellowish crusting were observed over the left side of the face, extending from the preauricular region to the corner of the mouth and involving the lower lip. Similar vesicular lesions with crusting were also noted over the left pinna. Left eye examination revealed mild conjunctival congestion, while the eyelids, cornea, anterior chamber, vitreous and retina were normal. The lesions were distributed along the ophthalmic, maxillary and mandibular divisions of the trigeminal nerve and did not cross the midline. Tenderness was elicited on palpation of the affected area (Figure1). Bilateral submandibular lymphadenopathy was noted, with two palpable lymph nodes measuring approximately 1 cm × 1 cm. The lymph nodes were firm in consistency, mobile, and tender on palpation.

Intraoral Examination

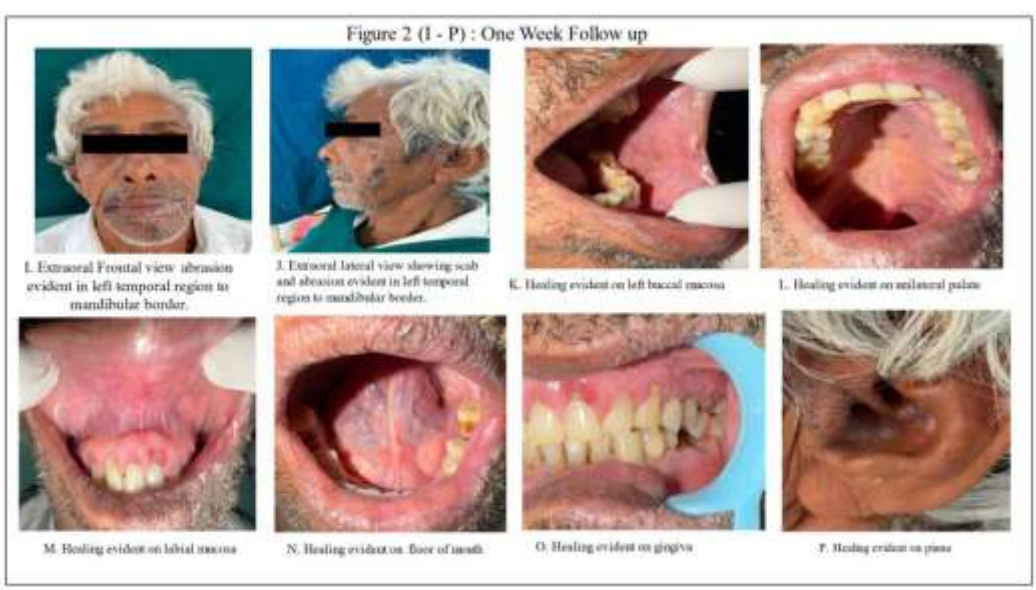
Intraoral examination revealed multiple erosive and erythematous lesions involving the left buccal mucosa and the left palate. Similar lesions were also observed on the marginal and attached gingiva of both the maxillary and mandibular arches on the left side. The lesions were unilateral and corresponded to the distribution of the affected trigeminal nerve divisions. The lesions appeared as vesicular and ulcerative areas associated with erythema and tenderness. A solitary erythematous erosive lesion was observed on the left side of the lingual frenum on floor of the mouth.

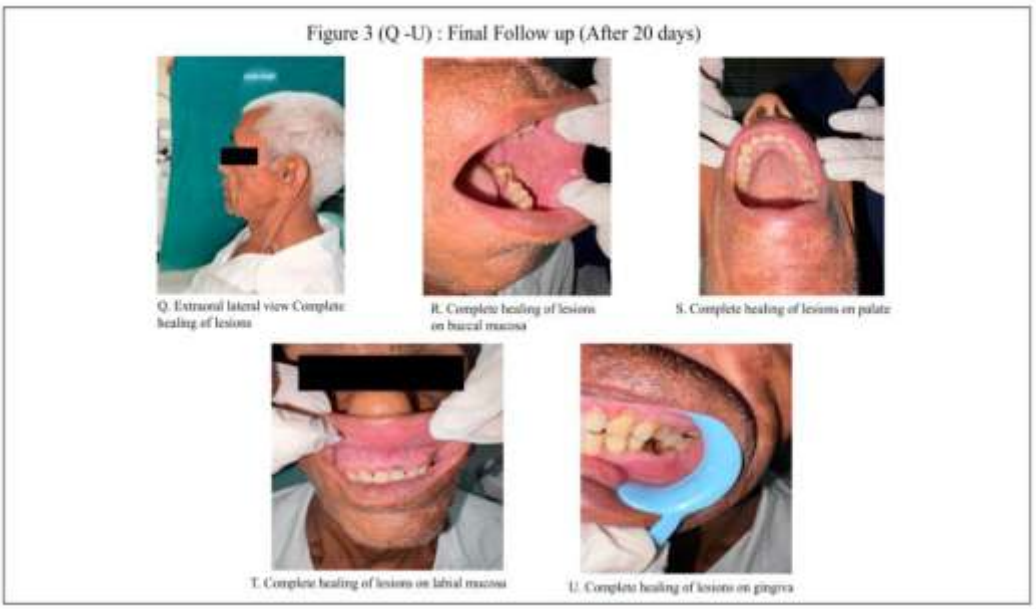
Based on the history and clinical findings, a clinical diagnosis of herpes zoster involving the ophthalmic, maxillary and mandibular divisions of the trigeminal nerve was made. The patient did not exhibit any clinical signs of facial nerve (cranial nerve VII) involvement, including facial paralysis, tinnitus or hearing loss.

Management

The patient was prescribed oral acyclovir 800 mg three times daily for 7 days, amoxicillin 500 mg five times daily for 5 days, and Coolora mouthwash (benzydamine hydrochloride 0.15% w/v) three times daily. The patient was also advised adequate hydration and regular follow-up.

At the one-week follow-up, significant improvement was observed with reduction in facial swelling and healing of the vesicular lesions. The patient was advised to maintain adequate hydration, consume a soft and liquid diet, and continue the prescribed medications. Additionally, Hexidine mouth rinse was prescribed three times daily along with topical Soframycin ointment to be applied three times daily over the affected area. The patient was recalled after 10 days for further evaluation (figure 2). However, the patient reported after





approximately 20 days. On subsequent examination, satisfactory healing of the lesions was noted with marked reduction in erythema and crusting, and the patient reported significant symptomatic relief (figure 3). No significant complications, including postherpetic neuralgia, secondary infection, or ocular sequelae, were observed.

DISCUSSION

The incidence of herpes zoster has been shown to increase with advancing age due to a decline in cell-mediated immunity, with elderly individuals being particularly susceptible to viral reactivation, as reported by Schmader.8 The present case involved a 70-year-old male, which is consistent with the age group most commonly affected by the disease. Epidemiological data from Johnson et al. further corroborate that the lifetime risk of developing herpes zoster is approximately 30%, with the risk rising steeply after the sixth decade of life.[9]

Early diagnosis and management are important in reducing disease burden and improving clinical outcomes in patients with herpes zoster, as emphasized by Dooling et al.[10] In the present case, timely initiation of therapy was associated with progressive healing of both extraoral and intraoral lesions during follow-up. Acyclovir, the antiviral agent of choice in herpes zoster, accelerates lesion healing and reduces viral shedding when initiated within 72 hours of rash onset, while concurrent antibiotic coverage is warranted to prevent secondary bacterial superinfection of ruptured vesicular lesions.[11,12] Benzydamine hydrochloride mouthwash (0.15% w/v), owing to its local analgesic, anti-inflammatory, and antimicrobial properties, effectively alleviates pain associated with oral mucosal lesions and supports mucosal healing.[13,14]

Post-herpetic neuralgia is considered one of the most common complications of herpes zoster, particularly among older adults, as highlighted in the systematic review by Kawai et al. 15 Although the present patient demonstrated satisfactory clinical healing with significant symptomatic improvement, continued follow-up remains important for monitoring potential complications. Beyond post-herpetic neuralgia, delayed or missed diagnosis of herpes zoster especially in atypical presentations can predispose patients to a spectrum of serious sequelae. Ocular involvement in herpes zoster ophthalmicus may result in keratitis, uveitis, or vision loss when treatment is deferred, as documented by Liesegang et al.[16] Ramsay Hunt syndrome can manifest as facial nerve palsy, sensorineural hearing loss, and vertigo when recognition is delayed, as described by Sweeney and Gilden.[17] In immunocompromised individuals, failure to

initiate early antiviral therapy may lead to disseminated zoster with encephalitis, myelitis, or visceral involvement carrying significant morbidity and mortality, as outlined by Gnann and Whitley.[11] Secondary bacterial superinfection of unrecognised herpetic lesions may further complicate wound healing and necessitate prolonged antimicrobial management, as noted by Nikkels and Piérard.[12] Of particular relevance in the dental context, delayed recognition of herpes zoster affecting the maxillary or mandibular divisions of the trigeminal nerve may precipitate significant oro-dental sequelae. These include osteonecrosis of the jaw, spontaneous exfoliation of teeth due to devitalization of the dental pulp and periapical involvement, and persistent anesthesia or hypoesthesia of the affected dermatome, as reported by Levin et al. in their review of oral complications associated with varicella-zoster virus reactivation.[18] These potential outcomes collectively underscore the critical importance of early clinical recognition and timely institution of antiviral therapy, particularly in older adults and those with underlying systemic conditions.

CONCLUSION

The present case highlights the rare and diagnostically challenging nature of simultaneous involvement of all three divisions of the trigeminal nerve in herpes zoster. Diagnosis was established based on the characteristic unilateral distribution of vesicular lesions along the ophthalmic, maxillary, and mandibular divisions, supported by clinical history and extraoral and intraoral findings. Prompt antiviral therapy with oral acyclovir, adjunct antibiotic coverage, and benzydamine hydrochloride mouthwash resulted in satisfactory healing with no significant complications. This case underscores the importance of early clinical recognition, particularly in elderly patients, to prevent debilitating sequelae such as postherpetic neuralgia and ocular complications. Dental practitioners should maintain a high index of suspicion when encountering unilateral orofacial vesicular lesions, as early diagnosis and prompt management are critical determinants of favorable clinical outcomes.

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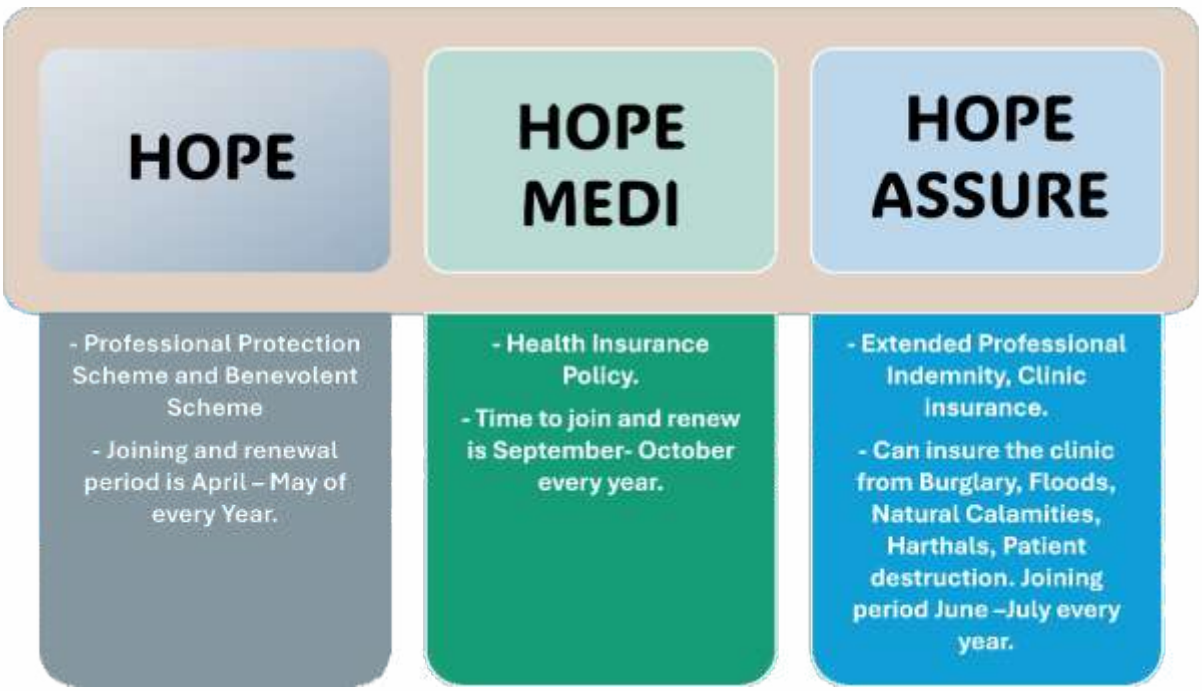

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