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Cape Recife Lighthouse,

Cape Recife Lighthouse, built in 1851, stands on Cape Recife in the Eastern Cape, South Africa. Rising 24 meters high, it has an octagonal masonry tower painted in bold black and white bands, a feature added in 1929. The lighthouse serves as a critical navigation aid, warning ships of the hazardous reefs and rocks that mark Algoa Bay, including Thunderbolt Reef and Roman Rock, making it an enduring coastal landmark.

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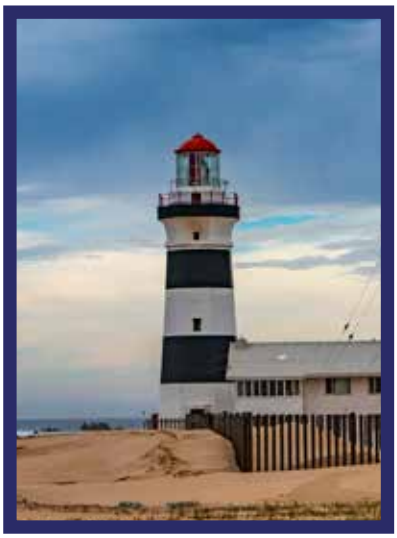

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Compliance or Competence? Re-thinking Leadership Pathways in South African Dentistry

SADJ AUGUST 2025, Vol. 80 No.7 P345-349

Prof NH Wood, Managing Editor, SADJ – BChD, DipOdont(MFP), MDent(OMP), FCD(SA), PhD

INTRODUCTION

For South African dentistry, the challenges are well known: too few clinicians, persistent inequities in access, and fragile institutions. Added to this are the pressures of academic renewal and the shifting demands of regulatory reform. These forces are not unique to South Africa, but they are intensified by the country's socioeconomic realities and the strain on its health system. The more unsettling question, however, is whether the profession has the leadership it needs to respond. Leadership is not a peripheral concern: it is the capacity that determines whether oral health can adapt, innovate, and remain credible in the eyes of patients, students, and society at large.

Yet concerns are increasingly voiced that dentistry is experiencing a paucity of strong, credible leaders. The visible symptoms include shrinking senior academic ranks, high attrition of mid-level cadres, and uneven implementation of oral health programmes at district level, and even concerns with training programs. Beneath these symptoms lies a more uncomfortable question about the systems through which leaders are identified, prepared, and appointed.

Patterns of appointment and promotion sometimes reward compliance over competence, raising concerns about whether current systems reliably identify, utilise, and retain high-performing leaders. The question is: "are those most capable of shaping the future of the profession (whether clinicians, academics, or policymakers with demonstrable expertise and vision) side-lined, while less qualified or less prepared individuals are advanced into positions of influence and the spaces of decision-making?". The downstream effects are profound: misalignment between policy and practice, disengagement of talented professionals, and ultimately a dilution of the standards expected from teaching, training and a health profession that serves the public good.

Perhaps it is time for this profession to consider why dentistry in South Africa is struggling with leadership renewal, how our situation reflects broader systemic pressures, and what pathways might ensure that competence and integrity, not mere compliance, become the decisive factors in shaping the leaders of tomorrow.

Why leadership matters in dentistry

Leadership in dentistry must be understood broadly and substantively, not reduced to holding titles or accumulating peripheral committee memberships. Effective leadership is multi-dimensional, encompassing clinical, academic, and policy/management spheres, each with distinct competencies and responsibilities, the latter being often neglected from CV-building activities.

Clinical leadership requires more than technical proficiency. It involves setting standards of care, modelling ethical practice, and creating environments where patient safety and quality improvement are actively pursued. In resource-constrained systems, clinical leaders must also make complex decisions about allocation, innovation, and service design, while also ensuring support and upliftment of those they lead.

Academic leadership can be viewed as three interdependent domains:

a. Educational leadership: sustained measurable self-improvement in health-sciences education with meaningful contributions to curriculum design, delivery, and evaluation; building true teaching portfolios that demonstrate reflective practice and continuous professional development; and mentoring the next generation of clinicians and educators.

b. Research leadership: establishing a sustained, independent research portfolio that demonstrates intellectual independence, originality, and the capacity to attract funding and collaboration. Importantly, leadership is not about isolated publications but about building a coherent body of work that influences policy, practice, or pedagogy and contributes meaningfully to the knowledge frontier. This opens the proverbial can of worms where "leaders" may demand their names on publications, and have a faux-active research component on a CV that still lacks demonstrable independent original-research capacity, but this is an issue for another editorial.

c. Institutional contribution: serving on and often chairing committees that matter for governance such as senate, faculty boards, ethics committees, professional councils, are often required as proof of leadership, rather than peripheral or "CV-padding" activities. However, dormant occupation of positions on committees has no reflection in evidence of contribution to these important activities. Nonetheless, leadership is evidenced by influence where informed strategic decisions about education and health systems are made.

d. Policy and management leadership demands the ability to translate professional expertise into governance impact: influencing regulatory frameworks, designing and implementing oral health programmes, and aligning dental services with broader health system goals. This must be evidence-based and grounded in best-practice. This level of leadership requires sustained engagement with organisations of consequence, whether within government, regulatory bodies such as the HPCSA, or national and provincial health departments. Progressive or regressive, there is currently no feedback-loop to hold those accountable on these key performance areas. There is the potential for systems strain to occur, especially if the guidance received is "because I said so".

Taken together, these elements begin to define a credible leadership profile: grounded in professional development, demonstrable competence in teaching and research, and meaningful participation in decision-making structures that shape the trajectory of the profession. By contrast, advancement based on compliance or superficial CV-building undermines the profession, leaving dentistry without the leaders it deserves.

The South African context: pressures on the leadership pipeline

Claims of leadership scarcity in South African dentistry cannot be explained away as a mere lack of qualified people. On the contrary, there are many clinicians and academics with established teaching portfolios, sustained independent research contributions, and even years of institutional service who are fully prepared to assume senior roles. Perhaps the difficulty lies in determining why and how these individuals are overlooked. Has dentistry rewarded competence and ability, or did it reward compliance?

Across dental schools, senior academic ranks were thin, with recent pressures to deliver academic promotions from all schools. Where once professors and senior lecturers provided mentorship and intellectual direction, the decline in these posts has the potential for pressure to fill leadership gaps quickly. In this scenario, selection processes could possibly elevate individuals without established teaching portfolios, without evidence of original and independent research leadership, and without experience of sustained progressive institutional service. The risk is obvious: when senior roles are awarded on grounds other than demonstrated academic and clinical leadership, credibility is weakened within the profession and in the eyes of students who look for authentic models of excellence.

In the public service, dental therapists and dentists with long-standing experience in patient care could find themselves passed over for managerial or programme leadership roles when preference might be given to high-visibility individuals whose public profile outweighs their record of service or policy implementation. While visibility can raise awareness of oral health, it cannot substitute for the managerial and governance competencies needed to sustain programmes at scale. The result is that seasoned professionals, those most able to bridge clinical realities with system priorities, are left without a voice at the leadership table and are forced to enact instructions they may disagree with, and to the detriment of the big picture.

The same pattern emerges in oral health programme management. Policy initiatives, such as school-based oral health, falter not because expertise is lacking in the profession, but because decision-making authority is too often concentrated in hands untested in educational delivery, programme design, or system-level research. The consequence is uneven implementation, reduced accountability, and a sense of frustration among those whose professional training and experience are sidelined.

South African dentistry thus finds itself in a paradoxical position: the problem is not an absence of competence, but rather the risk that competence is not consistently the decisive factor in leadership advancement. This raises a disquieting but essential question for the profession: if qualified, credible leaders are present but remain overlooked, why do our systems allow the advancement of those less prepared for the demands of leadership?

The appointment question: merit, governance, and system risks

If the profession is not short of competent individuals, why is it possible for key leadership roles to end up occupied by those whose qualifications and portfolios do not meet the expected benchmarks? The answer may lie less in dentistry itself than in the broader patterns of public-sector governance in South Africa.

The Public Service Commission has repeatedly highlighted irregularities in recruitment and promotion processes across national and provincial departments. These include bypassing competitive advertising, constituting selection panels improperly, and overlooking candidates who clearly meet the requirements of posts. Such practices erode confidence in the system and generate environments in which compliance, loyalty, or visibility may matter more than documented competence. Dentistry, as a health profession nested within this broader governance ecosystem, cannot consider itself immune from these risks.

The Ministerial Task Team that investigated the Health Professions Council of South Africa (HPCSA) in 2015 reported serious governance lapses, irregular expenditure, and administrative dysfunction. While reforms have since been attempted, the episode exposed how easily a regulator can drift away from its professional mandate when governance is weak. Because the HPCSA directly oversees the registration, scopes, and professional advancement of all oral health practitioners, instability or inconsistency at this level inevitably weakens confidence in leadership pathways within dentistry.

The Health Ombud has documented recurring failures of accountability in public hospitals, pointing to a culture where poor performance is rarely sanctioned and excellence often goes unrewarded. This dilutes morale and disincentivises high performers from pursuing leadership tracks. In such environments, those with strong academic or clinical credentials can find themselves stalled, while others advance through non-merit channels.

The result is a profession caught in a paradox: highly qualified academics and clinicians wait in line, while those with limited teaching experience, thin or non-existent research portfolios, and little exposure to consequential institutional governance are advanced into senior positions. The downstream effect is not only weakened institutional credibility but also a subtle redefinition of what leadership means.

The lesson here is that dentistry's leadership challenges cannot be separated from the governance systems in which it is embedded. The question for the profession, then, is not only how to prepare competent leaders, but also how to ensure that appointment processes consistently recognise and reward that competence rather than bypass it.

Global parallels: dentistry's leadership challenge is not unique

The governance dynamics shaping leadership in South African dentistry may appear stark, but they resonate with challenges observed across the world. International evidence demonstrates that dentistry, as a profession, often struggles to sustain robust leadership pipelines though the drivers differ from country to country.

In the United States, the American Dental Education Association (ADEA) has consistently reported difficulty recruiting and retaining senior faculty. Salaries that lag behind private practice earnings, coupled with heavy teaching and research expectations, have left many schools with thin senior ranks. The result is a leadership gap that mirrors South Africa's academic pipeline strain: fewer professors, fewer mentors, and weaker succession planning for deanships and department heads. In the United Kingdom, similar patterns have been described, with vacancies in senior academic posts creating instability in dental education.

A systematic review of leadership in dental practice concluded that research on the topic is fragmented, with inconsistent conceptualisation and limited empirical evaluation of training programmes. Leadership, in other words, has not historically been a core scholarly focus in dentistry. This lack of a strong evidence base makes it easier for superficial markers of leadership, visibility, personality, profile, to displace the deeper competencies of research independence, teaching excellence, and managerial governance.

In the UK and other high-income countries, service leadership has been undermined by broader workforce crises. Maldistribution between urban and rural areas, together with declining morale in public-sector dentistry, has made leadership roles difficult to fill with experienced clinicians. This, again, creates an environment in which visibility and availability, rather than competence, can become decisive factors in appointments.

Recent systematic reviews highlight the high prevalence of burnout among dental professionals worldwide, intensified by the COVID-19 pandemic. Burnout reduces willingness to assume leadership responsibilities and contributes to attrition from academia and public service. Even highly competent individuals with strong academic and clinical portfolios may choose to step back from leadership pathways when the personal and professional costs feel unsustainable.

South Africa's context, therefore, reflects both universal and particular elements. Like colleagues abroad, our profession is navigating faculty shortages, uneven leadership preparation, and the corrosive effects of burnout. Yet our situation is compounded by systemic governance weaknesses, irregular appointments, accountability deficits, and regulatory fragility, that magnify the risk of leadership misalignment. The global parallels provide reassurance that dentistry is not alone, but they also sharpen the imperative: if others are struggling despite stronger governance frameworks, then South Africa has even more reason to strengthen the merit-based identification, development, and appointment of its future leaders.

Consequences of misaligned appointments

When leadership appointments are not grounded in demonstrable competence, the consequences extend far beyond individual careers. They shape the culture, credibility, and sustainability of the profession. Dentistry, as a discipline that sits at the intersection of clinical care, education, and policy, is especially vulnerable to the distortions that arise when titles are awarded without the requisite teaching, research, or managerial experience.

a. Erosion of academic standards
- When senior academic posts are filled by individuals without substantive teaching portfolios or a record of sustained, independent research, the result is a weakening of mentorship and academic credibility. Students and junior staff, who depend on leaders to model excellence, may perceive a lowering of standards, creating cynicism about the value of academic achievement. This could be more pronounced when instructions are issued that do not align to currently accepted norms, standards and evidence.

b. Fragmentation of service delivery
- In service environments, programme leadership placed in inexperienced hands often produces variability in quality and accountability. Well-qualified practitioners who are overlooked for advancement may disengage, leaving essential services without the benefit of their expertise. The cumulative effect is fragmentation: uneven programme implementation, inconsistent patient outcomes, and an erosion of trust from the communities dentistry seeks to serve.

c. Morale and professional disengagement
- Perhaps the most corrosive consequence is the effect on morale. When high-performing individuals recognise that advancement is decoupled from competence, they either withdraw from leadership aspirations or seek opportunities outside of the public and academic sectors. Over time, this drains the system of its most credible leaders and reinforces the cycle in which visibility, compliance, or connections outweigh substance.

d. Institutional credibility
- Universities, hospitals, and regulatory bodies are judged by the calibre of their leadership. Appointing individuals without the academic or managerial credentials expected for senior roles diminishes institutional reputation, both domestically and internationally. For dental schools especially, credibility with accreditation bodies and professional councils depends on demonstrating that leadership is anchored in merit.

Defining demonstrable competence

If dentistry is to align leadership with merit, then the profession must be clear about what constitutes "demonstrable competence." This cannot be reduced to holding a title, accumulating committee memberships, or gaining visibility in professional networks. Leadership credibility cannot rest on titles, visibility, or loyalty to networks; rather, competence in dental leadership rests on a portfolio of sustained achievements and contributions across four domains:

a. Teaching and Educational Leadership
- Documented contribution to curriculum design, delivery, and evaluation.
- A teaching portfolio that demonstrates reflective practice, peer evaluation, and student outcomes.
- Evidence of mentoring and developing junior colleagues.

b. Research and Scholarly Independence
- A coherent body of original research that demonstrates intellectual independence.
- Ability to attract funding, supervise postgraduate students, and contribute to advancing knowledge in dentistry or oral health sciences.
- A research profile that is sustained over time, not built on isolated outputs.

c. Institutional and Professional Governance
- Active and substantive involvement in decision-making bodies that matter: faculty boards, senates, ethics committees, or health policy advisory groups.
- Contributions that influence policy, accreditation, or governance processes beyond peripheral or "CV-padding" organisations.

d. Clinical and Service Leadership
- Setting standards of care, ensuring patient safety, and innovating in service delivery.
- Experience in managing teams, implementing programmes, and delivering outcomes in resource-constrained environments.

Taken together, these domains provide a transparent and testable framework for assessing competence. They move the discussion away from personality, visibility, or compliance, and instead foreground the qualities that sustain institutions, strengthen the profession, and serve the public good.

Suggesting pathways to align leadership with competence

a. Transparent and competency based appointment frameworks
- Universities, hospitals, and provincial departments should adopt explicit criteria for senior appointments in dentistry, drawing directly on the domains outlined above. Appointment panels should require documented teaching portfolios, evidence of research independence, and governance contributions, not only clinical experience or public visibility.

b. Independent oversight in selection processes
- To protect integrity, appointment processes should include independent observers or external examiners, a common practice in global academia. This helps reduce the perception, or reality, of favouritism, or of having seats occupied by biased collaborators, and ensures that the profession holds itself accountable to its own standards.

c. Performance compacts tied to measurable outcomes
- Appointments to senior roles should be coupled with formal performance agreements that track outputs in teaching, research, service, and governance. This creates accountability and provides clarity about what leadership must deliver.

d. Building the leadership pipeline
- Competence at senior levels cannot emerge spontaneously. Leadership development must be embedded throughout the professional life course:
  - At undergraduate level, through early exposure to teamwork, communication, and leadership competencies.
  - At postgraduate level, through structured opportunities in curriculum leadership, research supervision, and service management.
  - At CPD level, through sustained professional development in leadership and management.

e. Supporting leaders to thrive
- No leadership system can succeed if leaders are chronically overburdened. Addressing burnout through protected time for research, mentorship, and professional development is not a luxury; it is the infrastructure upon which sustained leadership rests. Leaders must not only provide, but create opportunities to grow and develop others.

By defining demonstrable competence and insisting that it guide appointments, South African dentistry can resist the drift toward superficiality and compliance, and instead cultivate leaders who inspire confidence, advance knowledge, and strengthen the profession's service to society.

Leadership in dentistry is not an optional extra. It is the force that determines whether academic programmes retain credibility, whether clinical services remain sustainable, and whether policy reforms achieve their intended impact. South Africa is not without competent individuals; our institutions are full of clinicians, academics, and researchers with the portfolios, independence, and commitment required for leadership. The concern is that systems of appointment and recognition do not always elevate them.

Patterns of appointment and promotion sometimes reward compliance or agreeability over competence, raising concerns about whether our current systems reliably identify and retain high-performing leaders. When leadership becomes decoupled from demonstrable achievement, the costs are borne not only by the profession but by patients, students, and communities who rely on dentistry's integrity.

In this piece I have suggested that competence can be defined in transparent, testable terms: through teaching portfolios, independent research leadership, governance contributions, and clinical service impact. The profession has the tools to measure and reward these achievements. What is needed is the collective will to insist that appointments at every level, from clinical units to dental schools to regulatory structures, are grounded in these criteria.

The uncomfortable but unavoidable reflection remains: if credible, qualified leaders are present but overlooked, why do our systems allow this? The answer is not to personalize blame, but to reform processes so that merit is visibly rewarded. For dentistry, the stakes are high: leadership choices today will shape the standards of our teaching, the quality of our services, and the credibility of our institutions for decades to come.

If South African dentistry is to thrive, we must have the courage to ask not only who is appointed but also on what grounds. Only then can we ensure that leadership reflects competence, inspires confidence, and secures the future of our profession.

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Strengthening Oral Health in South Africa: The Role of Public-Private Partnerships

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Mr KC Makhubele – CEO, South African Dental Association

INTRODUCTION

As South Africa celebrates 31 years of democracy, it is imperative to reflect on the progress made in oral health and identify areas where improvements are still needed. Oral health is a critical yet often overlooked component of public health, directly impacting overall well-being and quality of life. Despite strides in policy development and service delivery, significant disparities remain in access to oral healthcare, particularly in rural and historically marginalized communities. One of the most effective ways to bridge these gaps is through **public-private partnerships (PPPs).** Collaboration between the government, private sector, professional organizations, and academic institutions has the potential to enhance service delivery, improve access, and drive innovation in oral healthcare.

ORAL HEALTH AS A GLOBAL PRIORITY

The World Health Organization (WHO) estimates that **3.5 billion people worldwide** suffer from oral diseases, with low- and middle-income countries disproportionately affected. Poor oral health is not only linked to pain and tooth loss but is also associated with systemic conditions such as **cardiovascular disease, diabetes, and respiratory infections.**

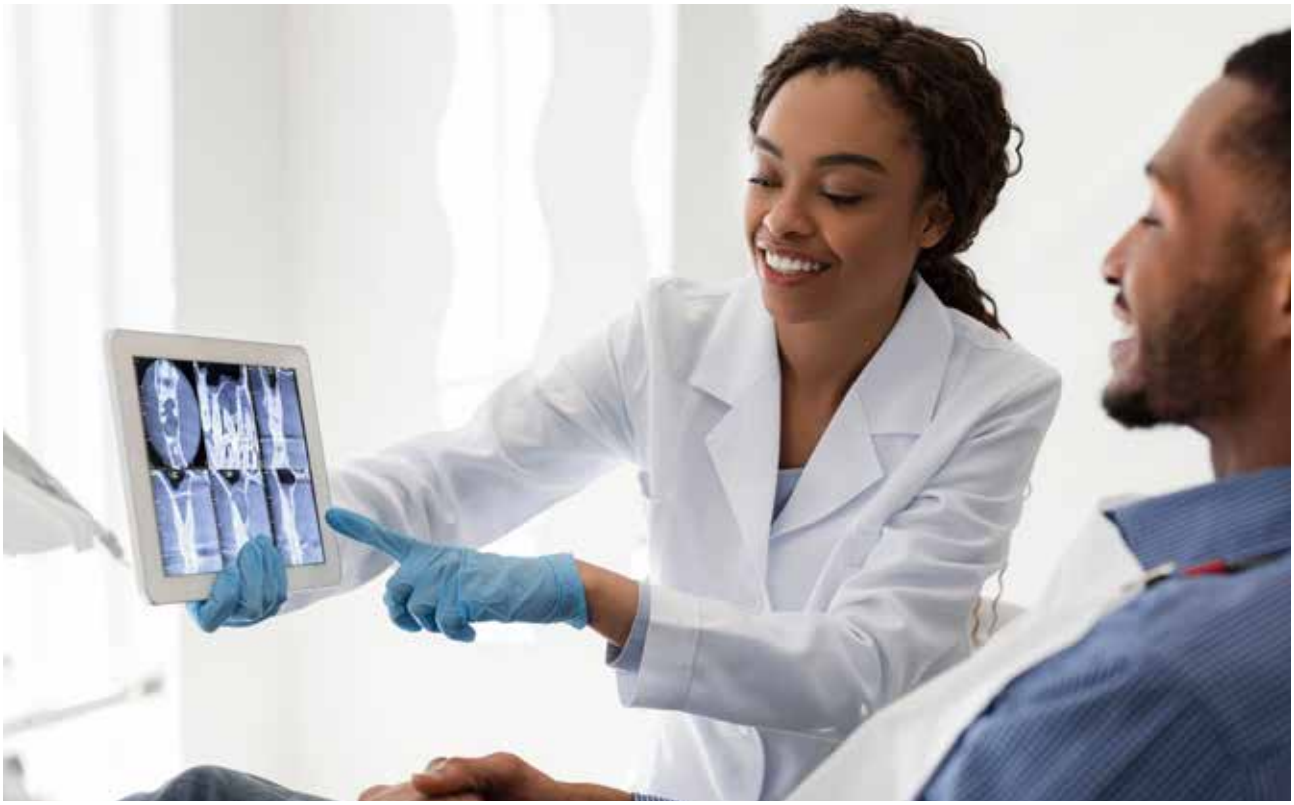
Globally, governments are recognising the importance of integrating oral health into primary healthcare systems. South Africa has made commendable progress, but the country still faces **significant challenges**, including workforce shortages, unequal distribution of dental professionals, and a lack of sustained funding for public oral health programs.

Public-Private Partnerships in Oral Health

PPPs are essential for addressing South Africa's oral health challenges. The private sector, including **corporate sponsors, dental product manufacturers, insurance companies, and NGOs,** can complement government efforts by providing funding, expertise, and technology. Effective PPPs align with national policies and contribute to **sustainable**, long-term solutions rather than temporary relief efforts.

Successful **global** examples of oral health PPPs include:

- **Brazil's "Smiling Brazil" Initiative** – A collaboration between the government and private partners to expand access to dental care for over 120 million people.
- **The UK's NHS Dental Model** – A blended approach that balances public and private dentistry services.
- **Rwanda's School-Based Oral Health Program** – A



government-private sector initiative that promotes **preventive oral care** among schoolchildren.

South Africa's Public-Private Initiatives

South Africa has already seen **some success** with public-private partnerships in oral health, including:

- **SADA's Collaboration with the National Department of Health** – Supporting professional development and policy advocacy.
- **University and Research Institution Partnerships** – Advancing community-based oral health programs and training.
- **Corporate-Sponsored Initiatives** – Programs such as Colgate's "Bright Smiles, Bright Futures" have helped improve **oral hygiene education** in schools.

However, these efforts must be **scaled up and institutionalized** within the broader healthcare system. A key concern is the **lack of structured, long-term PPP frameworks**, which can lead to inconsistent funding and delivery.

Challenges in Implementing Effective PPPs

While PPPs hold immense potential, there are several obstacles to their effective implementation in South Africa:

1. **Limited Funding & Sustainability** – Many PPPs operate on short-term funding cycles, making it difficult to sustain long-term oral health programs.
2. **Regulatory & Policy Barriers** – Bureaucratic challenges often delay private sector involvement in public health initiatives.
3. **Workforce Distribution Issues** – Rural areas remain underserved despite government incentives for dental professionals.
4. **Integration into the National Health Insurance (NHI) Framework** – Uncertainty about how oral healthcare will be funded under the proposed NHI system.

The Way Forward: Strengthening PPPs for Oral Health Equity

To maximize the impact of PPPs and improve oral health outcomes in South Africa, the following steps are necessary:

- **Stronger Policy Frameworks** – The government must develop clear guidelines for PPP engagement in oral healthcare.
- **Expanded Investment in Technology & Infrastructure** – The private sector should be encouraged to invest in mobile dental clinics and teledentistry solutions to reach underserved areas.
- **Scaling Up School-Based Programs** – School oral health programs must be expanded to ensure preventive care reaches **children in disadvantaged communities.**
- **Enhanced Collaboration Between Stakeholders** – A multi-sectoral approach involving government, private industry, academia, and civil society is essential for sustainable progress.

Conclusion

Oral health is a fundamental part of overall health and should be treated as a national priority. While South Africa has made **significant progress** in oral healthcare over the past 30 years, persistent inequalities highlight the need for **innovative and collaborative solutions**.

Public-private partnerships offer a **pathway** to improving oral health outcomes by leveraging resources, expertise, and infrastructure from multiple sectors. To build a healthier future, South Africa must strengthen **policy integration, expand private sector engagement, and advocate for sustained investment** in oral healthcare.

By fostering **stronger partnerships**, we can work towards a future where **quality oral healthcare** is accessible to all South Africans, regardless of their economic or geographical status.

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A Review of Chemical Approaches Inherent to Endodontic Disinfection Protocols: Part 1

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F Peer [1],YE Choonara[2], P Kumar[3]

Key Words
Endodontics; chemical disinfection; endodontic irrigation.

Running title
Chemical Approaches for Endodontic Disinfection Protocols

ABSTRACT

Objectives
Endodontic treatment is a common dental procedure. This review paper discusses chemical endodontic disinfection protocols, including types of irrigation solutions, solution activation techniques, and intracanal medicaments. This comprehensive review is structured in two parts: Part one will examine the various types of endodontic irrigation solutions, while Part two will focus on adjunctive strategies to optimise irrigation efficacy, review the use of intracanal medicaments, and provide perspectives on future directions in endodontic therapy.

Materials and methods
Scientific platforms such as Pubmed and Google Scholar were (re)searched using the keywords: endodontics, endodontic disinfection, root canal disinfection, endodontic chemical debridement, endodontic irrigation, endodontic solutions, endodontic irrigant activation, and intracanal medicaments. Relevant articles were identified, screened, reviewed, and discussed.

Results
Sodium hypochlorite irrigation supplemented with EDTA remains the most popular, effective and economical protocol for endodontic disinfection.

Conclusions
Despite advancements in the field, no single ideal irrigant is available and sodium hypochlorite in combination with EDTA, is the gold standard for endodontic irrigation. Lately, there has been a shift toward developing biocompatible disinfection protocols. Materials such as ozonated oils, morinda citrifolia juice, photo-activated disinfection, nitric oxide-releasing nano matrix, and nanoparticles have been suggested, but further research on their effectiveness is still required.

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INTRODUCTION
Caries is a common disease and, when left untreated, spreads through enamel into dentine and the underlying delicate pulpal tissue, eliciting an inflammatory response. In addition, pulpal insults from trauma and periodontal infections make pulpal inflammation common, and when left untreated, pulpal tissues become necrotic, leading to apical periodontitis, which requires endodontic treatment to prevent tooth loss. Endodontic treatment is a fairly common and routine dental procedure whereby 10% of all teeth will require such treatment.[1] A review by Tibúrcio-Machado *et al.* found that half the adult population worldwide would have at least one tooth displaying signs and symptoms of disease requiring endodontic treatment.[2] For predictable and successful outcomes, the clinician must comprehensively understand endodontic principles.

The main goal of endodontic treatment is debridement and disinfection of the root canal system. In 1992, Chong and Pitt Ford emphasised the importance of controlled asepsis in infected root canals and the primary role of canal debridement and adequate canal preparation in successful outcomes.[3] Ordinola-Zapata *et al.*, also supports this concept: what is removed from the root canal is of greater significance with regard to success than what is used to seal the root canal system.[4] Therefore, it is vital for the clinician to have an understanding of tooth morphology, pathosis of pulp infection and an understanding of the materials and techniques available to debride and disinfect the root canal system.

Endodontic treatment is a complex multi-step procedure that aims to disinfect the root canal system to allow for the resolution of inflammation, infection and apical periodontitis. Complete disinfection is achieved with a combination of mechanical debridement, chemical irrigation and application of intracanal medicaments.[5] Mechanical debridement is carried out with manual and motorised filing instruments. This removes infected tissue while shaping the root canals to allow for the delivery of antimicrobial and sealing materials. Studies have

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shown that mechanical instrumentation alone is insufficient to remove microbes from infected root canals, and while microbial loads decrease during instrumentation, positive cultures are still found afterwards.[6] Combining mechanical instrumentation with chemical irrigation has effectively decreased microbial loads.[6, 7] This paper will focus on chemical disinfection protocols including irrigation solutions, its activation methods, and intracanal medicaments.

The first step to effective disinfection is understanding the pathosis of pulp infection. Microorganisms and their endotoxins are responsible for the initiation of root canal infections and persistent endodontic-induced apical periodontitis.[8, 9] The oral cavity is known to have more than 700 bacterial species,[10] but not all of these species are found in root canal infections. Understanding the specialised root canal microbial environment will help determine which biocides will be effective disinfectants. Studies have shown that a core group of microbes is responsible for root canal infections and of the hundreds of bacteria in the oral cavity, just twenty to thirty species have been consistently isolated in endodontic infections and are known as the core microbiome.[11] The root canal system is an interesting environment as it is a closed system which limits bacterial interactions, nutrient availability and produces low oxygen potentials restricting the number of bacterial species in endodontic infections. These conditions allow for mostly facultative and anaerobic microorganisms to dominate the microflora in infected root canals.[12] Of these, the most isolated species are gram-negative: Fusobacterium nucleatum, Porphyromonas species, Prevotella species, Treponema species and Tannerela forsythia and gram-positive bacteria: Pseudoramibacter alactolyticus, actonomyces species and Streptococcus species. [2, 11, 13-17]

To further complicate disinfection, these endodontic pathogens are in a coagulated mass or a polymicrobial biofilm.[18] Bacteria in biofilm are more resistant to antibacterial agents than the same bacteria in planktonic form,[19] making it difficult for antimicrobials to penetrate its structure.[20] Therefore, a two-prong approach is standard practice: mechanical disruption of the biofilm combined with a chemical biocide attack. An additional challenge to successful outcomes is the formation of a smear layer during mechanical debridement, which can be a nidus for secondary infections[21] and can compromise the final obturating seal.

The variegated anatomy of the root canal system adds further complexity to endodontic treatment. Complex and intricate anatomical variations such as isthmuses and ramifications often make mechanical irrigation impossible in these spaces. Chemical irrigation solutions are able to flow into these spaces, augmenting mechanical debridement for more thorough disinfection.[7]

Therefore, in addition to its bactericidal effects, chemical irrigation should eliminate the smear layer, organic and inorganic components, and necrotic debris and disinfect the difficult-to-reach anatomy within the root canal system. [7, 22] This paper will focus on chemical disinfection irrigant solutions. The materials and methods of mechanical instrumentation are not discussed and are beyond the scope of this paper.

IRRIGATION SOLUTIONS

An essential part of endodontic therapy is the chemical disinfection protocol. Chemical solutions augment mechanical debridement by removing or inactivating microbes, removing the smear layer, and disinfecting the hard-to-reach anatomical spaces within the root system. Many different chemical irrigants can be used to this end.

Each provides different benefits, but none provide complete disinfection with a one-step solution. Combination irrigant protocols are standard to overcome the individual limitations of each irrigant. An ideal irrigant should fulfil the following requirements: [21, 23-26]

1. Have broad-spectrum antimicrobial properties with rapid antimicrobial action
2. Have the ability to penetrate biofilms and dentine tubules
3. Dissolve organic, inorganic, necrotic tissue and smear layer
4. Inactivate endotoxin and lipoteichoic acid
5. Low surface tension for optimal irrigant penetration
6. Should not weaken or stain tooth structure
7. Easy to use and easy to remove from the root canal
8. Should be innocuous to dental materials
9. Be biocompatible with the adjacent oral tissues
10. Be non-toxic to local and systemic tissues
11. Have minimal ability to evoke an anaphylactic reaction
12. Low cost and easy to store

A practical way to classify these solutions is by their mechanism of action, which enables the clinician to choose an irrigant based on their usefulness and appropriate clinical application (see Figure 1):

- Antibacterial agents
- Chelating agents
- Combination of antibacterial and chelating agents
- Adjunct solutions
- A new subclass of natural irrigants with regenerative potentials

Some irrigants have a dual purpose and may not strictly fall into the sub-classification but cross over into other categories. We have used their most common purpose for classification purposes.

Antimicrobial Irrigants

Microorganisms and their endotoxins are responsible for the initiation of root canal infections and persistent endodontic-induced apical periodontitis.[8-9] Mechanical debridement alone is not sufficient to eradicate these microorganisms. A two-prong approach is standard, whereby mechanical instrumentation disrupts the microbial biofilm, enabling chemical biocides to attack the microbes. Furthermore, complex root anatomies make it impossible for mechanical instruments to navigate into all areas of the root system. Antimicrobial irrigant solutions can reach these complex areas, augmenting disinfection for improved results.

Sodium Hypochlorite

Sodium hypochlorite (NaOCl) has an extensive history in endodontic therapy and is still the most widely used irrigant today.[27-30] NaOCl is a proteolytic agent that works as an oxidiser and hydrolysing agent and is effective against bacterial biofilms, removal of organic tissue remnants and necrotic debris.[27, 31] It plays a minor role in lubricating the canal for easier instrumentation and cooling the tooth when higher-powered instruments are used.

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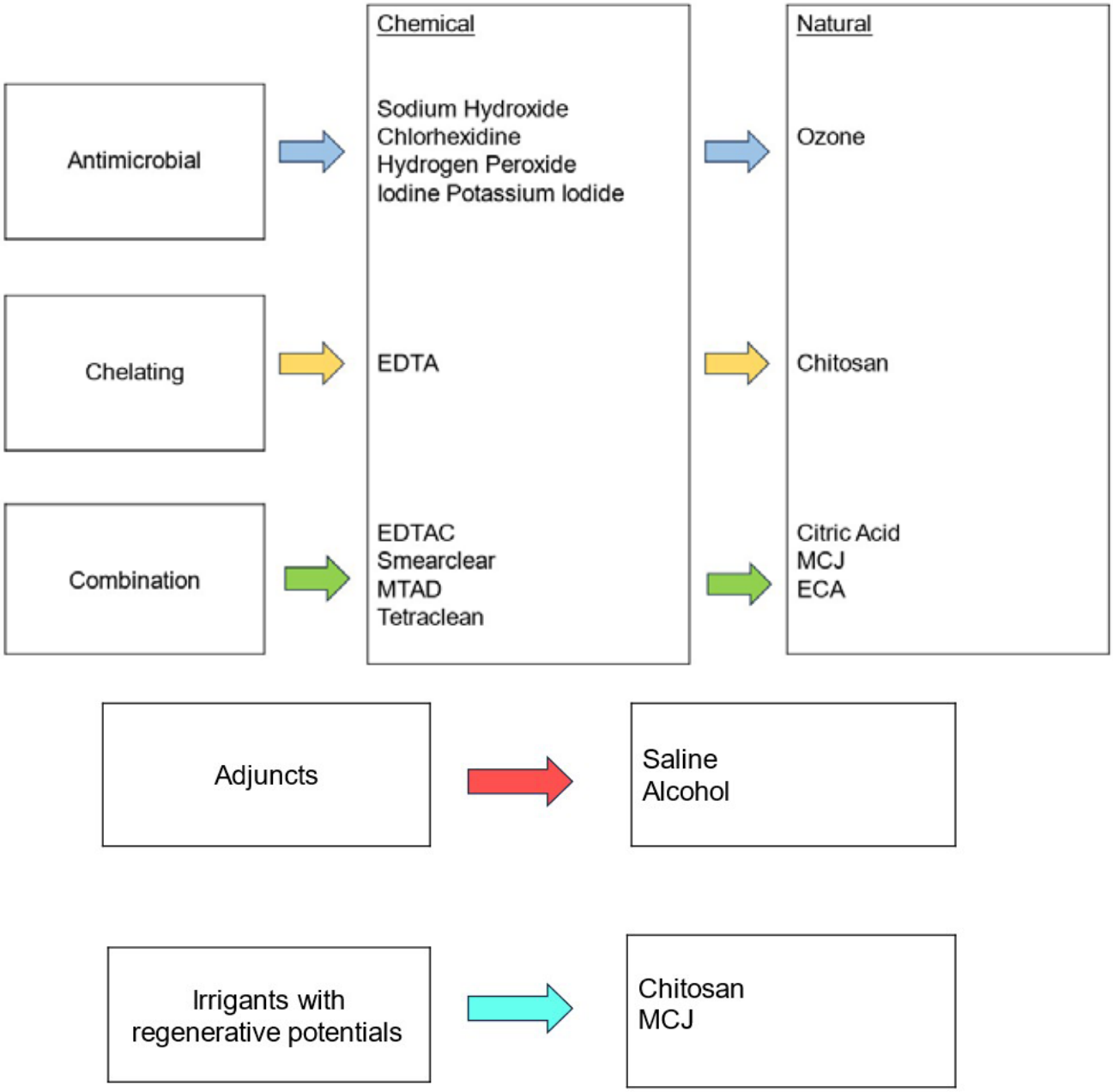

Figure 1: Classification system for irrigation solutions.

NaOCl is a strong bactericidal base commonly used in concentrations of 0.5% to 6%. NaOCl ionises in water into sodium (Na+) and hypochlorite ions, OCl–, and establishes a dynamic balance with hypochlorous acid (HOCl) as depicted in the equation below.[32]

$$NaOCl + H2O \leftrightarrow NaOH + HOCl \leftrightarrow Na+ + OH- + H+ + OCl-$$

NaOCl has multiple modes of action. Firstly, the high pH of the hydroxyl ion groups compromises the integrity of cytoplasmic membranes and irreversibly inhibits enzymatic functions. Secondly, NaOCl dissolves organic tissue through saponification reactions where NaOCl dissolves fatty acids, converting them into fatty acid salts (soap) and glycerol (alcohol). Thirdly, NaOCl neutralises amino acids forming water and salt, removing the hydroxyl group and lowering the pH. Lastly, when HOCl comes into contact with organic tissue, it acts as a solvent, releasing chlorine.[32] Chlorine is a strong oxidant that not only inhibits bacterial enzymes but also interacts with amino groups and forms chloramines, affecting the cellular functions of microbial cells and causing rapid cell death.[27]

NaOCl toxicity can induce severe adverse reactions if the irrigant accidentally extrudes into the surrounding tissues. At high concentrations, NaOCl damages vital tissues making it extremely cytotoxic, while at lower concentrations, it induces an inflammatory reaction in vital tissues.[7] Therefore, care must be taken to prevent spillage and extrusion, which can cause severe adverse reactions. There are a few ways to limit this risk, from the use of a dental rubber dam, which protects the oral cavity and throat, to using specially designed endodontic needles without exerting pressure or using negative pressure irrigation systems. Heating NaOCl to between 45°- 60° increases its efficacy, and it can be more effective at lower, safer concentrations.[7] Despite its limitations and toxicity

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potential, NaOCl is the most widely used irrigant because of its effectiveness, low cost and ease of availability.[30, 33]

Chlorhexidine

Chlorhexidine (CHX) is an antimicrobial agent with many uses in dentistry. It was first used as a general antiseptic. It is effective against a wide variety of micro-organisms, making it effective as a periodontal and endodontic irrigant, typically in a 2% solution.[34]

CHX is a cationic bis-biguanide antiseptic with broad spectrum qualities. CHX is bacteriostatic at low concentrations and bactericidal at high concentrations.[35] As a cationic molecule, CHX is strongly attracted to the negatively charged components of the biofilm, i.e., bacterial cell wall, glycoproteins and phospholipids.[36-38] This results in adsorption to the phosphate-containing components of the cell, allowing CHX to passively diffuse into the cell towards the cytoplasmic membrane. The CHX molecule attaches to the inner cell membrane changing the membrane's osmotic equilibrium increasing its permeability.[39, 40] This results in the loss of low-molecular-weight molecules and cytoplasmic components, which in turn inhibits cytoplasmic enzyme activity.[37] This action occurs at low concentrations of CHX (0.2%) and is bacteriostatic; if CHX is removed at this stage, the processes will reverse. If CHX concentration increases to 2% or is sustained for an extended period of time, the process becomes bactericidal[36] where cytoplasmic coagulation and precipitation occurs with irreversible cellular damage and cell death ensues.[35, 36, 38, 41]

Multiple studies have shown that CHX exhibits antimicrobial action dependent on the solution's type, concentration and presentation.[39, 41-44] CHX is also an effective anti-fungal agent, particularly against Candida Albicans, and is clinically relevant as secondary endodontic infections tend to have increased levels of fungi within their biofilm.

CHX has been shown to have a sustained antimicrobial effect - a phenomenon known as substantivity.[45] The cationic molecules of CHX binds to the negative components of the biofilm and the hydroxyapatite of dental tissue, and is released slowly thereby prolonging its antimicrobial effects. [41, 44, 46] CHX on its own does not dissolve necrotic tissue and is less effective on gram-negative than gram-positive bacteria and, therefore, cannot be used as a single endodontic irrigant. The substantivity properties of CHX make it an ideal final irrigant, as its effects are prolonged from 48 hours up to 12 weeks, depending on the concentration used and contact time.[41]

To further support this idea of CHX as a supplementary final irrigant, studies have shown that dentine, dead microorganisms and inflammatory products from the apical exudate exhibit some buffering effect on CHX and can decrease or inhibit its antibacterial effects.[39, 47, 48] Using CHX in cleaned, debrided and disinfected root canals will improve its efficacy.

CHX demonstrates low toxicity. The worst reported adverse effects are contact dermatitis and dysgeusia. When used for prolonged periods, it causes brown staining of teeth, but this is usually reversible upon cessation. Its genotoxicity has been shown to be irrelevant on its own,[49] but when combined with NaOCl or calcium hydroxide, it can produce oxidative and pro-oxidant reactions.[45] However, this is concentration-dependent, and care should be taken to ensure that the irrigant remains within the root canal space.[45]

The main disadvantage of CHX is its inability to dissolve tissue. In an attempt to overcome this drawback, Kuruvilla and Kamath combined 0.2% CHX with 2.5% NaOCl and found this combination to be effective in reducing microbial load.[49] The active mechanism in this combination is thought to be due to the formation of CHX chloride. CHX chloride increases the ionising capacity of CHX, increasing the effectiveness of CHX alone but not NaOCl.[49] Despite the increased potential efficacy, NaOCl and CHX combination is known to produce a brown precipitate that can cause tooth discolouration and potentially interfere with the final obturation seal,[51-53] and care must be taken when this protocol is used.

Hydrogen peroxide

Hydrogen peroxide (H_2O_2) is an active biocide against viruses, bacteria, fungi and spores.[50] H_2O_2 is routinely used for sterilisation and disinfection. In dentistry, it is used in concentrations of between 1 and 30%. According to McDonnell and Russell, H_2O_2 is most effective at higher concentrations (10%-30%) and when used over longer periods of time.[51] As an endodontic irrigant, it is used in concentrations of 3-5 %.[52] Its mechanism of action involves the formation of free hydroxyl radicals, which leads to oxidation of proteins, membrane lipids, and DNA, disrupting cellular structure and function.[53] At higher concentrations, H_2O_2 is bactericidal as it causes damage to the microbial cell wall, resulting in loss of intracellular material and cell death.[54, 55]

H_2O_2 dissolves organic tissue, which may allow for deeper dentine penetration of the irrigants that follow, and is often used in combination with other irrigant solutions, thereby increasing the overall effectiveness of these irrigants. When 3% H_2O_2 was combined with CHX, the efficacy of each irrigant improved and in lower concentrations.[56] This mechanism of action is poorly understood, but it is thought that once CHX causes damage to the cytoplasmic membrane, thereby changing its osmotic permeability, H_2O_2 is able to penetrate more easily and cause irreversible damage.[52]

In the medical concentrations where H_2O_2 is used, it is non-toxic and safe as H_2O_2 degrades to water and oxygen, making it biocompatible. However, H_2O_2 has effervescent properties and there is a risk of air emphysema if seepage occurs into the surrounding tissue. Case reports have shown that extrusions of H_2O_2 into the periapical tissues cause intense pain, erythema and oedema, and treatment involves antibiotic cover with symptomatic relief.[52]

Ozone

Ozone is a natural gas in the stratosphere consisting of three oxygen atoms. Ozone has high oxidant properties and is a strong bacteriocide.[24] It reacts with the hydrocarbons in cell membranes destroying bacterial cell walls and cytoplasmic membranes increasing cell membrane permeability allowing ozone molecules to enter the cell causing cell death.[5, 57] Ozone is effective in multiple forms: ozone gas, ozonated water or ozonised oils. As a gas, ozone is unstable and lasts only a few minutes. Ozonated water and ozonised oil have a longer shelf life of a few days and months to years, respectively. Side effects of long-term exposure include epiphora, irritation to the upper airways, bronchoconstriction, rhinitis, coughing and vomiting. Ozone toxicity treatment is mainly supportive with oxygen, ascorbic acid, vitamin E, and N-acetylcysteine.[57]

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In endodontics, ozonated water has been used as an irrigant while ozonised oil has been used an intracanal dressing. In a study by Nagayoshi *et al.*, the effects of ozonated water against and Streptococcus infections in vitro in bovine dentin were evaluated. They found that the viability of both bacteria was significantly decreased in the dentine tubules. The authors also compared the cytotoxicity between ozonated water and NaOCl against L-929 mouse fibroblasts. They found that the metabolic activity of fibroblasts was high when the cells were treated with ozonated water. In contrast, when the cells were treated with 2.5% NaOCl, fibroblast activity was significantly decreased. The authors suggest that ozonated water can be useful in endodontic therapy.[58] Interestingly, Reddy and co-workers found that when sonification was combined with ozone water, the antimicrobial activity was almost the same as 2.5% NaOCl.[59] In another study by Nagayoshi *et al.*, it was found that in concentrations of 0.5–4 mg/L, ozonated water killed pure cultures of Porphyromonas endodontics and Porphyromonas gingivalis effectively.[60]

Despite this promising potential, Hems et al; discovered that ozone was only effective on planktonic bacteria and not on bacterial biofilms, which is the predominant state of bacteria within the root canal system.[61] Estrela *et al.*, studied the antimicrobial efficacy of ozonated water, gaseous ozone, sodium hypochlorite and chlorhexidine against Enterococcus faecalis in human root canals. The authors found that after twenty minutes of exposure, none of the irrigants were effective against Enterococcus faecalis.[62] These contradictory results limit the antibacterial activity of ozone as part of a root canal disinfection protocol.

Iodine potassium iodide

Iodine potassium iodide (IKI) is a combination of potassium iodide and iodine dissolved in distilled water. IKI is a potent antimicrobial agent with quick antiseptic action against microorganisms while displaying low toxicity. It is used in various concentrations ranging from 1% to 5%.[63, 64] It has shown excellent elimination of bacteria, especially Enterococcus faecalis, within a short time. Iodine is an oxidising agent that reacts with free sulfhydryl groups of bacterial enzymes. This causes disulphide linkages and destroys bacterial cell walls. Vapour evaporation and sublimation expands the reach of its antibacterial effects. As a 2% root canal irrigant, IKI has sufficient antimicrobial effects, a more pleasant odour and taste with lower toxicity compared to NaOCl and can penetrate deep into the dentine walls.[65]

However, IKI does not exert any effects on organic and necrotic tissue. Despite IKI demonstrating promising antimicrobial effects, it is less effective against bacterial biofilms. Biofilms are inherently more complicated in structure and more resistant to attack than planktonic bacteria. Abbaszadegan *et al.* state that to improve the antimicrobial effects of IKI, exposure time needs to increase. The authors state that a five-minute final rinse with IKI may be insufficient to kill the microorganisms in the extensive biofilms of necrotic pulps. They recommend using it as part of the irrigation protocol from the beginning or increasing the exposure time at the end.[66] As yet, there is no clear recommendation on the application time of IKI, with suggestions ranging between 10 and 15 minutes,[67, 68] which can be impractical in the clinical setting.

In an attempt to improve microbial elimination, IKI has been added to conventional disinfection protocols.[67, 69] Studies have shown that if IKI is used as a final rinse after mechanical instrumentation and NaOCl irrigation, it can produce negative culture tests. Peciuliene *et al.* reported a 95% culture-negative test in retreatment cases.[69] Tello-Barbaran *et al.* reported that a 15-minute rinse with 2% IKI after instrumentation and NaOCl irrigation produced 95% negative cultures.[67] However, other studies have found no additional benefit to adding IKI to the disinfection protocol. Molander *et al.* found no added antimicrobial benefit when IKI was used as an intracanal medicament for 3-7 days. The authors postulated that the organic tissue and fluids within the root canal inactivate the medicament.[70] CaOH demonstrates better antimicrobial effects over a longer time than IKI. Kvist *et al.* stated that a final rinse with IKI had the same antibacterial effects as calcium hydroxide and found no added benefit.[71] The long working time and contradictory reports on its antimicrobial effectiveness make the addition of IKI to standard disinfection protocols controversial with no clear advantage.

Enzymatic Irrigation

Niazi and co-workers proposed using enzymatic irrigation to kill and disrupt the biofilm. They developed a nutrient-stressed multispecies biofilm model from refractory endodontic infections to test the effectiveness of trypsin and proteinase K against 0.2% CHX and 1% NAOCl with or without ultrasonic activation.[72] Despite NaOCl demonstrating the best antibacterial properties, trypsin and proteinase K displayed biofilm-disrupting capability. The exact mechanisms at work are unclear, but the protease is thought to act by degrading the protein components of the bacterial cell walls and membranes, causing cellular damage and, ultimately, cell lysis and death. In addition, the proteolytic enzymes might disrupt the extracellular matrix, which is also made up of proteins secreted by bacteria, thus reducing the cohesion of the biofilm.[72]

Chelating agents

During mechanical instrumentation, a smear layer is formed on the walls of the root canal, occluding dentine tubules. The smear layer comprises dentine, remnants of pulp tissue, odontoblastic processes and bacteria. This smear layer can prevent effective irrigation penetration into dentine and the biofilm and interfere with the adhesion and penetration of sealing materials.[73] Chelating agents supplement chemical disinfection by removing the smear layer, exposing the root canal surface for improved irrigant penetration, and are used alternately with antimicrobial solutions.

EDTA

Ethylenediaminetetraacetic acid, or EDTA, is a polyaminocarboxylic acid. It is a biocompatible chelating agent that binds to minerals and metals. It is commonly used to dissolve lime scale and, systemically to treat heavy metal toxicity. EDTA reacts with calcium ions forming soluble calcium chelates.[74] As an endodontic irrigation solution, EDTA reacts with calcium ions in the dentine, helping to remove the smear layer to improve irrigation penetration while also delivering some antimicrobial activity by detaching biofilms from the walls of the root canal.[24, 75] Therefore, an alternating regimen of NaOCl and EDTA is recommended to effectively lower bacterial loads in the root canal system.[21] Jaju et al, state that a combination of NaOCl and EDTA may be more efficient in reducing bacterial loads in root canal systems than NaOCl alone (24). EDTA reduces the available chlorine in the solution and thus can reduce the effectiveness of NaOCl[21]

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and therefore, the two solutions should not be mixed, but rather irrigation with each solution should occur separately using different syringes.

EDTA has been used in varying concentrations; the most used concentration in dentistry is 17%. EDTA is known to cause dentine demineralisation by liberating phosphorus from dentine. A study by Serper and Calt demonstrated that EDTA used at higher concentrations with increased exposure time caused increased amounts of phosphorus to be released, increasing the rate of dentine demineralisation[76]. Calt and Serper tested 10 ml 17% EDTA irrigation for 1 minute and found it effective in removing the smear layer. However, it was observed that a 10-minute application of 17% EDTA caused excessive dentine demineralisation.[77] These studies concluded that increasing contact time and EDTA concentrations increases dentine demineralisation and advised against rinsing with EDTA for more than 1 minute.[76, 77] Nakashima and Terata tested 3% and 15% EDTA concentrations. They observed that both concentrations were effective in smear layer removal allowing for irrigant permeability, and concluded that 3% EDTA is sufficient for clinical application.[78]

Citric Acid

Citric acid (CA) is a weak acid with antibacterial and chelating properties and has demonstrated effective smear layer removal. As an antibacterial agent, Yamaguchi *et al.* showed that CA is able to neutralise twelve different types of root canal bacteria.[79] A recent study by Scelza *et al.* showed that a combination of 10% citric acid and 1% CHX has promising antibacterial effects in root canal irrigation.[80]

As a chelating agent, CA is reported to be slightly more potent than EDTA at a similar concentration.[74, 79, 81] A study by Prado *et al.* showed that CA can be more effective than EDTA in short durations of 30 seconds 82). It provides the same benefits as a chelator, where it may detach biofilm from root canal walls, allowing for improved irrigant penetration. CA can also be useful to remove NaOCl/CHX precipitate should it form during irrigation.[83] Additional studies have also demonstrated that 10% CA is more cytocompatible and safer than NaOCl and EDTA.[80, 82, 84] Machado and co-workers have shown that the effectiveness of CA is comparable to EDTA while being less toxic and may retain the highest rate of cell viability, and CA appears to offer more advantages than EDTA[85].

CA has also been used in combination with other irrigants. Scleza et al, tested 10% CA combined with 1% CHX (CACHX). This combination was tested against 2.5% NaOCl, 1% CHX, 10% CA and sterile water. They found that CACHX was the only irrigant to sustain a total absence of E. faecalis for a longer time after treatment. The authors concluded that this CACHX combination contributes to biofilm-free root walls. They postulate that the reason for this total elimination is the combination of chelating and antimicrobial action. With continuous irrigation, there is less possibility of smear layer and dentine debris formation, allowing for CHX substantivity.[80] Dewi *et al.*'s study support these findings where they found that the CA/CHX combination is more effective at removing the smear layer than CHX or 17% EDTA.[86]

CA is biocompatible and the least toxic of root canal irrigants, with the highest rate of cell viability.[82, 87] Scelza and co-workers tested the biocompatibility of CA/CHX on Human Periodontal Ligament Fibroblasts (HPdLF). HPdLF are used to test irrigant toxicity as root canal irrigants should be harmless to peri radicular tissues. To stimulate the clinical scenario, HPdLF were exposed to a 0.1% solution for 15 minutes, and no significant toxicity was observed when compared to unexposed cells in either cell metabolism, membrane integrity or cell proliferation.[80] CA is not only a promising adjunct to root canal disinfection, but the antimicrobial properties combined with biocompatibility and protection of cell viability, could be valuable in regenerative endodontics and the development of biocompatible root canal disinfection protocols.

Combination solutions

Chelating solutions with additives for antimicrobial effects

EDTA has limited antibacterial properties, and in the quest to simplify disinfection, antimicrobial substances have been added to EDTA to create a new class of EDTA-combination alternatives (75). Antiseptics such as quaternary ammonium compounds, usually cetrimide, have been added to EDTA, forming EDTAC to improve its bactericidal effects and clinical performance.[88] EDTAC solutions have lower surface tension than traditional EDTA, increasing irrigant penetrability.[74] Another EDTA variant is Smearclear, a 17% EDTA solution with cetrimide and an anionic surfactant to reduce its surface tension and increase its wettability properties. However, Khedmat *et al.*, demonstrated that there was no significant difference in smear layer removal between Smearclear, 17% EDTA and 10% CA.[89] Dunavant *et al.* and Wu *et al.*, on the other hand, found that traditional irrigation solutions of 1 and 6% NaOCl and 17 % EDTA, respectively outperformed Smearclear in removing root canal biofilms.[90, 91] There is no clear indication of whether Smearclear offers any added advantage over traditional EDTA.

EDTA is also available in paste form, usually in combination with urea peroxide. Urea peroxide allows debris to float out of the root canal, but a residue may be left behind, which can compromise the final seal.[92] There are several different brands of these preparations available. The use of these pastes is controversial as some studies have shown that it is not as efficient as 17% EDTA solution in removing the smear layer.[74, 93, 94] A common use of EDTA paste is as a lubricant during mechanical instrumentation, and it is particularly important when using nickel-titanium (Ni-Ti) rotary files. Manufacturers of Ni-Ti rotary files recommend using these pastes to reduce the risk of file separation in the root canal.[95] To overcome the limitations of EDTA paste preparations, it is recommended that NaOCl must be used before using the paste and regularly during root canal disinfection to be most effective.

Antibiotics have also been added to EDTA solutions to improve their antibacterial properties, and examples of these types of EDTA-antibacterial solutions are MTAD and Tetraclean. Both these irrigants have similar ingredients: an antibiotic, an acid and a detergent. In 2004, Torabinejad *et al.* developed MTAD containing doxycycline (a tetracycline isomer), CA and Tween 80 detergent.[24] Tetraclean was developed by Luciano Giardino in 2008, and the active ingredients of Tetraclean are doxycycline, CA, cetrimide and polypropylene glycol. MTAD has a higher doxycycline concentration than Tetraclean: 150mg/ml and 50mg/ml, respectively.

The tetracycline family of antibiotics is a broad-spectrum antibiotic effective against a wide variety of infections. It

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works by inhibiting protein synthesis and interferes with normal cell functions, exerting bacteriostatic effects. It has a low pH and acts as a calcium chelator, causing enamel and dentine demineralisation. Tetracyclines have a strong affinity to dentine and are able to bind quickly to dentine, prolonging its effects and demonstrating substantivity properties.[24, 96] As discussed above, CA is antibacterial and a chelating agent and effectively removes the smear layer.[79] The antibacterial effects of these EDTA-antibacterial solutions are due to the synergistic combination of doxycycline and CA. The detergent decreases the surface tension of the irrigant, allowing for better wettability and deeper penetration of the irrigant into the dentine tubules.[97]

MTAD effectively dissolves organic and inorganic debris.[98, 99] It is less cytotoxic than other irrigants and medicaments such as EDTA, hydrogen peroxide and CaOH paste.[100, 101] Hence, MTAD provides some advantages over conventional intracanal irrigants and medicaments. Shabahang and Torabinejad found that MTAD is useful in eliminating microbes resistant to conventional endodontic irrigants and medicaments.[102] MTAD is recommended as a final rinse before sealing.

Another advantage of these chelating solutions is their substantivity effects. Neglia *et al*. tested Tetraclean effectiveness and demonstrated no negative effect on bacteria immediately after application, but its action progressively increases for 72 hours until the bacterial load is wholly eliminated.[103] The behaviour is partly due to the synergistic effects of the combination of its ingredients. The CA removes the smear layer, allowing direct access of the irrigant to the dentine wall. At the same time, the reduced surface tension causes wetting of the dentine walls and allows for deeper penetration of the irrigant into the dentine.[103] Finally, the doxycycline binds to the dentine and now has time to exert its gradual and prolonged antibacterial effects on the bacteria.[96] It is as if an antibacterial reservoir is created to continuously release its antibacterial agents, thereby prolonging its effects. In comparison to NaOCl, tetraclean, with its low surface tension, can penetrate the dentine. NaOCl, on the other hand, cannot penetrate dentine, and its effects are observed immediately with obliteration of bacteria. However, without the combination of additional irrigants and medicaments, root canals irrigated with NaOCl quickly become recolonised with bacteria. In this way, tetraclean and other substances with substantivity properties are advantageous in limiting or preventing bacterial recolonisation in root canals and are recommended as a final rinse.[7]

Electrochemically Activated Solutions

Electrochemically Activated (ECA) Solutions are produced by tap water and low-concentration salt solutions.[5] Two types of ECA solutions are produced: anolyte and catholyte. Anolyte solutions have a pH of between 2 and 9 with oxidative properties and are antibacterial[7]. In contrast, catholyte solutions are alkaline and have shown strong detergent properties.[5]

As a root canal irrigant, ECA solutions have shown to have broad-spectrum antimicrobial activity and can be effective against 99.999% of microorganisms making it potentially bactericidal.[24] Studies have also demonstrated promising results, with some studies showing ECA solutions to be as effective as NaOCl at eliminating bacteria.[104-106] A study by Jaju and Jaju, 2011 has shown that ECA solutions can also be effective at removing the smear layer.[24] In addition, ECA is nontoxic and harmless to human cells,[24, 107] and this characteristic makes ECA solutions a potentially biocompatible irrigant in a step towards dental pulp regeneration.

Etidronic acid/NaOCl combination

Etidronic acid is a weak chelator that can be combined with NaOCl, simplifying irrigation with a single solution, delivering a novel concept: continuous chelation.[108, 109] Etidronic acid, also known as 1-hydroxyethylidene-1,1- bisphosphonate or HEBP, is a non-nitrogenous bisphosphonate with various medicinal uses. Etidronic acid is a biocompatible chelator, and when combined with NaOCl, it does not consume the free available chlorine molecules, unlike other chelators. In 2005, Zehnder *et al.* proposed its use as a root canal irrigant. This combination solution allows for continuous chelation throughout instrumentation instead of using a chelator as a post-instrumentation rinse. Continuous chelation allows continuous removal of tissue debris and smear layer (or prevention of its formation), thus enhancing NaOCl's penetration and improving antimicrobial effects.[110, 111] Other possible solutions in this category are tetrasodium EDTA and clodronate.

Adjunct solutions

Adjunct solutions are mentioned as supplement irrigants and not as antimicrobial irrigants. Its purpose is usually as a final rinse to remove residual chemicals before obturation. The use of these final rinses is debatable without any clear evidence of its benefits. These solutions are mentioned here for the sake of completeness.

Alcohol

Alcohol irrigation is mainly intended as a final rinse to remove irrigants and medicaments. As mentioned, the combination of CHX and NaOCl results in the formation of a brown precipitate[112-114] and can cause tooth discolouration and prevent adequate sealing of the root canal.[115-117] It is thought that rinsing intermittently with alcohol or as a final rinse will remove this precipitate.[83] However, results from studies have been contradictory. Krishnamurthy and Sudhakaran tested the ability of isopropyl alcohol in removing debris from the root canal and found that as an intermediate flush between NAOCl and CHX, it prevents precipitate formation and completely cleaned the canals.[114] However, Magron *et al.* found no significant difference in debris removal and precipitate formation between isopropyl alcohol, distilled water and saline.[83]

If intracanal dressings are not completely removed, it can compromise the final obturation seal. Over time, root canal medicaments can be dimensionally unstable and soluble, allowing bacteria to infiltrate from the coronal, lateral or apical environments.[118, 119] Various irrigating solutions have been used to remove intracanal medicaments with limited success. These irrigants include NaOCl, EDTA, CA and phosphoric acid and their combinations but with limited success.[119, 120] Studies have shown that when alcohol is used as a final rinse, the wettability of dentine improves,[122] and sealer penetration increases.[121] De Lima Dias-Junior et al, compared the effectiveness of 2.5 % NaOCl, 17% EDTA + 1.25% sodium lauryl ether sulfate (EDTA-T), 37% phosphoric acid and 70 % ethanol in removing CaOH from the root canal. They found that 70% ethanol was more effective at cleaning and penetrating root canals than NaOCl and EDTA-T in the apical third of the canal with no difference in

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both outcomes between 70% ethanol and 37% phosphoric acid.[119] In addition, studies by Ramírez-Bommer showed that 70% ethanol does not affect the inorganic content in dentine after CaOH removal.[122] Therefore, alcohol can be beneficial as a final irrigant rinse.

An added advantage of an alcohol irrigation protocol is its fast-acting antimicrobial action. In concentrations of between 60-90%, ethyl alcohol and isopropyl alcohol have broad-spectrum activity against bacteria, viruses and fungi.[51] Krishnamurthy and Sudhakaran add that since alcohol is volatile, it can assist in drying the canals in preparation for obturation.[114] Alcohol as a final root canal rinse may have benefits in removing debris, residual irrigants and medicaments, supplementary antimicrobial effects and aid in drying the canals.

Saline

Saline is another adjunct endodontic irrigant and helps with lubrication and flushing of the canals. It does not exert significant antimicrobial effects and is usually the final rinse after chemical disinfection to remove any residual chemicals to allow for optimal canal sealing. In experiments, saline is often used as the negative control in bacterial elimination and smear removal (8).

Natural irrigants

The modern world is moving towards natural organic solutions that not only mimic nature but also preserve that which is natural. From the destruction of our natural world to the increase in antibiotic-resistant infections, there is the constant search for natural alternatives. Modern medicine follows suit by looking at these natural alternatives for contemporary solutions. The field of endodontics is no different. natural irrigants are being tested, and some of these solutions have the added potential for tissue regeneration.

Morinda Citrifolia

Morinda citrifolia juice (MCJ) is derived from the Morinda citrifolia or noni plant native to Southeast Asia. It has been used as an herbal remedy for centuries and all parts of the plant from the roots, bark, stems, leaves, fruit, juice and seeds are used. The Morinda citrifolia fruit has gained interest in recent years in the medical world for its diverse range of medicinal properties, some of which are immunostimulatory, antiviral, antifungal, antibacterial, anti-inflammatory, antiseptic, analgesic, antitumor and periodontal regeneration.[8, 123-125] Morinda citrifolia has been effective against several microorganisms, some of which are Salmonella typhimurium, Escherichia coli, Staphylococcus aureus and Candida Albicans.[126-129]

With these promising properties, it is no surprise that MCJ has been suggested as a root canal irrigant. In 2008, Murray *et al.* designed the first study to compare the effectiveness of MCJ against NaOCl and CHX in smear layer removal. The authors determined that the minimum inhibitory concentration of MCJ was 6%. They tested combinations of MCJ with EDTA flushing, MCJ/CHX combination with EDTA flushing, and MCJ with saline flushing; the positive control groups were NaOCl with EDTA flushing and 2% CHX, and the negative control was plain saline rinsing. The most effective smear layer removal occurred with MCJ and NaOCl, both with EDTA flushing. The effectiveness of MCJ and NaOCl was comparable, with both irrigants removing up to 80% of the smear layer. MCJ was more effective than CHX. The authors concluded that these results were revolutionary because they suggest that root canal irrigants and disinfectant solutions can be formulated from fruit juice. Using MCJ as a root canal irrigant might be advantageous because in vitro observations are promising and are not likely to cause adverse reactions unlike NaOCl.[8]

Morinda citrifolia leaf extract has been shown to have regenerative properties. Boonanantanasarn and co-workers evaluated the potential of Morinda citrifolia on cell proliferation, mineralisation and protein synthesis in the periodontal ligament of premolars and molars. Their results show that the Morinda citrifolia extract was effective at inducing cellular proliferation, protein synthesis, alkaline phosphatase activity and in vitro matrix mineralisation, thus having osteoinductive effects on periodontal regeneration.[130] Further, Al Moghazy and co-workers reported that MCJ (in combination with EDTA) can promote survival and attachment of DPSC to the root canal walls.[131] These regenerative properties of the Morinda citrifolia have promising implications in the progress towards biocompatible root canal disinfection protocols. Peer-reviewed research on MCJ is lacking, but it has promising and exciting potential. Further studies are needed to determine the effectiveness, safety, and biocompatibility of MCJ conclusively before general use.

Chitosan

Chitosan is an abundant natural polysaccharide obtained by the deacetylation of chitin from crab and shrimp shells. It is an attractive biomaterial as it fulfils many of the pre-requisites of a biomaterial: biocompatibility, biodegradability, bioadhesiveness, non-toxic, relatively low cost, good adsorption, and demonstrates tissue regenerative properties.[132, 133] Chitosan has also displayed high chelating and antibacterial properties and, therefore, has been proposed as a root canal irrigant.[134-138]

Chitosan is polycationic and can attach to the negatively charged components of bacterial cell walls, causing their disruption and loss of intracellular components and ultimately cell death. Chitosan is also capable of disrupting the extracellular matrix of biofilms, increasing the vulnerability of bacteria within the biofilm complex.[139] Chitosan nanoparticles have already been combined with endodontic sealers to provide antibacterial effects.[140-142] Chitosan can also enhance photodynamic therapy by attaching to photosensitisers.[143]

Silva *et al.* compared the efficacy of 0.2% chitosan against more common root canal irrigants; 15% EDTA, 10% CA, and 1% acetic acid. They observed that smear layer removal of 0.2% chitosan was comparable to 15% EDTA and 10% CA. In addition, 0.2% chitosan and 15% EDTA demonstrated the greatest effect on root dentine demineralisation.[134] In a similarly designed study by Pimenta et al, where 0.2% chitosan was compared to 15% EDTA and 10% CA in its effects on root dentine microhardness. All three solutions showed similar effects on dentine root microhardness, and SEM micrographs showed that all three solutions removed the smear layer from the middle third of the root canal.[136] Ratih *et al*. undertook investigated of the effect of chitosan nanoparticles as a final irrigation solution on smear layer removal, micro-hardness, and surface roughness of root canal dentin. It was shown that 0.2% chitosan nanoparticles and 17% EDTA were similarly effective in smear layer removal and better than 2.5% NaOCl. Further, 0.2% chitosan produced higher micro-hardness and lower surface roughness of root

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canal dentin than 17% EDTA but the same as 2.5% NaOCl.[135] Darrag *et al.* compared smear layer removal of 17% EDTA, 10% CA, MTAD and 0.2% chitosan as the final irrigant. All tested irrigants were effective at smear layer removal, but more so in the coronal two-thirds than the apical third of the root canal. However, 0.2% chitosan demonstrated increased efficiency at removing the smear layer than the other three test irrigants.[137]

These studies demonstrate that chitosan is an effective chelating agent. This establishes chitosan as a potential root canal irrigant, but further studies are needed to investigate all its benefits, particularly in regenerative endodontics. With its biocompatible, biodegradable, antimicrobial, and tissue regeneration properties, chitosan may provide a biocompatible disinfection protocol.

Berberine

Berberine is an antimicrobial plant alkaloid, and in combination with other substances, it has shown antibacterial activity. In combination with 1% CHX, the antibacterial activity of berberine is comparable to 5.25% NaOCl and 2% CHX.[144] Berberine, in combination with miconazole, has demonstrated favourable biofilm activity in a non-endodontic model.[145] Further studies are needed to determine the potential clinical effectiveness of these irrigants.

Despite the variety of endodontic irrigant solutions, NaOCl combined with EDTA still remains the gold standard for chemical disinfection. This combination fulfils many requirements for an ideal solution: high efficacy against most endodontic pathogens, good penetrability and dissolvability against organic, inorganic and necrotic tissue, cost efficiency and long shelf life. Other solutions tend to be used as an adjunct to the gold standard. With medicine evolving into preservation and tissue regeneration, there has been a shift to discover more natural and biocompatible disinfection protocols. Morinda Citrifolia, chitosan and berberine are just some chemicals that have been suggested, but further research is still required in this field.

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Data availability statement

No datasets were generated or analysed during the current study.

Competing Interests

The Authors declare no Competing Financial or Non-Financial Interests.

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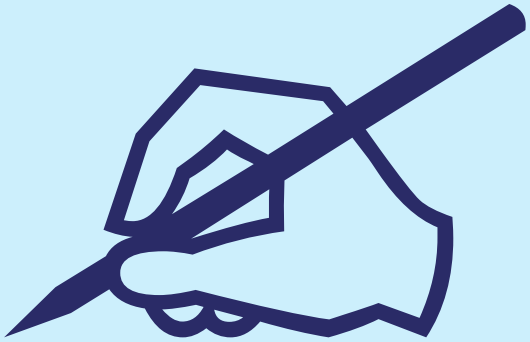
CPD questionnaire on page 392

The Continuing Professional Development (CPD) section provides for twenty general questions and five ethics questions. The section provides members with a valuable source of CPD points whilst also achieving the objective of CPD, to assure continuing education. The importance of continuing professional development should not be underestimated, it is a career-long obligation for practicing professionals.



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An evaluation of White Cell count, C-Reactive protein and Procalcitonin as diagnostic and prognostic biomarkers during the management of maxillofacial infections

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ABSTRACT

Introduction

Odontogenic infections (OI) and to a lesser extent non-odontogenic infections, constitute a substantial proportion of a maxillofacial and oral surgeon's work. These infections may be life threatening if not treated adequately. Aims and objectives: The purpose of this current study was to evaluate the diagnostic and prognostic value of White Cell count (WCC), C-Reactive Protein (CRP) and Procalcitonin (PCT), in the management of maxillofacial infections.

Design and methods: Quantitative, descriptive research was conducted to determine whether blood levels of the mentioned parameters, on day one and day three respectively, had any indication of patient's response to treatment received for the presenting infection. Serial blood samples were taken on day 1 and day 3 respectively and values were recorded in a data collection sheet and evaluated using Chi-squared tables with STATA-17 analysis.

The results showed that there was a statistically significant reduction in WCC and CRP levels following treatment, however, PCT levels did not change significantly.

In conclusion, this current study confirmed that specific blood test parameters, such as WCC and CRP, could be useful in evaluating patient's response to treatment of maxillofacial infections.

Keyword

White Cell Count, C-Reactive Protein, Procalcitonin, Maxillofacial Infections

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INTRODUCTION

Maxillofacial infections can have devastating consequences when not promptly diagnosed and treated adequately. [1] Periodontal diseases and dental caries are some of the leading causes of Odontogenic Infections (OI). [1] Therefore, good oral hygiene practice remains one of the most important factors in the prevention of these conditions. [1] The incidence, severity, morbidity and mortality of OI have declined over the past 60 years, specifically, the dramatic change in mortality, which is due to the introduction of penicillin in the treatment of infections. [2]

Special investigations used in diagnosis and treatment of OI and non-odontogenic infections include periapical radiographs and orthopantomograms, computed tomography (CT) scan, baseline blood tests (Biomarkers) and pus swab for microscopy, culture and sensitivity testing. [2]

A biomarker is described as a characteristic that can be objectively measured and evaluated as an indicator of a normal biological process, pathological process or pharmacological response to therapeutic interventions or treatment.[3]

Abnormal ranges in white cell count (WCC), C-reactive protein (CRP) and procalcitonin (PCT) are indicative of inflammation and are used to determine the presence of infection in cases with no obvious cause or signs, such as deep satellite or hidden pockets of infection, especially in ICU cases of immobile or comatose patients. Serial values are also used to monitor patient's response to treatment. [2,4,5,6]

Materials and Methods

In this prospective quantitative and descriptive study, 39 cases which satisfied the inclusion criteria were sampled in the period between the 1st of June and the 31st of December 2023. The study included patients presenting to the maxillofacial and oral surgery department with infection of the head and neck region. Serial blood samples were taken on days 1 and 3 respectively and the values were recorded and analysed. The occurrence proportions of the WCC, CRP and PCT were compared between each other and by demographic characteristics.

Furthermore, contingency (Chi-square) tables analysis were undertaken to measure the association between the

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outcome of the binary outcome of presence or absence of characteristics of interest (WCC, CRP, PCT) and the demographic characteristics. Finally, logistics regression analysis was used to identify the demographic factors that influenced the outcomes. All analysis was done using STATA-17.

Results

The total number of patients treated during the allocated time of six months was 48 (n=48). Nine patients were excluded from the study due to incomplete records. Thirty-nine (n=39) patients were included, of which 17 were female and 22 male.

Period	Day 1	Day 3	Total	Test
N	39 (50.0%)	39 (50.0%)	78 (100%)	
WCC	13.73 (5.95)	7.93 (4.0)	10.83 (5.82)	<0.001
CRP	68.31 (111.94)	74.92 (68.03)	121.62 (103.33)	<0.001
PCT	2.37 (6.65)	0.83 (1.67)	1.60 (4.88)	0.163

Table 1: Comparison of different parameters

The comparison above assumed normal distribution for WCC, CRP and PCT. The results using non–parametric method Kruskal-Wallis, still showed that differences exist between the two periods. WCC (chi2(1) with ties = 25.673 [pr=0.001]; CRP (chi2(1) with ties = 15.114 [pr=0.001] and PCT (chi2(1) with ties = 2,970 [pr=0.084]

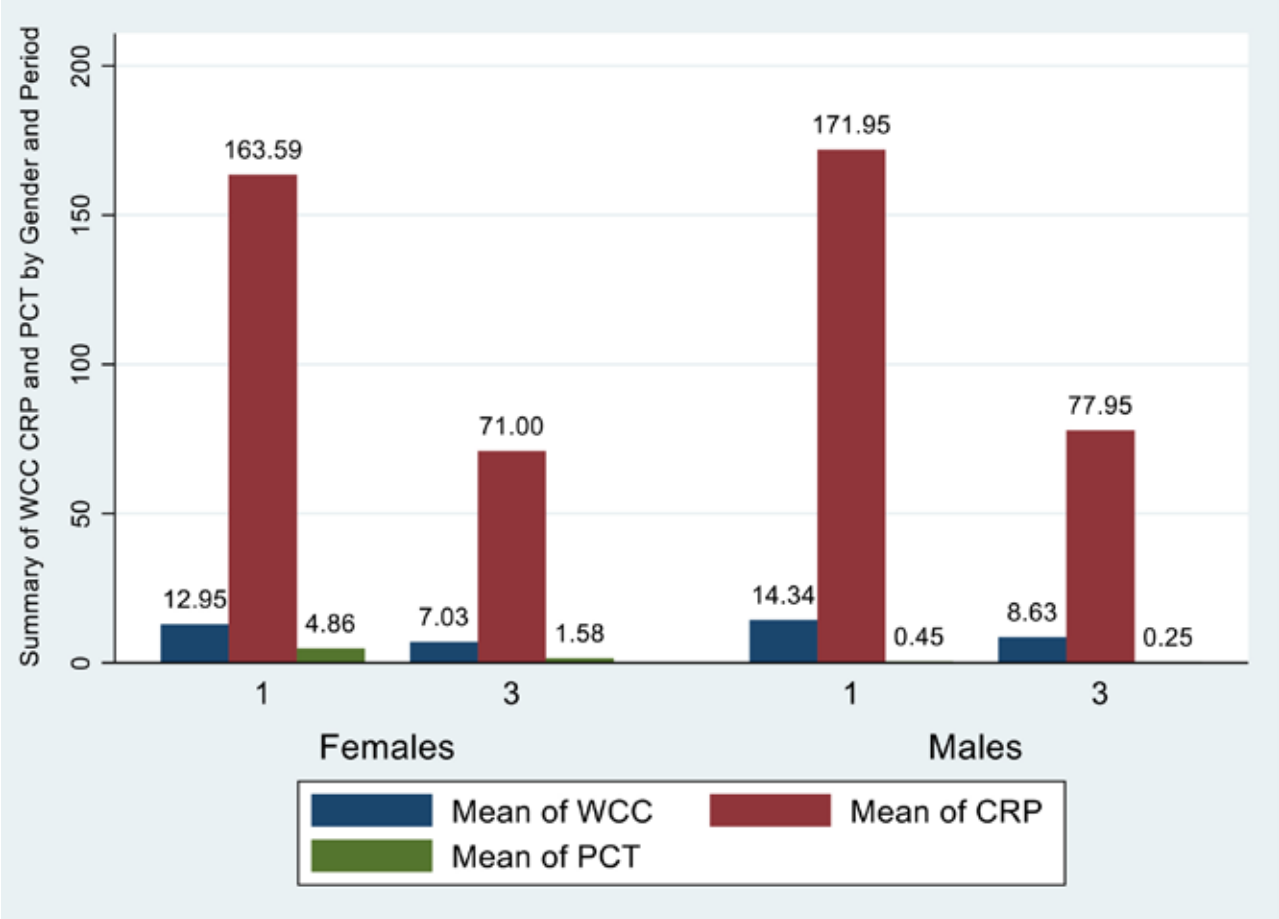

Fig 1: Graph of summary of WCC, CRP and PCT by Gender and Period

The results showed that there was a significant difference between PCT levels for males and females. The average PCT for females was 3.22 and for males 0.35.

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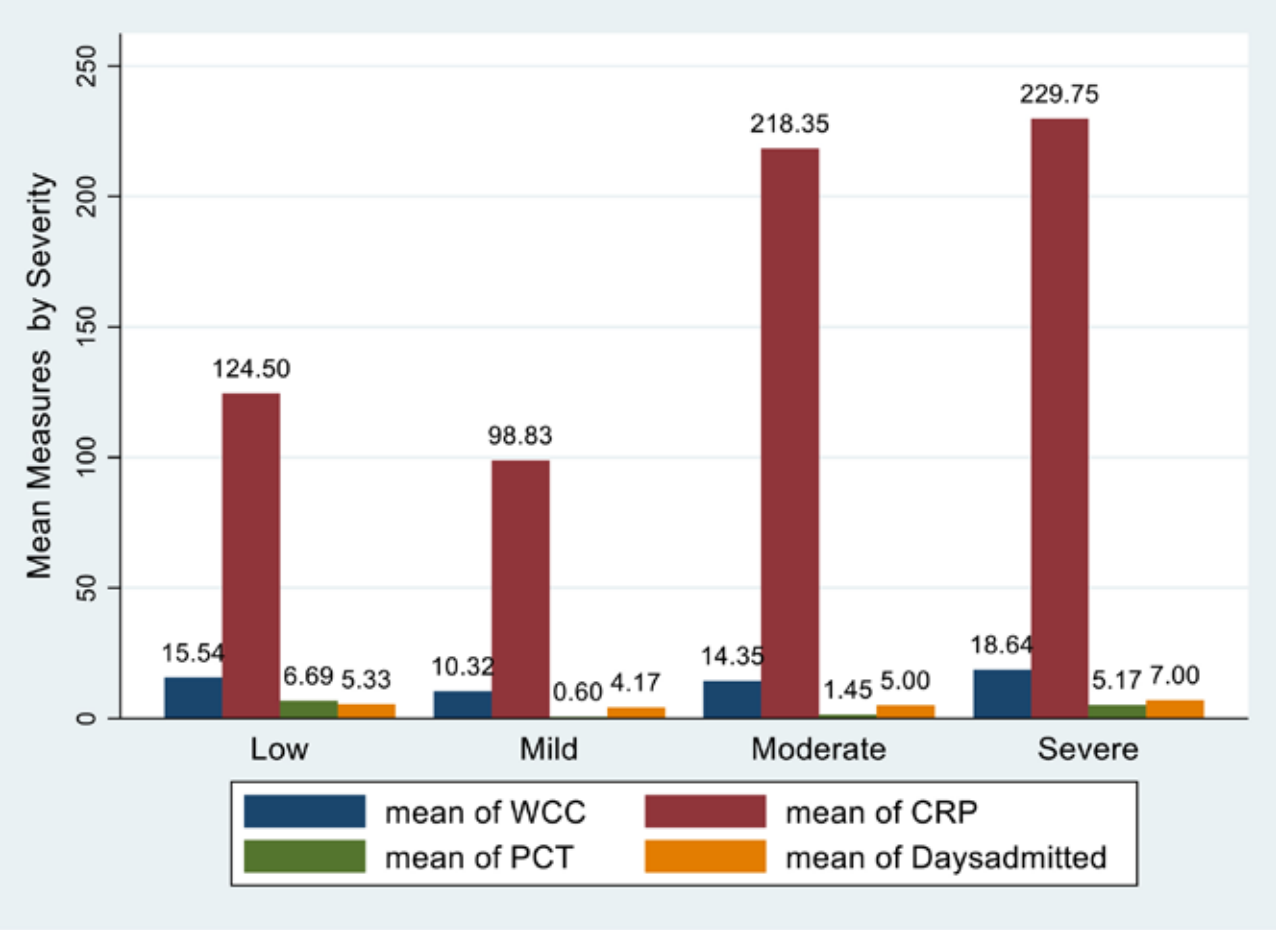

Fig 2: Graph of impact on severity on WCC, CRP and PCT

The graph above presents the outcome of the severity and the effect on WCC, CRP and PCT. This shows that the severity marginally impacted on the WCC (pr=0.06); and days admitted (pr=0.092). The level was significant for CRP (pr=0.01).

Table 2: Gender distribution of areas involved

Female: Maxillary	29%
Female: Mandible	71%
Male: Maxillary	14%
Male: Mandible	86%

The comparison in the table above does demonstrate a difference in distribution of anatomical areas involved between different genders, even though statistically insignificant.

DISCUSSION

Maxillofacial infections are common conditions that the maxillofacial and oral surgeon will encounter in his or her practice. Management of these infections require prompt diagnosis and appropriate treatment modalities. Removal of the cause, surgical incision and drainage are the corner stones of these treatment modalities.[2] The patient's response to treatment can be evaluated clinically and by means of biomarkers that can be detected in the patient's blood.[3,6,7] This current study compared the different biomarkers, WCC, CRP and PCT as potential diagnostic and prognostic tools.

The results obtained in this study of 39 (n=39) patients, regarding the demographic data related to age and gender distribution, revealed that the average age for male patients was 42.7 years (19 – 67), and for female patients 42 years (14 - 82). The total sample was 22 males (56.4%) and 17 females (43.6%). This correlates with similar studies by Kent in 2021[8] and Kaminski in 2022[9] regarding gender distribution of patients presenting with maxillofacial infections, where it was found that more males than females presented with infections. This can be attributed to cultural, behavioural and social factors causing male patients to present later when infection was already present.[8,9.10,11]

White Cell Count as the first parameter (Biomarker) in this study has a normal range between 3.92 X 10^9/L and 10.4 X 10^9/L.[8] The data for this study illustrated a range between 3.61 X 10^9/L and 35.29 X 10^9/L. On the day of presentation, the average was 13.73 X 10^9/L, and on day 3 the results showed a decrease in the average WCC to 7.93 X 10^9/L (Fig 1). This constitutes a decrease of 57.8%. Shuman 2012 [32] and Heffernan 2021[3] also demonstrated a reduction in WCC after initial treatment of infection and clinical improvement of the patient. In the same study Heffernan 2021[3] found that

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WCC as a biomarker still lacks sensitivity and specificity regarding distinction between inflammation and infection.[3]

The second parameter in this study was the CRP value. CRP is synthesised and released by the liver in response to inflammation and infection.[3] The normal value for CRP is less than 0.3 mg/dL. Values ranging from 0.3mg/dL - 1.0mg/dL are regarded as minor elevation, whilst values between 1.0–10.0mg/dL are regarded as moderate. Elevations above 10mg/dL show a marked elevation whilst more than 50mg/dL are regarded as severe elevation. In 90% of cases with CRP >50mg/dL, it is associated with bacterial infections.[7,12,13] The CRP levels on day one and three ranged between 9 and 418 mg/dL (121.6mg/dL). For day 1, the range was 2 to 213 mg/dL (168mg/dL) and for day 3, 2 to 357 mg/dL (74.9mg/dL). This shows an over-all reduction in CRP levels of 44.6% following initial treatment. This finding in the current study is in keeping with the findings of studies by Dias[14] and Largman[15] who also indicated a decrease in CRP levels after initial treatment and clinical improvement.

The third biomarker in this study was PCT, with normal values being below 0.05ug/L.[6] The value of PCT on day 1 ranged between 0.01 and 36.02ug/L (2.37ug/L), and on day 3 between 0.01 and 6.70ug/L (0.83ug/L). This demonstrates a decrease of 35% in PCT concentration following treatment. Although compared to the other biomarkers, the concentration levels of PCT in this study did not demonstrate any statistical significance. Several studies have demonstrated PCT to be a sensitive and reliable biomarker in the diagnosis and prognosis of inflammation and infection.[3,6,16] However in this current study, we did not find it to be significant. Clinicians should be cautious with patients presenting in the acute phase (within 24h) of infection that might not have an elevated PCT concentration yet, as concentration of PCT peaks at 24 hours. Shorter intervals (<12h) of re-testing levels may have no significant benefit.[3] In this current study the second test was done after 72 hours, thus enough time lapsed for the body to release PCT.

The origin of maxillofacial infections can be from various anatomical areas, but in this study we distinguished between maxillary and mandibular spaces involvement. In this study population of 39 (n=39) patients the mandibular spaces were involved in 31 patients (79.5%) and the maxillary spaces in 8 (20.5%). There was no statistically significant difference in fascial space involvement between males and females. Table 3 illustrates that maxillary spaces were involved in 29% of female and 14% of male patients. Mandibular spaces were involved in 71% of females and 86% of males respectively. This is in correlation to other studies found in the literature by Veronez[17] and Singh[18] that also indicated that the mandibular spaces are more frequently involved in relation to maxillary spaces.

CONCLUSION

The findings from this study are in keeping with the global literature regarding the usefulness of WCC and CRP levels in maxillofacial infections. PCT was non-specific in the current study, which is contrary to what is reported in the literature concerning the sensitivity of PCT as a sole biomarker.

The Maxillofacial and Oral Surgeon will encounter numerous infections in his or her career, some of which can be life threatening. Timeous diagnosis, relevant treatment and the utilization of blood tests available, will ensure a successful outcome in the majority of cases.

There is no consensus on the golden standard or perfect biomarker in the diagnosis and management of patients with inflammation and infection in the literature, however the current study demonstrated that WCC and CRP could be utilised in diagnosis and prognosis of maxillofacial infections. Although PCT was non-specific in this current study, it is still recommended in the literature as a specific and sensitive biomarker in the diagnosis and management of patients with inflammation and infection.

The current study was limited to evaluating these three biomarkers (WCC, CRP, PCT), but future studies may include more parameters.

Furthermore, this can also be done as a multi-centre collaboration to collect more data and compare the experience of different units regarding treatment of maxillofacial infections, and the utilization of different blood tests or parameters to evaluate the progress and prognosis of their patients.

Declaration

There is no conflict of interest to declare.

Ethical clearance

Ethical clearance was obtained from SMU REC with number SMUREC/D/409/2023:PG

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Impact of different types of smoking on the discolouration of teeth and nanocomposites

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ABSTRACT

Background

Tobacco is a commonly used and misused psychoactive substance.

Objective:

Comparing the impact of different methods of smoking tobacco on tooth discolouration and colour stability of 3M™ Filtek™ Universal Nanohybrid composite.

Materials and Methods

For this *in vitro* study, 40 sound premolars and 40 composite discs were randomly divided into 4 groups (N=10 teeth and N=10 composite discs per group). A machine mimicking smoking was utilised, exposing the study groups to tobacco smoke as follows: **Group A to cigarette smoke, Group B to e-cigarette smoke, Group C to waterpipe smoke, and Group D was the control group.** The study period was over 5 days, completing 10 cycles/day. Two readings were recorded, at baseline and on day 5 for each group. Colour changes for both teeth and composite discs were determined using a stereomicroscope. Statistical analysis included using the two-way mixed measures ANOVA with Bonferroni corrections.

Results

The darkest colour was shown with cigarette smoke exposure in group A for the teeth and composite discs. A statistically significant difference in change of tooth and composite colours were observed (p-value < 0.001).

Conclusion

All different tobacco consumption methods contributed some degree to tooth discolouration and composite colour change.

Keywords

Cigarette smoking, E-cigarette smoking, Waterpipe smoking, Tooth Staining, Colour Stability, nanocomposite.

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INTRODUCTION

Tobacco has been reported to be a very misused psychoactive substance among the world's rural and urban populations.[1] The World Health Organisation (WHO) reported that more than 8 million individuals die every year from tobacco use.[2] This number is predicted to rise to 10 million deaths by 2031.[3] Smoking tobacco has increased, and new consumption methods have become a trend, especially amongst the younger generations.[4]

Tobacco is generated from two plant species: Nicotiana tabacum and Nicotiana rustica.[5] Tobacco products are manufactured from raw tobacco leaves which all contain highly addictive psychoactive ingredients.[6] Some of the active ingredients of tobacco include solid submicron-sized particles like nicotine, polyaromatic hydrocarbons, phenols and nitrosamines, and the gas constituents are carbon monoxide, hydrogen cyanide and nitrogen oxides.[6] Damage caused by tobacco is from one of 3 ways: (i) Its addictive ability from nicotine [5]; (ii) the physical and /or heat irritation from the devices wherein it is used[7], and (iii) development of pathology from chemical and molecular interactions between oral cavity tissues and tobacco products.[7]

Generally, tobacco products are divided into two types, smoked tobacco and smokeless tobacco.[8] The smoked tobacco products include normal cigarettes (menthol cigarettes, light, hand-rolled, natural, or herbal cigarettes), clove cigarettes (kreteks), bidis (flavoured cigarettes), electronic or e-cigarettes (ECIGs), waterpipes, cigars, little cigars and sticks are included under this category.[8] Smoked tobacco comes in different types and methods of consumption and the method of tobacco use determines the site at which tissues are most impacted.[7]

Cigarettes represent the core of all tobacco products.[9] *In vitro* and clinical studies indicate that the toxicity and the smoke produced from conventional cigarettes is more than any other type of tobacco product.[10] These researchers also found that smoke from ECIGs and other tobacco heating products was much simpler and contained fewer elements.[10] Moreover, their research indicated that human cells and composite material responded less to ECIGs and tobacco heating products.[10]

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ECIGs or electronic nicotine delivery systems (ENDS) or vaping, was first introduced to the market in 2004 as an approach to help smokers quit smoking by delivering nicotine in a vapour form (nicotine-containing aerosol) without calcination.[7, 11-12] Their popularity has significantly increased worldwide in recent years. Vaping is becoming a popular trend among both traditional cigarette smokers and non-smokers, including adults and teenagers.[13] Since its introduction, significant advancements have resulted in multiple generations of ECIGs, thus 460 different types and 7000 different E-liquid flavours, which is its greatest appeal, are currently available.[12-13] However, the long-term effects of ECIGs use remain unclear, notwithstanding the risk of nicotine addiction, which is higher among its users.[14-16]

Tobacco in all its forms has deleterious effects on the population and their health, including oral health, and are the cause of several systemic diseases and oral conditions. The oral effects of smoking tobacco range from simple tooth staining to more serious and fatal diseases like oral cancer.[17-18] According to researchers, smokers not only had poor oral and dental hygiene (such as poor tooth brushing practices), but also unacceptable views of health (consuming more sugars and alcohol). Dentists, due to the nature of their patient interactions, will likely have easy access to 'healthy' smokers, even if there are no tobacco-related illnesses observed in the mouth. Dentists can determine, as part of routine history taking, and quickly detect the patient's smoking status. This places them in a unique position to guide smokers to prevent developing tobacco-related illnesses.[17, 19]

Tooth staining or tooth discolouration is one of the major aesthetic concerns experienced by the population. Extrinsic discolouration, which is caused by external factors, adheres to the outer surface of the tooth, for example, tea, coffee, tobacco stains and medications.[20] Smokers develop tobacco stains on their teeth due to exposure to inhaled cigarette smoke. Pigmented compounds in the tar may be deposited on the surface or even penetrate dental enamel, thus causing discolouration.[20-21] In an *in vitro* study aimed to evaluate the effect of ECIGs on enamel colour, bovine enamel blocks were exposed to 20 cycles of ECIG smoke with different e-liquid flavours and nicotine concentrations. The results indicated that ECIGs do change the colour of enamel as well as the micro-hardness of enamel.[14, 22] A recent survey aimed to look at the effect of waterpipe smoking on oral health and here 60% of the participants noticed stains on their teeth after its use.[23]

Similarly, composite restorative material colour changes, developing from either extrinsic or intrinsic factors, have been identified by practitioners impacting on aesthetics.[24] Other studies conducted to determine the effect of cigarette smoking on composites indicated a substantial decrease in the colour stability and exacerbated the staining of materials with smooth or texturised surfaces.[25-26] Although repolishing helps to reduce surface stains, the composite may not return to its original colour.[26]

Rationale

The different methods of smoking tobacco have increased and become a trend amongst young adults. Moreover, smoking that causes staining of teeth and restorations impacts patients' aesthetics and thus social relations, especially of those teeth in the aesthetic zone. Nanohybrid composite shows superior properties compared to the other available composite resins, thus it is the material of choice for clinicians.

This study therefore aimed to detect the effect of the different types of tobacco smoking methods on teeth and 3M™ Filtek™ Universal Nanohybrid composite to give value and a reference for future clinical use.

Null Hypothesis

There is no significant difference regarding the impact of the different types of smoking tobacco on teeth and nanohybrid composites such as 3M™ Filtek™ Universal Nanohybrid.

Methodology

This *in vitro* experimental laboratory study explored the effects of different smoking methods viz: cigarettes, e-cigarettes and a waterpipe on tooth colour and nanohybrid composite colour, and compared these between the different exposure groups. The samples included sound extracted premolar teeth obtained from the service rendering department at the Tygerberg Oral Health Centre and 3M™ Filtek™ Universal Nanohybrid composite discs. Following previous studies, it was determined that a definitive sample size of 40 teeth and 40 composite discs would be sufficient to yield results which would be statistically significant.[27-28]

1. Preparatory stage:

Machine preparation:

A machine which mimicked smoking was custom made. The machine was constructed using a Clements High Suction Unit (H.I. CLEMENTS PTY.LTD; Sydney, Australia), a glass

Figure 1: Set up of machine which mimics smoking

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Sample	Material	Number (N)	Size	Storage after preparation	Groups	Type of Smoke Exposure
Teeth	Maxillary & Mandibular extracted premolars	40	N/A	Samples set in silicone lab putty & stored at 37° in artificial saliva	A: 10	Cigarette
					B: 10	E-cigarette
					C: 10	Waterpipe
					D: 10	Control
Composite Discs	3M™ Filtek™ Universal Nanohybrid (Shade A3.5)	40	15mm diameter x 4mm thickness in Teflon ring mould	Stored in artificial saliva at 37°	A: 10	Cigarette
					B: 10	E-cigarette
					C: 10	Waterpipe
					D: 10	Control

Table I: Sample preparation explained indicating the different groups

container, pneumatic valves, and polyurethane pipes (Figure 1). Two holes were prepared on the glass container and the pneumatic valve was attached to each, to control the inflow and outflow of air via these (Figure 1). The sealed glass container (airtight lid and black tape) also included polyurethane pipe connections to ensure a closed seal of the entire system. The Clements high suction unit was used to produce the required pressure to mimic the inhaling process, which was calibrated to be approximately 20mmHg.[27] The machine was placed in a fume cupboard under a fume hood to remove all smoke produced by any of the methods of smoking.

Sample preparation:
The table explains the groups used in the study.

All 40 extracted premolars were cleaned, sterilised, and scaled using a Satelec Newtron Handpiece and polished using a slow handpiece and NUPRO fluoridated polishing paste (Dentsply, USA) 2 weeks before the experiment was conducted and then kept moist. Tooth samples were set in silicone lab putty 24 hours before the experiment (Table I). Each increment of each composite disc (N=40) was cured using an Elipar DeepCure-S LED curing light (3M ESPE, USA), for 10 seconds as per manufacturer's instructions. Disc thickness was measured using an electronic digital calliper (Ketotek, China).

The discs were polished using the 3M ESPE Sof-Lex polishing discs and finished using the Enhance Finishing System from Dentsply Sirona (USA). Both tooth and composite disc samples were stored in artificial saliva, made in the laboratory, at 37°C (Table I).[29]

2. Testing Stage:
Group A: The smoking machine was set, and a Malboro cigarette filter tip was attached to the polyurethane pipe, sealed using a mouth tip and electrical tape. The cigarette was placed inside a flask to eliminate any air that may accelerate its burning. The Clements high suction unit was switched on, the cigarette lit, and the suction unit was switched off when the cigarette had burned up to the filter tip. The time for the consumption of each cigarette was also measured. The smoke produced during this action, was transferred to the glass container via the polyurethane pipe. A period of 10 minutes was allowed between each cigarette to allow the smoke to be circulated and its chemicals deposited on the teeth and composite discs. This smoking cycle was repeated 10 times per group of teeth and composites as there were 10 cigarettes per pack for 5 days.

Each cigarette's burning time was calculated, and an average daily exposure time was used to be a standard for the other two groups' cycle time. Both the teeth and composite discs were stored in distilled water at 37°C, that was replenished daily.[22, 29]

Group B: The SMOK® e-cigarette (ECIG) was installed and charged daily. The e-liquid was poured into the glass reservoir and filled for each cycle. The flask holder was used to hold the e-cigarette in place and the drip tip (mouth part) was fixed into the polyurethane pipe with electrical tape. The Clements high suction unit was turned on, as was the power switch of the e-cigarette. The produced smoke was transferred through the polyurethane pipes into the glass container. This cycle was repeated 10 times for 5 days for the composite discs and extracted teeth of Group B.

Group C: The waterpipe was set up, water filled ¾ of the vase as recommended, 2 small spoons of Two Apples flavour (Al Fakher Tobacco Trading Co. Ajman, UAE) were stuffed in the bowl and covered with foil. The foil was punctured to allow the heat from the burnt charcoal to reach the flavoured tobacco. Two tablets of instant-light charcoal were used every 5 cycles. The mouthpiece was fixed into the polyurethane pipe with electrical tape. The Clements high suction was switched on and the produced smoke was transferred to the glass container via the polyurethane pipe. The cycle time was determined according to the average time for a cigarette to burn. This cycle was repeated 10 times a day for 5 days.

Group D: Both the composite discs and the teeth served as the control group, and these were not exposed to anything. The samples were stored in distilled water at 37°C which was replenished daily. The following protocols were followed for all 4 groups of tooth and composite samples daily. At the end of each smoking exposure cycle, the fume cupboard hood was turned on to remove any residual smoke.

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3. Analysis Stage: Colour Changes
Prior to examining the colour measurement of the teeth and composite discs, the Zeiss Stemi 508 stereomicroscope (Zeiss, Oberkochen, Germany) was calibrated as per manufacturer's recommendations. Images were transferred using ZEN Lite software. To standardise the colour measurement process, the teeth were dried for 3 seconds, and then absorbent paper was used to remove excess moisture. A white sheet of paper was used as a background to eliminate any error in the readings.

The sample teeth were placed under the microscope and the colour readings of each sample were recorded usig the L*, a* and b* scale of the CIELAB colour space (Fig 2).

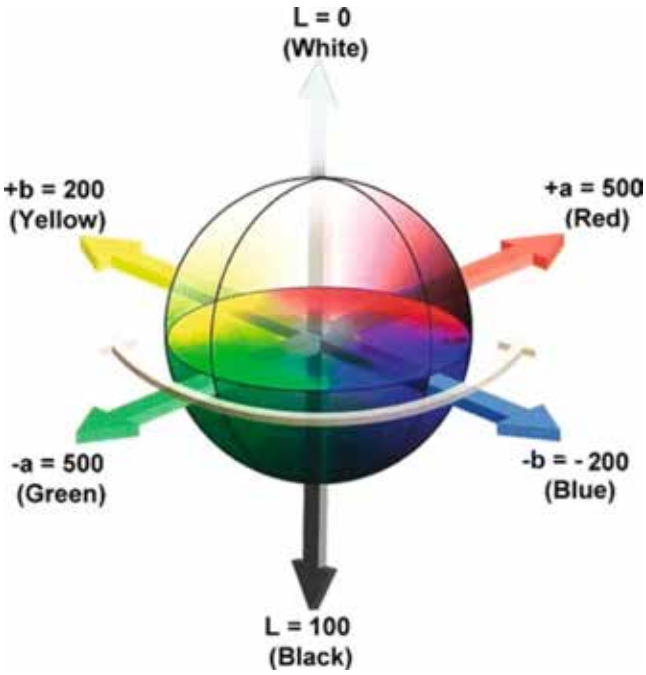

Figure 2: The CIELAB Colour Space

The explanation of the scales of the CIELAB colour space chart are:
- **L*** represents *lightness from black to white* on a scale of *zero to 100*,
- **a* and b*** represent *chromaticity* with no specific numeric limits,
- **Negative a*** corresponds with *green*, and positive a* corresponds with red, and
- **Negative b*** corresponds with *blue* and positive b* corresponds with yellow (Fig 2).[30]

For this study, baseline colour readings were obtained for each sample, colour measurements were taken on both buccal and palatal/lingual surfaces. Each reading was repeated three times. Subsequent readings were obtained after 5 days. A single specimen from each group which was exposed to the different types of tobacco was photographed to visually demonstrate any possible effects. To illustrate the effect of the different types of smoked tobacco on nanohybrid composite restorations, one specimen of each group was photographed before and after exposure to smoke.

Disposal of the extracted teeth was done through Tygerberg hospital disposal system for human tissue.

Statistical Analysis
The changes in tooth colour and composite disc colour after staining were observed and recorded. The results hereof are displayed by box plots and mean and standard deviation tables. The statistical analysis includes the 2-way mixed measures ANOVA with Bonferroni corrections.

Results
For this cross-sectional laboratory study, the project was registered with the institutional ethics review board (BMREC Reg No: BM19/9/4). The results of the pilot study with teeth and composite discs (N=10) guided the sample size finalisation. Following this, the effect of the different types of smoking was studied and its impact on the colour of the teeth and composite material in the form of composite discs is reported below.

a. Changes in tooth colour
The sample of teeth (N=40) were finalised for each group exposed to:
- cigarette smoke (Group A),
- e-cigarette (Group B),
- water pipe (Group C) and
- control group (Group D – no exposure).

Colour readings were taken on both buccal and lingual surfaces of each tooth and an average per tooth was calculated. Readings were documented as an intensity mean value which indicates the hue of the tooth colour. All samples (tooth and composite) had readings done at baseline (Day 0) and on the 5th day of exposure (Day 5) (Figure 3).

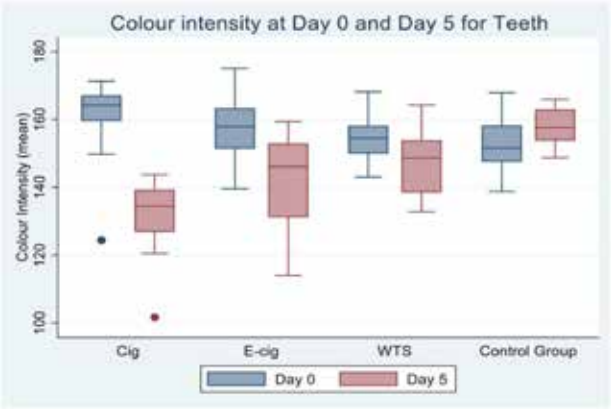

Figure 3: Box plot of mean tooth colour intensity for different groups

Figure 4 indicates the comparison of tooth staining between the different exposure groups, indicated by the mean percentage tooth colour change. The variation in colour changes between exposure groups was recorded at baseline and day 5. The negative change is indicative of darker colour intensity. The darkest colour is shown in group A exposed to cigarette smoke (mean colour change=132.51 and SD=10.03955), followed by group B exposed to e-cigarettes. Whilst the mean colour change for Group C that was exposed to waterpipe smoke, showed even less colour change compared to Groups A and B. The smallest percentage change in tooth colour is shown among group D, the control group.

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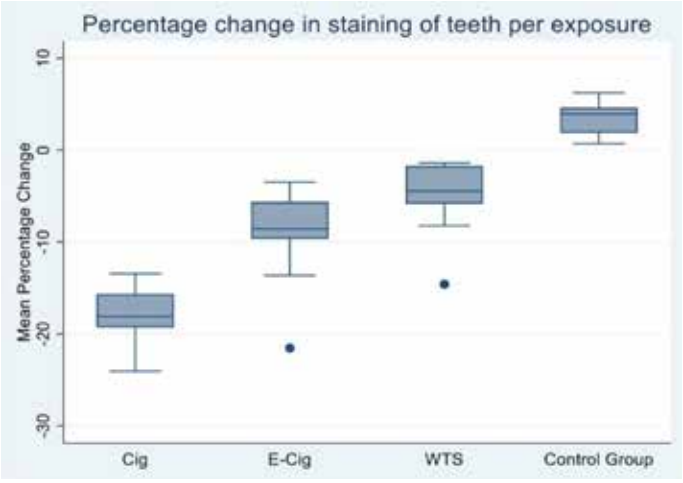

Figure 4: Comparison of percentage colour change of tooth staining of different exposures

To determine and compare the effects of different types of smoking exposures on teeth, a two-way mixed measures ANOVA with Bonferroni corrections for tooth discolouration analysis, was employed. The results of the ANOVA test where the average mean of tooth staining readings between groups was compared, indicates that there was a statistically significant difference in change of tooth colour between the four different exposure groups (p-value of < 0.001).

When applying the Bonferroni corrections for tooth discolouration analysis between these 4 exposure groups, the largest difference in tooth colour intensity was seen between group D and group A at a 95% confidence interval (Fig 4, 5). Group A was darker than group D with a contrast of 21.22 (CI: 16.51-25.96), which was statistically significant (p < 0.001). This was followed by a statistically significant difference (p < 0.001) between group C and group A with a contrast of 12.793 (CI: 8.082-17.504), and which was followed closely by the difference between group B and D (p < 0.001; CI: 8.025-17.447). A statistically significant difference was also observed between groups A and B (p < 0.001; CI: 3.777 to 13.199) and between groups C and D (p < 0.001; CI: 3.720 to 13.142). However, the smallest difference was seen between groups C and B with a contrast of 4.305 (CI: -.405 to 9.016) but this was not statistically significant (p-value = 0.091).

Figure 5: Buccal surfaces of permanent premolars following Cigarette smoke exposure and viewed under Zeiss Stemi 508 Stereomicroscope.

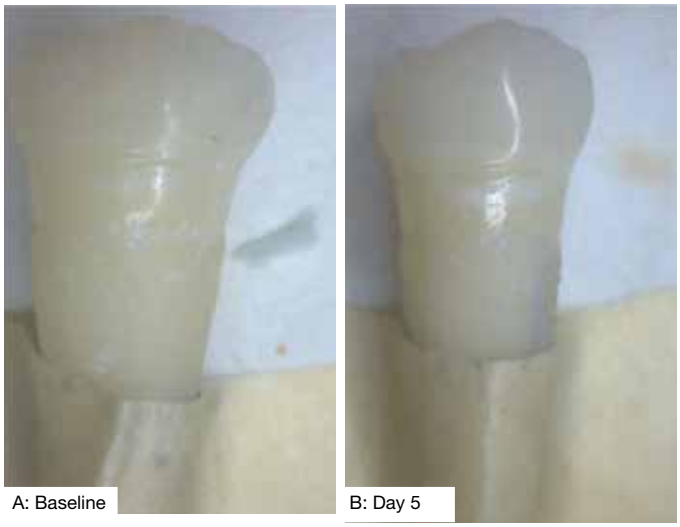

Figure 6: Buccal surfaces of permanent premolars of the Control group viewed under Zeiss Stemi 508 Stereomicroscope

b) Composite Staining

The colour staining of 3M™ Filtek™ Universal Nanohybrid composite in the four study groups exposed to cigarette smoking, e-cigarettes, waterpipe smoking, and the control group was also measured. Two readings were recorded, first at baseline (Day 0), and then the second reading was taken on the fifth day after the exposure (Day 5). Reading values were reported according to the intensity mean value, which reflects the hue of the colour from the scale of the CIELAB colour space chart.

The box plot (Fig 7) displays the mean values of the study composite discs colour intensity on day 0, and day 5. Baseline colour was the lightest for group A, followed by group C then by group D, the control group. The darkest baseline colour was for group B, the E-cigarette group.

On day 5, the mean colour change was the lightest for groups D, B, C, and A with the intensity in this order (Figure 7 below).

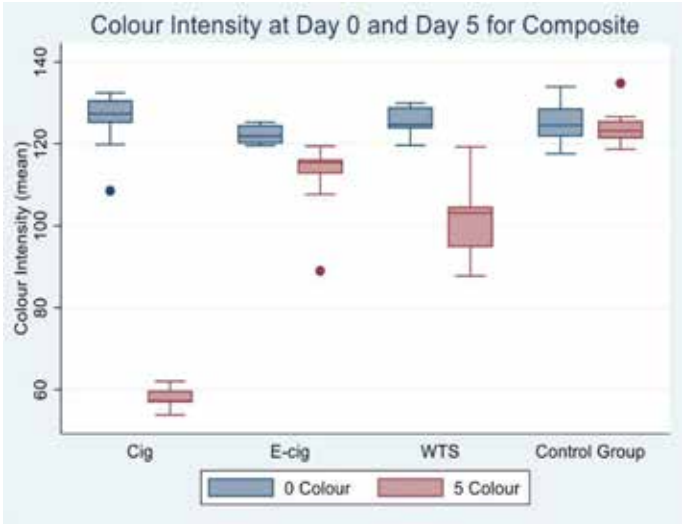

Figure 7: Box Plot of the colour intensity mean of composite discs

The mean composite colour % change among the four groups is shown in the box plot (Fig 8 below). The negative change is indicative of a darker colour intensity. The darkest colour showed in group A exposed to cigarette smoke (mean colour change -53 and SD=4.45), followed by the group C exposed to waterpipe

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smoke, then by group B, the E-cigarette sample. The smallest percentage change in composite colour was shown among group D, the control group (Fig 8 below).

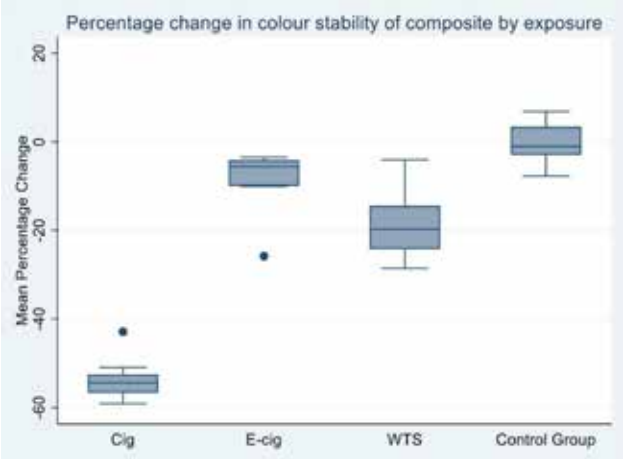

Figure 8: Mean of composite colour percentage change among the exposure groups

On average, the 3M™ Filtek™ Universal Nanohybrid composite colour is darker between day 0 and day 5 for the group exposed to cigarette smoke (Fig 9). The waterpipe exposure group C showed some colour changes too, with the E-cigarette showing minimal differences between the shades for this period. However, there was a decrease in colour intensity in exposure D control group.

The effects of different types of smoking exposures on 3M™ Filtek™ Universal Nanohybrid composite discs were measured, analysed, and compared across the study groups using a two-way mixed measures ANOVA with Bonferroni corrections for colour staining analysis.

When comparing the different exposure groups for the colour change of the composite samples by employing the ANOVA test, the average mean of the colour staining readings were found to be statistically significant (p-value< 0.0001). In addition, when applying the Bonferroni corrections for composite colour change analysis, to examine the comparison between exposure groups at a 95% confidence interval, results confirmed that there was a statistically significant difference between some of the exposure groups. The difference seen between exposure groups D and B was not statistically significant (p = 0.066).

The largest statistically significant difference in composite colour intensity was seen between groups D and A, where group A was darker with contrast of 53.11878 ($p < 0.001$; CI: 45.29316-60.94441). Comparing the different groups to Group A, the difference in colour intensity was also statistically significant between groups B and A ($p < 0.001$) and between groups C and A ($p < 0.001$), where Group A was always darker (Fig 9, 10). The difference between the control group D and group C (waterpipe group) was also statistically significant ($p<0.001$), but the difference between groups C and B was not significant ($p=0.006$).

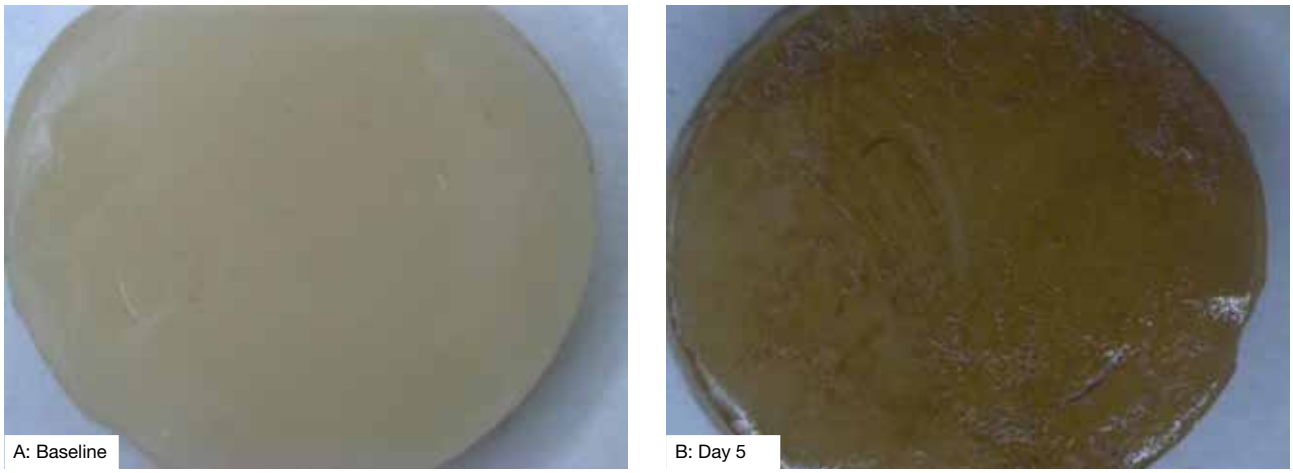

Figure 9: Microscopic view of Cigarette exposure group of Nanohybrid composite discs

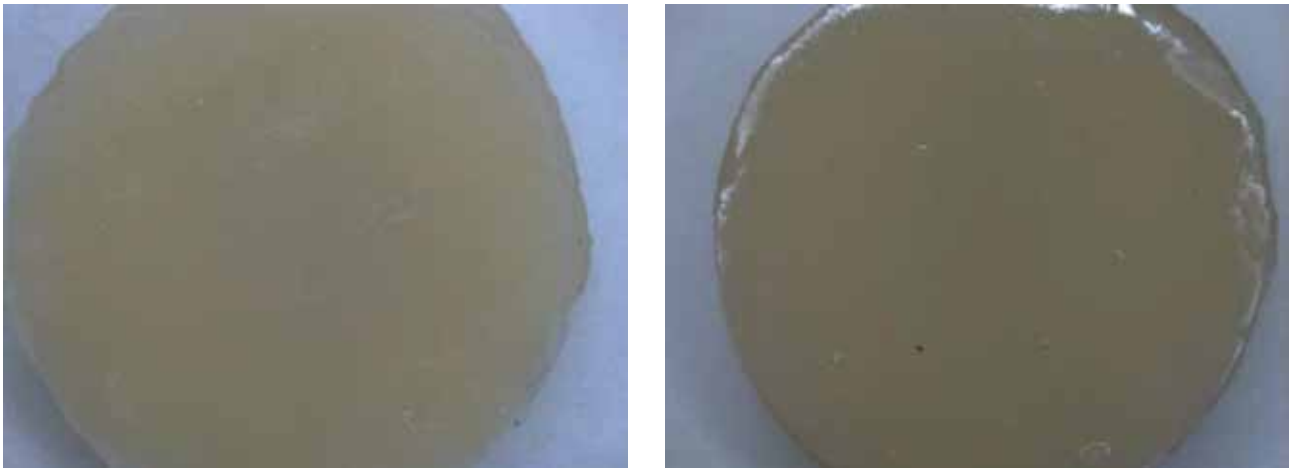

Figure 10: Day 5 of E-Cigarette exposure and Waterpipe exposure of composite discs

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DISCUSSION

Following the completion of this study and the outcomes achieved, the null hypothesis '*there is no significant difference in the impact of the different types of smoking tobacco on teeth and nanohybrid composite*' can be refuted. The details of these outcomes are outlined further and in line with the literature.

This study was rather unique as it used different smoking types and compared these. In many other studies, the researchers demonstrated the effect of cigarette smoking on the staining of teeth, but very few have investigated the effects of e-cigarette and waterpipe smoke on teeth. For this study, the sample selection was also random, and it was observed that there was a difference between baseline colour readings in all the exposure groups as the sample of teeth were from different people. The importance of similar variables at baseline is thus important as difference can impact on the study outcomes.

It was also observed that staining between groups differed, especially between exposure to cigarettes and e-cigarettes. This could be attributed to the fact that the composition of tobacco in a cigarette is more complex than that of the liquid in an e-cigarette.[10]

The results from this study showed that different smoking methods may cause some degree of tooth staining and composite colour change, and this is supported by findings of several researchers.[10, 22, 31] These findings reported how cigarette smoking causes the darkest tooth discolouration, followed by e-cigarette and waterpipe smoking, and where the control group was the lightest in colour, which is similar to this study.

The current study's results also showed that e-cigarette smoke resulted in less tooth discolouration compared to cigarettes. However, Dalrymple *et al* (2018)[31] proposed that a more plausible explanation for this difference can be related to the complex nature of the composition of the cigarette compared to that of the e-cigarette.[31] Zhao *et al* (2019)[10], in line with this study's outcomes, indicated that cigarette smoke caused more discolouration of teeth than e-cigarette smoke.[10] The effect of waterpipe smoking on tooth discolouration conducted in this study, was supported by the Lakdawala *et al* (2019) study.[23] They investigated the effect of waterpipe smoking on enamel and found that it also caused an alteration in tooth colour.

This study showed that there was a statistically significant difference in the change of tooth colour amongst the four groups of different types of smoking. This is important and the outcomes significant as the study conditions were the same for each exposure group. The implication was that when different smoking methods are used under the same circumstances, each of them would have a different effect on tooth colour. However, there was only a small statistical difference between the effects of waterpipe smoking and e-cigarette smoking, while differences between the effects of other types of smoke exposure were significant. More importantly, the impact of smoking on teeth affects the aesthetics, which will be of great concern for clinical practitioners.

Similarly, for this study the greatest colour change on the composite discs was noted in the group exposed to cigarette smoke, followed by waterpipe smoking and e-cigarette smoking. Thus, all smoking methods lead to a change in composite colour, and the implication of this means that clinically exposure to smoking would lead to aesthetic failure. This conclusion is supported in the literature by findings by Zhao *et al*. (2019)[10], Raptis *et al*. (1982)[25], and Vieira-Junior *et al*. (2020).[10, 25, 32]

Raptis *et al* (1982)[25] many years ago suggested that tobacco smoking caused a change in colour due to the remaining unreacted monomers after curing. Then years later, Vieira-Junior reported in 2020[32] that 99% of the nicotine present in the particulate phase of tobacco happens to be yellow in colour.[32]

Zhao *et al* (2019)[10] conducted research and reported that cigarette smoke showed a greater colour change in composite colours than any exposure to e-cigarette smoke.[10] It was also reported that the cause for the discolouration of both teeth and composites which are exposed to e-cigarettes was because of the yellowish colour which is produced from the oxidation of nicotine in the e-cigarette flavours.

New smoking trends have resulted in an increase of tobacco use across a much broader age spectrum. In contradiction to the various methods of tobacco use, there is a greater awareness and concern about dental aesthetics and the appearance of the smile. The population is becoming more concerned about having stain free, white teeth. Thus, the importance of conducting this research cannot be overemphasised and the next phase in translating these *in vitro* outcomes would be to conduct more clinically related research that could guide clinical practice.

CONCLUSION

The different means of consuming tobacco causes various degrees of tooth and composite discolouration. Cigarette smoking still causes more drastic tooth and composite colour changes, compared to an e-cigarette, and waterpipe smoking.

CLINICAL SIGNIFICANCE

The dental professional is in a good position to monitor "healthy" smokers and can identify tobacco-related conditions, and even recognise a patient as a smoker based on the presentation of the oral cavity. This means that the dental professional is in a unique position to counsel a patient on smoking cessation and should seek formal training to achieve this.

That said, not having had any formal training in counselling patients in smoking cessation, identifies this as an important gap in their undergraduate training. This type of counselling can be routinely included in the dental profession and should be part of plaque control, nutritional guidance, and oral hygiene instruction.[17] In addition, during dental appointments, smoking cessation treatments (including counselling) are effective in helping patients quit smoking.[12]

LIMITATIONS

The study conducted was *in vitro*. Staining has a multifactorial aetiology and is impacted by several factors such as dental hygiene, consumption of certain foods and beverages and even the aging process.[20] Since these factors cannot be addressed in an *in vitro* study, or was not even the aim of the researchers, it clearly is a limitation of the study. In addition, the composite discs (study sample) were polished using a handpiece, 3M ESPE Sof-Lex polishing discs and finished

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using finishing discs from the Enhance finishing system by Dentsply Sirona. The resultant thickness of the discs after polishing and the smoothness of the discs would differ from disc to disc as pressure during polishing would not have been consistent using a handpiece. This clearly makes polishing in this manner and its effect a limitation of the study.

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Exploring Oral Health Care-Seeking Behaviours: Patient Perspectives on Western and Traditional Health Practices in Rural KwaZulu-Natal

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ABSTRACT

Background

South Africa (SA) is currently undergoing significant demographic shifts, particularly in patterns of population distribution, while simultaneously grappling with a complex burden of disease characterized by high costs, mortality, and morbidity. Despite its classification as a developing country, SA continues to face persistent challenges in delivering effective primary health care, especially in rural communities. These systemic limitations often compel patients to seek alternative care, including traditional health practices.

The environment in which individuals live, particularly factors including accessibility, availability, and affordability of health services, plays a critical role in shaping their health-seeking behaviours. This is equally true for oral health care, which is intrinsically linked to overall health and well-being. In rural areas of KwaZulu-Natal (KZN), where access to formal dental services may be limited, understanding patients' attitudes and behaviours toward oral health care is essential. Such insights can inform targeted interventions to improve oral hygiene practices and reduce the prevalence of oral diseases within these rural, underserved communities.

Objective

This study aimed to explore patients' treatment-seeking behaviours for oral health conditions and examine their perceptions of Western and African traditional health practices in the context of accessing oral health care.

Methods

This quantitative study employed an explorative cross-sectional design, using a self-administered questionnaire to obtain patients' knowledge, attitudes, and preferences when seeking oral health care in rural KZN. The sample size was 120, recruited using snowball and stratified random sampling techniques. Completed questionnaires were analysed using Social Sciences (SPSS) software version 26.0. The outcomes were presented by descriptive analysis using cross-tabulations, graphs, and other figures.

Results

While dental professionals and traditional healers were reported as accessible within the communities, the choice of consultation was shaped by a complex interplay of dental pain, cultural beliefs, personal experiences, and perceived effectiveness.

Conclusion

This study highlights participants' dual engagement with Western and African traditional health practices for treating oral diseases. Dental pain emerged as the predominant driver of treatment-seeking behaviour, significantly impacting participants' self-esteem, social interactions, and overall lifestyle. Understanding these nuanced behaviours is essential for developing culturally sensitive and contextually relevant oral health programs.

Keyword

oral diseases, oral health care, health-seeking behaviour, dental professionals, traditional health practice

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Exploring Oral Health Care-Seeking Behaviours: Patient Perspectives on Western and Traditional Health Practices in Rural KwaZulu-Natal

INTRODUCTION

South Africa (SA) is currently undergoing notable demographic shifts alongside a persistent quadruple burden of disease. This burden encompasses a rise in chronic illnesses, the persistence of poverty-related diseases, increasing rates of injury, and the ongoing impact of opportunistic infections associated with HIV/AIDS[1,2]. Despite being classified as a developing country, South Africa's Primary Health Care (PHC) system faces ongoing challenges in delivering equitable and effective health services, particularly in rural and underserved areas. Addressing these challenges requires the development of informed health policies and programs grounded in an understanding of health-seeking behaviours. Such insight is vital for facilitating early diagnosis, ensuring timely and appropriate treatment, and implementing contextually relevant health strategies[3]. Understanding how individuals engage with the health system becomes increasingly important in this context.

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Health-seeking behaviour refers to individuals' actions to maintain or restore their health. These behaviours are shaped by a complex interplay of personal, social, and environmental determinants, including the availability, accessibility, and perceived quality of health care services[4]. Additionally, individuals' knowledge, attitudes, and cultural beliefs significantly influence their decisions regarding when, where, and how to seek care[5]. Therefore, a comprehensive understanding of rural populations' health-seeking behaviours is essential for designing and delivering responsive and culturally appropriate health services.

Environmental factors, such as the accessibility and reliability of health care facilities, significantly influence how individuals seek care. In South Africa, these patterns are further shaped by deeply embedded cultural and religious practices, which inform community perceptions of illness and treatment[6]. Moreover, the pursuit of general health cannot be fully realised without addressing oral health, which is often overlooked despite its integral role in overall well-being[7,8]. The oral cavity functions as a critical gateway to systemic health, with oral diseases frequently serving as indicators or contributors to broader health conditions[9].

Personal characteristics, including age, gender, and family background, also contribute to health-seeking behaviours and are associated with the progression of oral diseases in rural communities. These populations are particularly vulnerable due to geographic isolation, dietary habits, inadequate oral hygiene practices[11], and stoicism in illness behaviour. Stoicism, characterized by silent endurance and emotional restraint[11], marked by emotional restraint and the silent endurance of discomfort[11], often results in delayed symptom reporting, contributing to "patient delay," "delayed diagnosis," and ultimately, postponed treatment initiation[12].

In KwaZulu-Natal (KZN), the burden of oral diseases, including dental caries and periodontal conditions, remains disproportionately high[13]. Gaining insight into the health-seeking behaviours of rural patients is essential for identifying prevailing attitudes toward oral health, reducing neglect of oral hygiene, and mitigating the overall burden of oral disease[14].

Despite the significance of this issue, there remains a paucity of research exploring the intersection of oral health care and traditional health practices. His study seeks to address this gap by examining patients' health-seeking behaviours about oral disease treatment, with a particular focus on their perspectives regarding both Western biomedical and African traditional health systems. It forms part of a broader mixed-methods investigation to identify strategies to improve oral health care in rural communities.

OBJECTIVES OF STUDY

This study aimed to explore patients' treatment-seeking behaviours for oral health conditions and examine their perceptions of Western and African traditional health practices in the context of accessing oral health care.

METHODS

Study design

This quantitative study employed an exploratory, cross-sectional design to investigate patients' health-seeking behaviours and preferences when consulting Western and African traditional health practitioners to treat oral diseases. Data were collected using a structured, self-administered questionnaire.

Setting

The study was conducted across five KwaZulu-Natal (KZN) rural districts, including Amajuba, Ilembe, King Cetshwayo, Ugu, and Uthukela district municipalities. Initially, the study was to be carried out in the 11 district municipalities of KZN, but only five district municipalities participated due to the lockdown restrictions imposed by the COVID-19 pandemic. Private practitioners, including dentists and dental therapists in the selected areas, were approached to allow their patients to participate in the study.

Sampling and selection criteria

A combination of snowball and stratified random sampling techniques was used to recruit participants for the study. Initially, dental therapists in the selected districts referred other practitioners in private practice. Following this, permission was obtained from five nominated practice owners to recruit patients from their practices.

Proportional allocation of stratified random sampling was applied using the formula:

$n_1 = (N_1/N) \times n$, where N represents the total target population, N_1 the population size within each stratum, n the total sample size (initially calculated as 379 using Raosoft software), and n_1 the sample size per stratum. Due to COVID-19 lockdown restrictions, the study was limited to five originally intended eleven district municipalities. Following consultation with a statistician, the estimated population size was revised, and the final sample comprised 120 participants, distributed as follows: Amajuba (n=23), Ilembe (n=25), King Cetshwayo (n=27), Ugu (n=26), and Uthukela (n=19). Eligibility was based on residence in rural KZN and attendance at participating dental practices.

Data collection tool

The questionnaires were distributed to dental therapists in the participating districts, who recruited and facilitated completion by willing patients. Informed consent was obtained from all participants. The questionnaire focused on the patients' treatment-seeking behaviour for common oral diseases. To ensure confidentiality and privacy, participants completed their questionnaires independently in a private space.

Pilot study

Due to the lockdown restrictions imposed by the COVID-19 pandemic, a pilot study was not done.

Data analysis

Quantitative data was entered into an Excel spreadsheet and analysed with the Statistical Package for Social Sciences (SPSS) software version 26.0. The outcomes were presented by descriptive analysis using cross-tabulations, graphs, and other figures. Inferential techniques included correlation and chi-square test values, transcribed using the p-values.

Ethical clearance

The researcher adhered to the ethical principles; consent was obtained from all participants, the study protocol was approved, and permission to conduct the research was granted by the Human and Social Sciences Research Ethics Committee of the University of KwaZulu-Natal (HSSREC/00000951/2020).

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RESULTS AND DISCUSSION

The results are presented in two parts: participants' demographics and responses.

Socio-Demographic Characteristics

This study had a total sample size of 120. Most participants, 27% (n=32), were from King Cetshwayo, Amajuba district, with the least, 14% (n=17). Most patients, 62% (n=74), were males and 38% (n=46) were females. The participants' highest level of education is summarized in Table 1.

Table 1: Level of education

Highest level of education	Count	Percentage (%)
Primary School	14	12
Secondary School	4	3
High School	45	38
Tertiary Level	57	47
Total	**120**	**100**

Less than half, 47% (n=57), of the participants obtained a tertiary level, 38% (n=45) a high school level, 12% (n=14) a primary school level, and 3% (n=4) a secondary level.

The majority of the participants were single and religiously affiliated. Table 2 depicts the participants' religious affiliations and marital and employment statuses.

Table 2: Religion, marital, and employment statuses.

		Count	Percentage
Religion	Christian	94	78
	Islam	1	1
	Hindu	3	3
	Shembe	17	14
	Other (specify): Africanist	5	4
Marital Status	Single	91	76
	Married	21	18
	Divorced	8	6
Employment Status	Unemployed	46	38
	Self-employed	16	13
	Employed by state	36	30
	Employed in the private	22	18

The majority of participants identified as Christian, 78% (n=94), followed by Shembe adherents14% (n=17), Hindus, 3% (n=3), and the rest identified themselves as Africanists. In terms of marital status, most respondents were single, 76% (n=91), while 18% (n=21) were married, and 6% (n=8) divorced. The high unemployment rate in SA is reflected in the statistics, 38% (n=46) were unemployed, the state employed 30% (n=36), and 18% (n=22) were employed within the private sector.

Socio-Economic and Cultural Influences on Health-Seeking Behaviour

Socio-demographic and socio-economic factors influence health outcomes, particularly their impact on individuals' beliefs about disease causation and treatment preferences[15]. This study supports such associations, as a significant proportion of participants (38%, n = 46) were unemployed—aligning with national and provincial unemployment trends. For instance, district-level unemployment rates were reported as follows: Amajuba (35.6%), Ilembe (31%), King Cetshwayo (28%), Ugu (36.3%), and Umzinyathi (57.8%)[17].

Prevalence of Oral Disease and Access to Information

A substantial proportion of participants (71%, n = 86) reported having experienced oral diseases. This finding is consistent with the World Oral Health Report (2003), which identifies oral diseases as a significant global public health concern due to their high prevalence and disproportionate impact on disadvantaged populations[16].

Access to health information is a critical determinant of treatment outcomes. While 55% (n = 66) of participants indicated they had access to new information on oral health, a notable 38% (n = 46) reported lacking such access. This gap is concerning, as previous research has shown that patients often struggle to comprehend or retain information provided during clinical encounters, particularly those with low functional health literacy[18]. Tailoring health communication strategies to meet the needs of these populations is essential for improving oral health outcomes.

Knowledge

Participants' knowledge of oral diseases and the roles of both Western and African traditional health practices in oral health care was assessed using a Likert scale. Knowledge scores were categorised as follows:

- **Good knowledge:** Participants who correctly answered more than 50% of the knowledge-related items.
- **Not good knowledge:** Participants who answered fewer than 50% of the items correctly.

Overall, participants demonstrated a generally acceptable level of knowledge. However, notable variations were observed across district municipalities. The Ilembe and Ugu districts recorded the lowest proportions of participants with good knowledge, at 45% and 43%, respectively. In contrast, King Cetshwayo and Umzinyathi districts exhibited the highest knowledge scores, with 59% and 57% of participants, respectively, demonstrating good knowledge. In Amajuba, 47% of participants showed fair knowledge, while 53% demonstrated good knowledge.

More than half of the participants (55%, n = 66) reported having access to new information on oral health, while a significant proportion (71%, n = 86) indicated that they had experienced oral diseases. The choice of health care providers, whether Western or traditional, is often influenced more by perceived quality, reputation, and anecdotal success stories than by formal qualifications or institutional affiliations. This aligns with findings in consumer decision-making literature, which highlight the power of word-of-mouth as a trusted, influential, and credible source of information[19].

When participants were asked whether they had ever recommended a traditional health practitioner (THP) to

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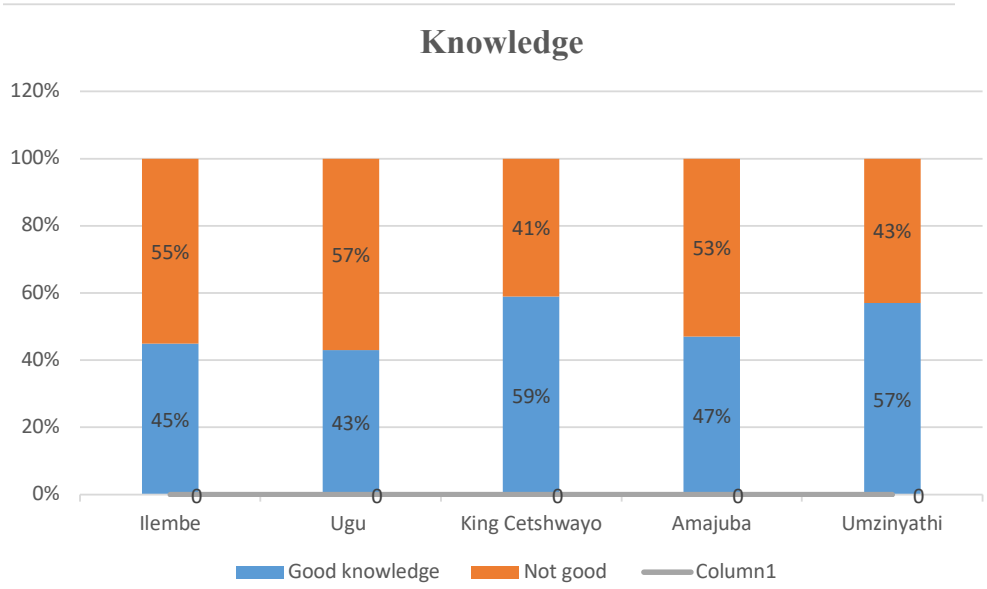

Figure 1: Knowledge levels of oral health care per district.

someone for an oral health-related condition, 68% (n = 82) responded negatively, 28% (n = 34) responded affirmatively, and the remaining participants were unsure. In contrast, when asked the same question regarding dental professionals, 76% (n = 91) reported that they had recommended a dental practitioner, while 24% (n = 29) had not.

Attitude

This section explored participants' attitudes toward oral health-related quality of life and the perceived role of traditional healers in oral health care.

Although a slight majority of participants (56%, n = 67) reported satisfaction with their current oral health status, a substantial proportion (44%, n = 53) expressed dissatisfaction. Given that general health cannot be achieved without good oral health[7,8], this study examined oral health-related quality of life (OHRQoL) through a broader lens. Literature suggests that oral health providers should assess physical symptoms such as pain, discomfort, and functional limitations (e.g., mastication and speech) and psychosocial dimensions including appearance, self-esteem, and social interaction[20].

Numerous studies support the notion that oral diseases significantly impact quality of life[21-24]. The concept of health-related quality of life acknowledges the importance of psychological and social well-being alongside physical health[24]. As such, a shift from a narrow biomedical focus to a more holistic, patient-centred approach is essential for effective oral health care[25].

Findings from this study reinforce this perspective. Most participants (72%, n = 86) reported that dental pain negatively affected their social lives, while 84% (n = 100) indicated that oral pain or discomfort disrupted their lifestyle and diminished their sense of hope. Furthermore, 86% (n = 91) agreed that dental pain adversely impacted their self-esteem.

Regarding the role of traditional health practitioners (THPs), 23% (n = 29) of respondents expressed satisfaction with the treatment received from THPs for oral health conditions. However, a significant majority (76%, n = 91) reported never disclosing their use of traditional healers to their dental professionals, highlighting a potential gap in communication and integrated care.

Perspectives

This section explored participants' perspectives on the attitudes of dental professionals toward traditional health practitioners (THPs) and the extent to which societal influences shape their health care choices. THPs continue to play a vital role in the health care systems of many South Africans and other African populations[26]. Previous research suggests that THPs are often perceived as attentive, respectful, and responsive to patients' concerns, contributing to their enduring popularity[26].

Given their cultural relevance and accessibility, this study considered THPs as alternative oral health care providers. When asked about their beliefs, 39% (n = 46) of participants expressed confidence in the healing powers of traditional healers, although only 20% (n = 24) reported having used traditional medicine for oral health-related conditions.

Health care providers' knowledge, attitudes, and perceptions influence patients' decisions. Some practitioners hesitate to advise on or engage with complementary and alternative medicine (CAM), despite acknowledging the validity of certain therapies[30]. In this study, 38% (n = 46) of participants felt that their dental professionals were comfortable with their use of THPs, while 36% (n = 43) disagreed, and 26% (n = 31) were unsure.

Consistent with previous findings[27], most participants (76%, n = 91) reported never disclosing their use of THPs to their dental professionals. Only 17% (n = 21) had done so, while 7% (n = 8) were uncertain. This aligns with Bahall's research, highlighting patients' reluctance to discuss CAM use with conventional health care providers. However, literature emphasizes the importance of open communication between patients and providers regarding CAM use[28]. Health professionals also bear responsibility for initiating such discussions, particularly when conventional treatments are ineffective or adverse effects are observed[29].

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When asked whether their dental professionals had ever advised against using traditional healers, 58% (n = 70) said they had not received such advice. Encouragingly, 80% (n = 88) of participants expressed satisfaction with the treatment received from dental professionals. However, 54% (n = 65) were unsure whether their providers were uncomfortable with their consultation of THPs for oral health issues.

Societal Influence on Treatment Choices

Figure 2 illustrates participants' perceptions of how societal norms and expectations influence their treatment decisions. A majority (74%, n = 89) reported that society did not affect their choice of treatment, with 42% strongly disagreeing and 32% disagreeing with the statement. Meanwhile, 21% (n = 26) were unsure about the extent of societal influence.

Figure 2 represents how patients' perceptions of society influence their treatment choices.

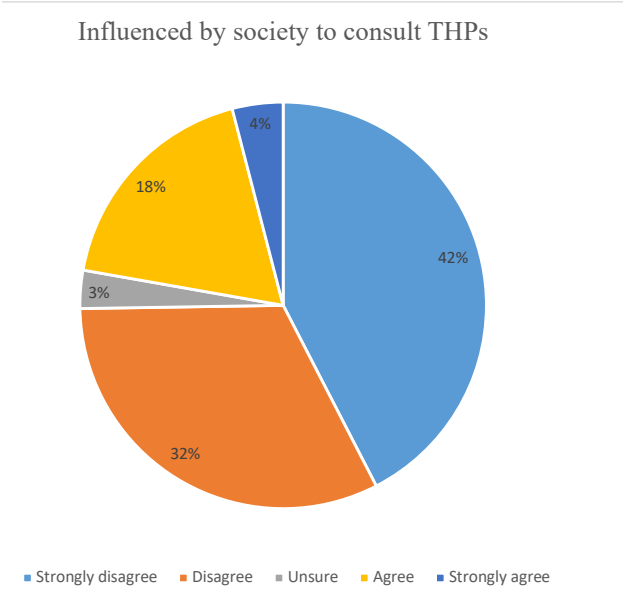

Figure 2: Participants' perspective on how society influences their treatment choice.

Preferences

Currently, there is limited literature explicitly detailing whether patients prefer conventional Western or traditional African health practices for oral health care. Findings from this study suggest that participants often engage with both systems, though it remains challenging to determine a clear preference.

Most participants (80%, n = 96) reported not consulting traditional health practitioners (THPs) before seeking care from dental professionals for oral health-related conditions. In contrast, 44% (n = 53) indicated they do not consult dental professionals before visiting THPs. This overlap suggests a pattern of dual consultation rather than exclusive reliance on one system.

When asked about the influence of cultural beliefs on their choice to consult THPs, 34% (n = 40) were unsure, indicating some ambiguity in the role of belief systems in shaping health-seeking behaviour. Additionally, just over half of the respondents (51%, n = 61) stated that their cultural or belief systems did not influence their decision to consult dental professionals. These findings highlight the complexity of patient preferences in oral health care and underscore the need for culturally sensitive approaches that acknowledge the coexistence of multiple health paradigms.

Treatment-seeking behaviour

Previous research on sexually transmitted diseases (STDs), including HIV/AIDS, has shown that traditional health practitioners (THPs) are often the first point of consultation for many individuals in both urban and rural areas of KwaZulu-Natal (KZN)[31]. However, findings from this study suggest a different pattern in the context of oral health. When participants were asked whom they consult first for oral health-related conditions, 52% (n = 63) reported consulting dental professionals before THPs, while 16% (n = 19) indicated that they consult THPs first. A notable 32% (n = 38) were unsure, reflecting some uncertainty or variability in consultation patterns.

Several factors influence individuals' treatment-seeking behaviour, including familial, cultural, and environmental elements. Families often share similar lifestyles and belief systems, which can shape collective attitudes toward illness and health care utilisation[32]. Shared physical, economic, and social circumstances may reinforce specific health behaviours within family units[33].

In this study, 74% (n = 89) of participants reported that family did not influence their decision to consult THPs, while 22% (n = 27) said it did. Regarding cultural beliefs, 55% (n = 66) disagreed that such beliefs influenced their decision to consult THPs, whereas 34% (n = 40) agreed, and 12% (n = 14) were unsure. When asked whether cultural beliefs influenced their decision to consult dental professionals, 51% (n = 61) disagreed, 41% (n = 49) agreed, and 8% (n = 10) were unsure.

Accessibility also emerged as a key factor in treatment-seeking behaviour. While 51% (n = 61) of participants reported that they could easily access a dental professional in their area, 47% (n = 56) indicated difficulty in doing so, and 3% (n = 3) were unsure. In contrast, 48% (n = 57) said they could easily access a traditional healer, 35% (n = 41) disagreed, and 18% (n = 22) were unsure.

Research has shown that perceptions of dentistry can either facilitate or hinder oral health care-seeking behaviour. These perceptions are often shaped by a range of barriers, including fear of pain or discomfort, the inability to cope with symptoms, particularly when they disrupt sleep, limited access to dental professionals, and the high cost of dental treatment[34]. In this study, pain and discomfort emerged as significant motivators for seeking care, with 77% (n = 91) of participants identifying them as primary reasons for consulting about oral diseases (Figure 3).

Responses were mixed when asked whether cost influenced their decision to consult traditional health practitioners (THPs). While 32% (n = 38) agreed that cost played a role, a majority (65%, n = 78) disagreed, and 3% (n = 4) were unsure. These findings suggest that while affordability may influence some individuals' choices, the decision to consult THPs is likely shaped by a broader set of contextual and cultural factors. (Figure 3)

CONCLUSION

This study highlights participants' dual engagement with Western and African traditional health practices for treating

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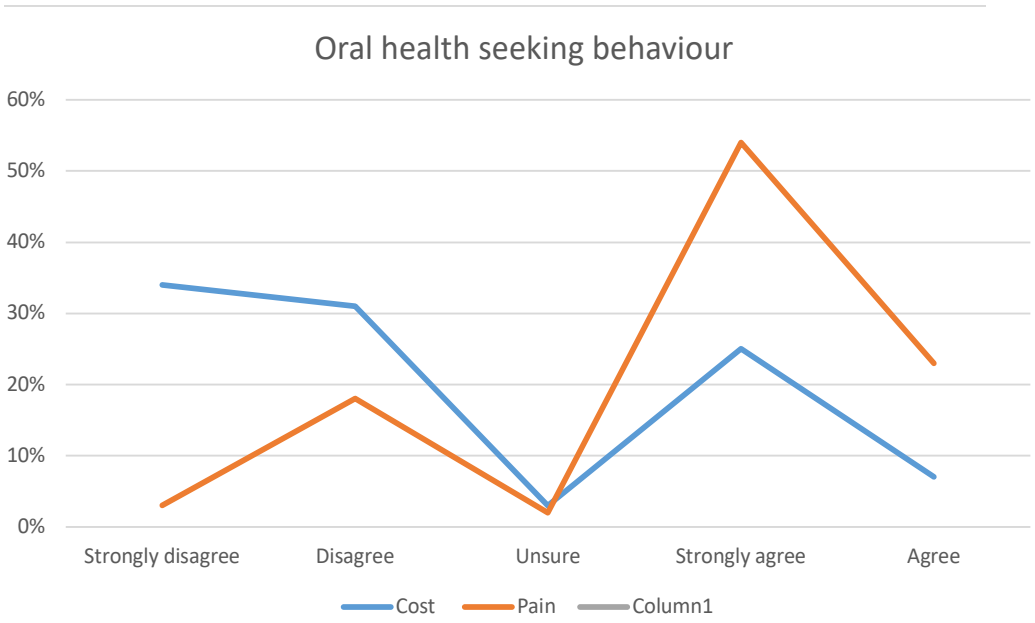

Figure. 3: Influence of pain and cost on the respondents' oral health seeking behaviour

oral diseases. Dental pain emerged as the predominant driver of treatment-seeking behaviour, significantly impacting participants' self-esteem, social interactions, and overall lifestyle. While dental professionals and traditional healers were reported as accessible within the communities, the choice of consultation was shaped by a complex interplay of cultural beliefs, personal experiences, and perceived effectiveness.

Understanding these nuanced behaviours is essential for developing culturally sensitive and contextually relevant oral health programs. By aligning health interventions with rural populations' lived realities and preferences, policymakers and practitioners can enhance service delivery, promote early diagnosis, and improve oral health outcomes in underserved communities.

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A 13-Year Follow-Up of a full mouth rehabilitation using a fixed PFM bridge opposing an acrylic veneered implant supported hybrid prosthesis

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ABSTRACT

This case report presents a 13-year follow-up of a patient rehabilitated with maxillary and mandibular prostheses made of dissimilar materials to address the differing aesthetic and functional demands in each arch. In the maxilla a fixed telescopic crown-retained porcelain fused to metal (PFM) prosthesis was fabricated which opposed a mandibular implant-supported acrylic veneered hybrid prosthesis. A 51-year-old female initially presented with functional and aesthetic concerns as a result of a fractured maxillary provisional restoration spanning from the 13-23, pain on the 13, and failing crown and bridgework on her remaining maxillary teeth. This was opposed by an acrylic provisional immediately-loaded implant supported hybrid prosthesis that had been placed in 2009. She was rehabilitated using telescopic-crowns supporting a fixed porcelain fused to metal (PFM) bridge, and an acrylic veneered implant supported prostheses. In the 13 years of follow-up, both prostheses have shown excellent longevity with the maxillary prosthesis having had only one incident of de-cementation, and the prosthesis needing repair/replacement of the veneering material and screw-access-hole closure on two occasions in 2018 and 2022. This report highlights the efficacy and long term success of using prostheses made with different materials and techniques in each arch in complex rehabilitation cases.

INTRODUCTION

Telescopic crown-retained prostheses and implant-supported hybrid prostheses are established modalities for rehabilitating patients with compromised dentitions The choice between porcelain and acrylic veneering materials involves trade-offs between aesthetics, durability, repairability and maintenance.[2] This case highlights the long-term outcomes of a maxillary porcelain fused to metal prosthesis opposing a mandibular acrylic-resin veneered hybrid prosthesis supported by five implants. It emphasises the material-specific challenges and solutions encountered in each.

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Literature Review

Telescopic crowns (double crowns/crown and sleeve copings/konuskrone) are a well-established prosthodontic solution for patients with compromised dentitions allowing for the maintenance of teeth and their periodontal ligaments (PDL) enhancing proprioception, as well as bone preservation and the potential for future modifications when neccessary.[1] They were initially introduced as retainers for removable partial dentures, and have since been used in fixed restorations as well. Despite their long historical use, published follow-up data on their durability remains limited. Telescopic crowns are indicated for patients with a compromised periodontium, caries, or trauma requiring splinting of mobile abutment teeth.[2] They allow redistribution of occlusal forces, help preserve compromised dentition, and facilitate hygiene through removable components.[3] Langer and Langer (2000) emphasised their role in rehabilitating non-parallel abutment teeth and in limiting alveolar bone loss.[4] They are however contraindicated in cases where there is poor oral hygiene, insufficient abutment support, and high aesthetic demands due to the added bulkiness.[5] Breitman *et al.* (2012) also confirmed the concerns of unaesthetic outcomes in patients who have high smile lines as well as the increased costs as disadvantages.[6] Further reported complications include cement failure and marginal and/or recurrent caries in patients with poor oral hygiene. Despite these limitations, studies report 85–95% 5-year survival rates for telescopic crown-retained prostheses.[7]

Implant-supported acrylic veneered hybrid prostheses are indicated for edentulous patients requiring cost-effective, retrievable solutions.[3] Studies report survival rates of 90–95% over 5–10 years for prostheses supported by 4–6 implants.[4] The use of five implants is believed to be ideal as its argued this will distribute occlusal loads more effectively, thus reducing cantilever strain and peri-implant bone loss.[5] Acrylic veneering, is prone to wear of approximately of 2–3 mm over 10 years, depending on factors such as occlusion, diet, and the material in the opposing arch.[6] This wear may necessitate periodic veneer replacement, typically every 5–7 years, but the process is relatively cheap and easy when compared to porcelain.[7,10]

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Acrylic, though less aesthetic than porcelain, also acts as a good shock absorber of masticatory forces which helps protect underlying frameworks and implants.[9] Porcelain prostheses on the other hand, provide superior aesthetics and wear resistance but are brittle and prone to fracture under parafunctional loads.[8] In patients requiring full mouth rehabilitation, the use of a combination of porcelain in the maxilla, and acrylic resin in the mandible can address both their aesthetic and biomechanical functional needs.[11]

Case Report

In 2013, a 51-year-old female patient presented with a main complaint of a fractured maxillary provisional bridge spanning from 13-23, pain from the 13, and a worn mandibular implant retained provisional prosthesis (figure 1). The implant-retained prosthesis had been placed in 2009, but no definitive prosthesis was ever made. The patient was adamant that she did not want to lose any more teeth, and neither did she want to wear a removable appliance.

Figure 1

Figure 2

Key Clinical Findings:

The maxilla had six remaining teeth, pain from the fractured 13 abutment tooth and grade 2 mobility of the 11 (which was expected as it had been serving as a pier abutment tooth in the provisional prosthesis (figure 3). The mandible had a severely worn acrylic hybrid prosthesis retained by five implants (figures 1 & 2).

Figure 3

In consultation with the patient, it was decided that, although compromised, the clinician would try to save all the maxillary teeth. Initial treatment included endodontic therapy to address the pulpitis and pain in the fractured 13, followed by crown preparations on all of the remaining maxillary teeth. These were then used as abutments for the definitive prosthesis, which was a telescopic crown-retained porcelain fused to metal fixed partial denture (figures 4,5 & 6). The mandible was restored with an acrylic veneered implant supported hybrid prosthesis (figure 7).

Figure 4

Figure 5

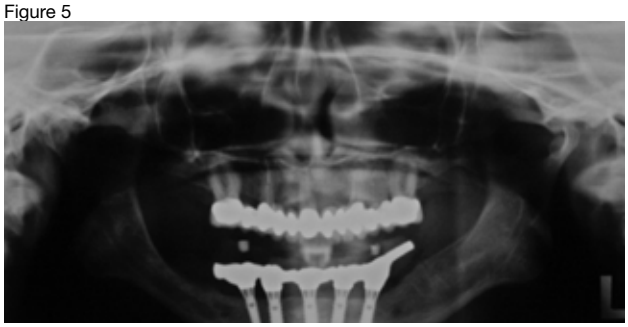

Figure 6

Figure 7

Follow up

In the maxilla, the porcelain prosthesis remained intact with no fractures for 13 years (figures 8 & 9), however there was a

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single event of cement failure (figure 10) at year 12 in 2022. This event was easily managed through sandblasting the intaglio surface of the FPD and re-cementing it. The mandibular acrylic prosthesis also remained intact and functional for over 13 years, but did exhibit ±2.5 mm occlusal wear during this time. Additionally at year seven (2019) and year ten (2022) it had two separate events requiring replacement of the screw access hole closure material which had been lost (figures 9 & 11). No implant or framework complications were observed, nor was there any noticeable bone loss in either the maxilla or mandible (figure 8). The patient reported high satisfaction with both her aesthetics and chewing efficiency.

Figure 8

Figure 9

Figure 10

Figure 11

Discussion

The 13-year success of the maxillary telescopic crown-retained PFM prosthesis (for aesthetics) and mandibular acrylic veneered hybrid prosthesis (for function) aligns with biomechanical principles. The mandibular prosthesis exhibited moderate occlusal wear (±2.5 mm over 13 years), necessitating two minor repairs. It may be argued that there is a need for the complete replacement of the veneering material, but in this instance, the patient was not keen to be without her prosthesis, and thus the wear was managed with minimal intervention, and the prosthesis was repaired and not replaced. The wear was anticipated as it aligns with studies showing acrylic's susceptibility to wear compared to porcelain, with average wear rates of 0.2–0.3 mm annually under functional loading.[5] The rate may have been accelerated in her case due to the harder porcelain material in the opposing arch. Acrylic's reduced wear resistance is a well-documented trade-off for its shock-absorbing properties, which protect implants from overload and potential peri-implant bone loss.[3,6] Notably, a four or five-implant support system distributed forces effectively, preventing framework fractures or implant mobility despite wear, consistent with protocols advocating ≥4 implants for cantilevered prostheses.[2,4] The loss of screw access hole closure material in the fourth quadrant was a minor complication, and has also been reported in the literature to occur in 15–20% of screw-retained hybrid prostheses over time.[5,8] These issues are attributed to cyclic masticatory forces and do not indicate prosthetic failure but rather routine maintenance needs.[7]

The maxillary telescopic crown-retained prosthesis has remained intact and in good condition for over a decade without fractures or caries recurrence. This underscores the durability of porcelain in splinted systems, its wear resistance and maintenance off aesthetic requirements.[9] However, one incident of debonding occurred at year 7, resolved by recementation. Cement failure in telescopic systems is reported in 5–10% of cases, often due to parafunctional habits or suboptimal cement selection, and does not compromise long-term success if promptly addressed.[10,11]

The combination of a maxillary porcelain prosthesis (prioritising aesthetics and rigidity) and a mandibular

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acrylic hybrid prosthesis (prioritising shock absorption and protective functions as well as reparability) reflects evidence-based principles for arch-specific rehabilitation.[3,12] While acrylic requires periodic veneer replacements, its ease of repair and cost-effectiveness make it ideal for the mandible, where functional demands outweigh aesthetic concerns.[5,13] Key clinical implications are that patients should be informed of the need for acrylic veneering material replacement every 5–7 years, and plan to have this carried out in order to maintain their occlusal relations and prosthesis efficiency.[6] The screw access holes composite material may require replacements which can be carried out during the advocated follow-up hygiene and maintenance appointments.[8] Cement selection is also important, resilient temporary cements (e.g., zinc oxide eugenol) are recommended for telescopic crowns to provide for retention and retrievability.[11]

Conclusion

This case illustrates that moderate acrylic wear and minor screw access hole complications are inherent to hybrid prostheses but do not equate to failure. Similarly, a single debonding event in the maxilla reflects routine maintenance needs rather than prosthetic inadequacy. The favourable 13-year outcome validates the strategic decision to use dissimilar materials in each arch to address biomechanical and aesthetic demands in complex mouth rehabilitations.

Patient Consent

Informed consent was obtained for use of illustrations for presentation and publication purposes.

Conflict of Interest:

None declared.

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The Paradox of Perception – You do not need THE EYES to SEE the person

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ABSTRACT

Covering the eyes of patients in reports or public images is often done to preserve anonymity, dignity and confidentiality. However, human recognition is a complex process involving a variety of sensory inputs that extend far beyond mere visual processing. One can often identify a person based on other non-visual cues, including auditory, tactile, social, contextual, cultural, and emotional dimensions. With regards to the face, blocking out the eyes alone does not guarantee that a person's identity will be concealed. This is because there are many other geometric and anatomical features that the brain is attuned to recognising. In addition, modern AI programmes can often be used to re-insert blocked-out features. This paper suggests that from both an ethical and legal perspective, we need to develop more sophisticated ways of treating patient facial photographs to ensure that they are truly not recognisable to others.

INTRODUCTION

The eyes are conventionally considered the primary sensory organs through which we interpret the world and see others. However, perception is a multifaceted process that extends beyond the physical sight of the observer, and their observation of the eyes of others. This phenomenon challenges conventional assumptions about what it means to "see" someone and calls attention to the diverse ways we recognize and understand others.[1] It is common practice in medicine and dentistry, forensic science, legal cases, journalism, social media, or other situations where one wants to hide an individual's identity to block out their eyes in order to maintain their anonymity. This paper argues that despite that practice, we do not need vision, nor do we need to be able to view the eyes of another to recognise and identify them. It speaks to the idea that understanding or "seeing" someone isn't just about physical sight, and explores how a person can still be "seen" by drawing on psychological, physiological, and social perspectives. We can "see" a person through many different aspects, including other physical features, their actions, words, energy, situation and setting, as well as the way they make us feel. It goes beyond just the visual—there's an emotional and intuitive aspect to it, too.

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The Role of Non-Visual Cues in Identity Recognition

When people think of recognition, they often associate it with facial features, especially the eyes. However, human recognition is a complex process involving a variety of sensory inputs that extend far beyond mere visual processing. Studies on prosopagnosia (face blindness) demonstrate that people with impairments in facial recognition often rely on several other cues, to identify individuals.[2] These alternative forms of recognition suggest that even with the eyes covered, one can still perceive and identify a person.

The Cognitive Science Behind Non-Visual Recognition

From a cognitive science perspective, the brain has specialized neural systems for processing different kinds of sensory information. Research on the brain's processing of faces (the fusiform face area) indicates that people are wired to recognize faces through visual cues, but other areas of the brain are responsible for recognizing people through sound, touch, and social context. This neural adaptability underscores the brain's ability to shift between different types of sensory data for identification purposes.[3] Furthermore, the brain's capacity for "multimodal integration" allows us to blend information from multiple senses to form a cohesive understanding of an individual, even if one sense—like vision—is not available.

Auditory Cues: The Role of Voice

One of the most prominent non-visual identifiers is a person's voice. Vocal characteristics such as pitch, tone, cadence, and rhythm are highly distinctive and are crucial components of identity. A person's voice often carries the nuances of their emotions, background, and unique speech patterns. Even when someone's eyes are covered or they are out of sight, their voice can reliably trigger recognition, particularly if they have an established relationship with the person.[4] This is why we can easily recognize others on the phone without needing to see them.

Tactile and Kinetic Recognition: The Power of Touch and Movement

In the absence of sight, tactile and kinetic cues can also help identify an individual. The unique way a person walks, moves, or gestures often leaves an imprint on their observer's memory. For instance, the rhythm or sound of someone's footsteps, the way they gesture during conversation, their stance, the tilt of their heads, their form of greeting such as a handshake or a hug, their style of speaking, or the emotional tone of their speech might all reveal their identity. Their mannerisms are usually very familiar to those who know them, and are often so distinct and unique that they may even allow us to recognize strangers and public figures who we have only observed from a distance.[1]

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Social and Contextual Recognition

Even without physical sight, we constantly rely on contextual and social clues to make sense of our environment. Context plays a large role in how we perceive and identify others. For example, if a person is at a familiar location or is in a situation with a group of people they know, the surrounding context helps identify who they are. This phenomenon aligns with the idea of "social recognition," where individuals are not only recognized by their physical features but also by their behaviours and interactions within a particular social framework.[5]

Cultural and Emotional Dimensions of Recognition

Cultural factors also play a significant role in how we identify others without seeing their eyes. In many cultures, people are taught to recognize not just the face, but other non-visual aspects of identity, such as voice, gait, or even scent. These learned patterns further reinforce the idea that identity is not limited to physical sight. Moreover, the emotional connection between individuals can serve as a powerful recognition tool. Emotional bonds can create a deeper form of recognition, where the mere presence of another person, irrespective of their visual appearance, triggers a sense of familiarity. This suggests that identity is as much about emotional connection as it is about physical features.[1]

Focusing in on the face – The use of facial photographs in medicine, dentistry and forensic sciences

Facial photography presents a unique ethical dilemma, as faces are difficult to de-identify if one wants to use patient photographs for teaching, at conferences, in publications, as illustration for other patients, or even for advertising purposes.[6] Blocking out of the eyes alone is no guarantee that a person's identity will be protected. Consider the photographs below (obtained from public domain) where the eyes have been blocked out, and try identify the people depicted?

In most cases, identification is still possible. This is because there are a myriad of other geometric and anatomic facial features that the brain is attuned to recognising.[7] These include the distances and angles between structures; eye-to-eye distance; pupil position and eyelid shape; eyebrow arch and thickness; nose shape, width, tip length, nostrils and bridge; mouth width, corners, lip shape, tonicity and fullness; chin and jawline; cheekbone structure; skin tone and texture; skin patterns including wrinkles and unique markings such as dimples, freckles, scarring and pigmentation; hairline; and the size, shape, inclination and visibility of the ears. If teeth are visible they offer even further means of identification. Unless a person has had extensive restorative dentistry they are often recognizable by their unique dental arrangement, tooth size, angulation and shade, class of occlusion, degree of overjet and overbite, buccal corridors, missing dentition as well as the presence of visible dental restorations.

The use of blocking out eyes has waned, as patients are often recognized by themselves and others in spite of this technique.[8] Some patients remain identifiable even when the eyes, nose, and mouth are also blacked out. This highlights the need for better means of de-identification when using facial photographs.[7] The first and most important requirement is to gain patient consent. This process must cover and describe all possible uses, including the possibility that the illustrations could end up on social media platforms. Patients can then sign full consent or only approve certain uses. They may also be allowed to view the manuscripts or presentations in which their photographs will appear and to withdraw their approval at any time if they are unhappy.[8] With regards to paediatric patients, assent refers to permission or consent from a patient less than 18 years of age and is required in almost all circumstances.[9] This can be written assent from patients 10 years of age and older and verbal assent from younger patients. Patients also tend to feel more comfortable and secure if the photographs are taken on a hospital-owned camera rather than a personal camera or cellular phone.[10] Other methods of de-identification include removing all metadata, cropping of non-essential features, blurring or pixelating the entire face, using silhouette-style settings such as high-contrast, shadowing or cloning and pasting over features. A concern is that with modern AI technology, computers can easily reconstruct people despite partial facial obfuscation using programmed deep learning tools, local binary pattern recognition, 3D shape mapping, or Eigenfaces and Principal Component Analysis (PCA) mathematical formulae.[1] AI may also be used to morph illustrations or the opposite, to fill in body parts that have been blocked out of an image. These methods help in identifying and verifying faces in images, even under varying conditions like different lighting, pose, and facial expressions. In criminal cases, forensic artists use this to create various composite portraits based on a witness's description of the individual features.

Ethical and Legal Principles

Medical and Forensic Ethics mandate covering eyes of patients in reports or public images in a professional responsibly in order to preserve patient anonymity, dignity and confidentiality. Whether the patient is deceased or

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alive, concealing identifiable features like eyes can prevent dehumanization. Graphic forensic images should be handled responsibly, avoiding unnecessary public exposure or exploitation. One must also be aware that some cultures have strong beliefs regarding the treatment of deceased individuals and how they should be represented in forensic or medical settings.

The legal requirements for covering the eyes of patients depend on the jurisdiction, ethical considerations, and the purpose of covering their eyes. For example, forensic patient information, including identifiable images, must be protected. However, if forensic photographs are used in court, the decision to cover the eyes depends on whether the identity needs to be protected. In some cases, courts may require unaltered images. If forensic evidence is presented in court or research, ethical considerations must balance the need for transparency with privacy protections. Many countries have patient privacy laws that may require anonymizing patient images, with extra legal protection for minors or vulnerable individuals. Furthermore, if forensic images are released to the media, covering the eyes may reduce privacy violations or legal liability. To this end many journalistic standards require anonymization of crime victims, forensic patients, or suspects by obscuring facial features. It also helps to preserve privacy rights and protect against accusations of defamation.[6]

CONCLUSION

The ability to "see" and identify a person does not depend solely on vision. Through auditory cues, tactile experiences, social context, and emotional connections, humans can recognize and understand others without relying on their own vision or seeing the eyes of the person being observed. The complex nature of recognition involves a blend of sensory inputs, cognitive processes, and emotional bonds that together create a more holistic view of identity. As we continue to explore the interplay between sight, sound, touch, and context, it becomes evident that the recognition of a person transcends the physical act of seeing—demonstrating that the true essence of "seeing" someone lies in the deeper connections we form beyond the visual realm.

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What's new for the clinician – summaries of recently published papers (August 2025)

SADJ AUGUST 2025, Vol. 80 No.7 P389-P392

Edited and Compiled by Prof V Yengopal, Faculty of Dentistry, University of the Western Cape

1. DIGITAL VERSUS TRADITIONAL APICAL BARRIER TECHNIQUES IN ENDODONTIC PROCEDURES

Endodontic procedures often require precise management of the root apex, particularly in cases involving open apices or periapical lesions. Apical barrier techniques are essential to achieve an effective seal and promote periapical healing. Traditionally, materials such as mineral trioxide aggregate (MTA) and calcium hydroxide have been used to create an artificial apical barrier. However, advancements in digital dentistry, including 3D imaging, guided endodontics, and bioceramic materials, are transforming the approach to apical barrier formation.

It is well recognised that apexification, apical barrier procedures, and regenerative endodontic procedures (REPs) can eliminate the symptoms and signs of pulp necrosis in immature teeth, with or without apical periodontitis, and promote healing of bone lesions[1]. Although the clinical application of REPs has increased, recent evidence confirms that their long observation periods, variability in outcomes, and dependency on multiple clinical factors currently limit their ability to replace apexification or apical barrier procedures entirely[1]. It should be noted that for immature teeth or adult teeth with an open apex, proper placement of barrier materials in the apical area remains a challenge for most dentists.

It is hypothesised that a novel apical barrier technique (N-ABT) using 3D printing technology to obtain filling instruments matching large root canals, using Cone Beam Computed Tomography (CBCT) data to calculate the volume of required barrier material, and using an apical barrier material that is easy to shape and transport, would achieve more ideal filling results. Moreover, this digital method would be beneficial for future automated obturation procedures. Wang and colleagues from China (2025)[1] reported on a trial that sought to improve the accuracy of filling in apical barrier procedures by comparing N-ABT with the traditional apical barrier technique (T-ABT).

Materials and methods

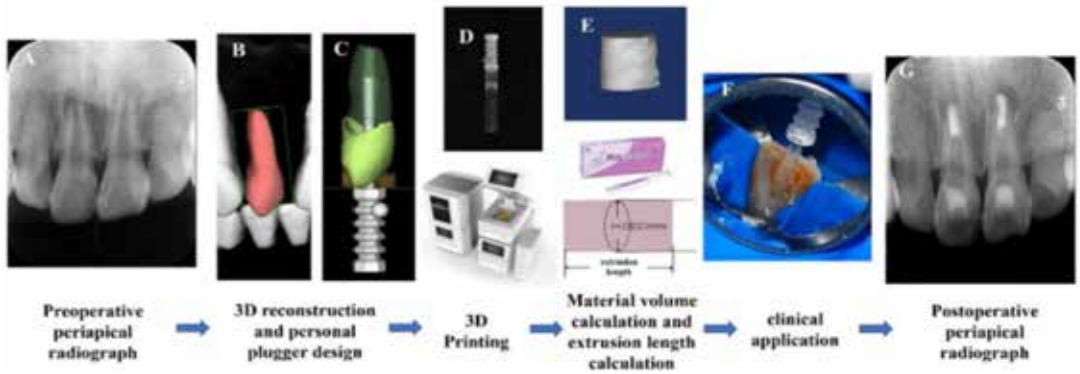
This randomised controlled clinical trial was reported according to CONSORT 2010 guidelines.

A total of 50 teeth from 47 patients were included. The first author enrolled participants and generated the random allocation sequence using a computer-generated method and sealed envelope allocation concealment. The study was conducted in a single-blind manner. Teeth were randomly assigned to either the N-ABT group ($n=25$) or the T-ABT group ($n=25$) using a 1:1 allocation ratio.

The inclusion criteria ensured that the teeth were anterior or premolar teeth with necrotic pulp and open apex, from cooperative and compliant patients who not allergic to agents necessary to complete the procedure, the degree of root canal curvature is less than 10 degrees. Patients were excluded if they had medical contraindications, systemic diseases or conditions known to affect periapical healing (e.g., diabetes, immunosuppression, smoking), teeth with vertical root fractures, teeth with apical cyst, or nonrestorable teeth, periodontally involved teeth.

The Novel apical barrier technique(N-ABT) is graphically illustrated in fig 1 below:

Fig. 1



The procedure of novel apical barrier technique. A. Preoperative imaging data were collected, and DICOM data were obtained from CBCT scans. B. A 3D tooth model was extracted using Mimics software. C. A personalized plugger matching the internal diameter of the root canal was designed in 3ds Max software. D. The personalized plugger was printed using a 3D printer. (E) The material volume was calculated and adjusted, and the material length from the material tube was determined. (F) The personalized plugger was used to place the calculated volume of material into the apical area. (G) Postoperative imaging data were collected

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Clinical procedures before apical barrier obturation

The tooth was anesthetised and a rubber dam was placed. After access opening, the pulp tissue was removed by hand-use 40# H file before irrigation. The canal was initially irrigated with 1.5% sodium hypochlorite (NaOCl) and sonically agitated for 15 s, followed by irrigation with saline. Next, the canal was irrigated with 17% EDTA, sonically agitated for 15 s, and irrigated again with 2% chlorhexidine for 2 min, followed by final irrigation with NS. A side-vented needle was placed 1 mm short of the working length for irrigation.

After drying the canals with sterile paper points, calcium hydroxide dressing was placed into the root canal, positioned within 1 mm of the working length. After placing a sterile cotton pellet, the access cavity was sealed with temporary restorative material (Caviton).

At the next visit, typically 14 days later, all teeth were required to be asymptomatic, with no signs of infection in the root canals. The calcium hydroxide dressing was removed using alternating irrigation with 1.5% NaOCl, 17% EDTA, and saline (20 mL each) under ultrasonic activation, monitored under a dental operating microscope. Complete removal of calcium hydroxide was confirmed under direct visualisation, and the canals were dried with sterile paper points.

Apical barrier obturation

In the N-ABT group, the volume-calculated iRoot BP Plus was placed into the middle third of the root canal using a traditional plugger and then condensed to the apex with the personalised plugger A minimum thickness of 4 mm at the apex was obtained and confirmed radiographically (see Fig. 1).

In the T-ABT group (control group), the operator used a traditional plugger to condense an uncontrolled volume of material into the apical area. If the periapical radiograph showed poor compaction or underfilling, a second obturation attempt was performed.

During this process, the number of obturation attempts and the total time spent (from initial material placement to completion of obturation, including any repeated material placements) were recorded.

Clinical procedures after apical barrier obturation

After apical barrier obturation, the remaining iRoot BP Plus material on the root canal wall was removed as much as possible with disposable micro applicator, and then a wet cotton pellet was placed inside the pulp chamber and root canal to facilitate the complete curing of BP in a humid environment, avoiding contact with the apical barrier material. The access cavity was sealed with temporary restorative material (Caviton). One week later, the temporary restorative material and cotton pellet was removed. Finally, the canal space was subsequently restored with dual-cure resin cement (Relyx™ U200), accompanied by a fiber post to provide mechanical support, and the tooth cavity was restored with a nano hybrid universal restorative (Filtek™ Z250).

Patients were followed up at 1, 3, 6, 12, and 24 months. The presence of pain during percussion, palpation, or biting was evaluated and recorded. Any tooth-related pain or soft tissue damage was considered treatment failure. Periapical radiographs were obtained at each follow-up point, and CBCT scans were taken at 12 and 24 months to evaluate the condition of the periradicular tissues. If acute symptoms developed, the patient was withdrawn from the trial.

Radiographic evaluation

CBCT data were calibrated and evaluated by two independent endodontist observers using the CBCT Periapical Index (CBCT-PAI) scores. CBCT-PAI scores range from 0 to 5. The difference between CBCT-PAI scores before treatment and at 12- or 24-months post-treatment was calculated as CBCT-PAI change (ΔCBCT-PAI).

Results:A total of 47 patients with 50 teeth requiring an apical barrier procedure were recruited. Of these, 45 teeth completed the 12- and 24-month follow-up. Chi-square test showed no significant differences between the N-ABT and T-ABT groups in terms of patient age, gender, tooth type, aetiology, apical foramen size, tooth length, and CBCT-PAI score.

Outcome of healed or healing between two groups

At the 12- and 24-month follow-ups, no differences in clinical outcomes were observed between the N-ABT and T-ABT groups, as none of the cases exhibited tooth-related pain or soft tissue damage.

All cases were considered successful, as they remained asymptomatic and radiographic results showed a reduction in the size of the apical radiolucency. Adjusted analysis revealed comparable healing probabilities between the N-ABT group (22.7%) and the T-ABT group (17.4%) at 12 months (RR = 1.30, 95% CI 0.65–2.61), persisting through 24 months (N-ABT 68.2% vs. T-ABT 47.8%; RR = 1.43, 95% CI 0.94–2.16). No statistically significant differences in healed rates were observed between the two groups.

Changes in CBCT-PAI between two groups

All intergroup comparisons remained nonsignificant ($P > 0.05$) suggesting that both procedures achieved comparable clinical efficacy and radiographic outcomes during the observation period.

Filling quality and efficiency between two groups

Filling status was categorised based on the extent of overfilling into no overfilling (0 mm), mild overfilling (< 1 mm), moderate overfilling (1–2 mm), and severe overfilling (> 2 mm), by CBCT scan and calculation. The N-ABT group showed a significantly higher rate of no overfilling (9/22, 40.9%) and mild overfilling (13/22, 59.1%) compared to the T-ABT group (2/23, 8.7%; 10/23, 43.5%). In contrast, the T-ABT group had higher rates of moderate overfilling (7/23, 30.4%) and severe overfilling (4/23, 17.4%), while no cases of moderate or severe overfilling were observed in the N-ABT group, with all differences being statistically significant ($P < 0.05$), except for the overfilling < 1 mm category. These results suggest that N-ABT can effectively reduce overfilling, particularly excessive overfilling, which may be attributed to the precise control of material volume and accurate positioning during obturation. Interestingly, overfilling appeared to have little effect on periapical healing.

N-The ABT group required only one obturation session, while the T-ABT group required an average of 1.41 ± 0.50 sessions ($P < 0.01$). This finding indicates that N-ABT facilitates one-time filling, which is advantageous for future automated filling and saves working time. Because only one session

was required in the N-ABT group, the total filling time was significantly shorter (38.78 ± 15.56 s) compared with the T-ABT group (99.31 ± 25.08 s), with a statistically significant difference ($P < 0.01$).

These results suggest that the N-ABT group improved both filling efficiency and quality, reduced technical sensitivity, and provided a foundation for future automated filling.

Conclusion

In this study population, the clinical effectiveness of N-ABT was found to be superior to that of T-ABT, with the difference (20.4%) at the 24-month follow-up exceeding the estimated minimum clinically important difference of 10%.

Implications for practice

These findings indicate that the novel apical barrier technique is a highly predictable and effective clinical procedure that reduces technical sensitivity and supports further automation in treatment, facilitating its broader therapeutic application.

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2. EFFECT OF DIFFERENT PACIFIER DESIGNS ON OROFACIAL TISSUES: A COMPUTATIONAL SIMULATION COMPARATIVE STUDY

Pacifiers, also known as soothers or dummies are a common tool used to comfort infants and promote self-soothing. They offer several benefits, including helping babies to settle, reducing the risk of sudden infant death syndrome (SIDS), and preventing thumb-sucking, which can be even harder to break as a habit. However, the prolonged use of pacifiers – especially beyond the recommended infant stage – has been linked to a higher risk of dental malocclusion. The risk of developing malocclusion increases with the duration and frequency of pacifier use. Effects are most pronounced when pacifier use extends beyond 12 months and becomes particularly significant after 4 years. These habits can alter the natural positioning of the tongue and affect muscle function and the development of the jaws, sometimes causing persistent dental and skeletal changes if not discontinued in time. Fortunately, early cessation of pacifier use often allows for self-correction of many mild malocclusions.

The design of the pacifier is crucial in minimising these risks. Pacifiers vary in shape, size, and stiffness, and the so-called "physiological" or "orthodontic" pacifiers are specifically engineered to adapt to the palate and better support natural oral development. Research suggests that these designs distribute tongue and sucking forces more evenly across the palate and reduce the risk of dental changes compared to conventional models. The correct size and shape also promote comfort, proper jaw development, and facilitate smooth transitions between breastfeeding and bottle feeding. Ultimately, while pacifier use can be beneficial in early infancy, thoughtful selection of a well-designed pacifier and restricting its use to the recommended age range are essential to safeguard healthy oral and facial development.

Computational modelling has been employed to investigate the mechanical effects of pacifiers on oral structures; however, many studies still rely on simplified representations. More recent models [1] have aimed to represent the suction cycle and pacifier-palate interaction with greater fidelity, incorporating hyperplastic materials and additional tissue layers. These studies demonstrated that pacifier design and size directly influence the stress and deformation distributions on the palate. Despite these advancements, limitations persist regarding the full anatomical representation of the oral cavity and the replication of real physiological conditions

In this study, Pereira et al (2025)[1] developed and validated their own computational model to compare the effects of different pacifier designs.

Methodology

For this study, the researchers used a validated and innovative computational model developed by their own team. The implemented approach consists of a computational methodology capable of providing quantified data on the effects of pacifiers on the oral cavity, thus inferring the relationship between the pacifier and the prevalence of malocclusions. The results obtained clearly complement the empirical tests presented in the literature regarding the effects of different pacifiers on orofacial structures. The computational model comprises a palate, a pacifier, and a tongue. The palate model, obtained by scanning a physical plaster cast of a six-month-old infant's palate, includes six tissues: mucosa, cortical bone, cancellous bone, alveolar bone, periodontal ligament, and teeth.

Three different pacifiers, representative of the wide range of products available on the market, were analysed: an orthodontic pacifier, a standard pacifier and a conventional pacifier, all illustrated in Fig. 1. The geometries of the orthodontic pacifier and the standard pacifier were provided by the manufacturer, while the conventional pacifier was modelled based on measurements taken from actual models using the 3D modelling software Blender™. These specific pacifier models were selected based on prior studies available in literature, which also compare the orthodontic and conventional designs. Furthermore, the inclusion of both the orthodontic and standard models in the present study aimed to assess whether minor design optimisations in pacifiers could contribute to reducing the adverse effects typically associated with their use.

Fig. 1

3D complete models of the tested pacifiers: a. Orthodontic Pacifier; b. Standard Pacifier; c. Conventional Pacifier.

One computational model was created for each pacifier using the OpenFOAM® open-source computational library. The model was implemented in the OpenFOAM® library to calculate tooth displacement, exerted force, and stress distribution on the palate tissues.

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Results

In this work the model identified as the most realistic in was used to obtain concrete results regarding the effects of different pacifiers: the orthodontic pacifier (OP), the standard pacifier (SP), and the conventional pacifier (CP).

The simulation studies comprise two suction cycles, during which different results were analysed, namely: stress distribution on the palate surface, the evolution of the force exerted by the pacifier on the palate, the maximum displacement of the teeth, and the force exerted on the teeth. Regarding stress distribution, OP and SP significantly reduced the volume of palatal mucosa exposed to von Mises Stress in the range of 0.01 to 0.05 MPa. Specifically, OP achieved a 95.70% reduction, while SP resulted in a 93.95% reduction, when compared to CP. Furthermore, they led to a maximum reduction in mean tooth displacement of 79% (OP) and 75% (SP). These findings indicate that the pacifier design can significantly impact mechanical loading on the palate and teeth, reducing the risk of developmental oral malocclusions.

Conclusions

This study underscores the importance of pacifier design in mitigating potential adverse effects on orofacial development. The orthodontic pacifier (OP),and the standard pacifier (SP), performed significantly better than the conventional pacifier (CP)for al outcomes measured.

Implications for practice

There is a growing need for pacifiers designed based on scientific evidence to reduce the risks of orofacial deformation resulting from non-nutritive sucking. The computational approach introduced provides valuable insights that can inform the design of improved pacifiers aimed at minimising risks associated with non-nutritive sucking habits.

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From Informed Consent to Shared Decision-Making – what does it mean for dentistry?

SADJ AUGUST 2025, Vol. 80 No.7 P393-P394
R Fung

INTRODUCTION

Clinical decision-making has evolved from paternalism, where doctors decided what was best for the patient, to informed consent which is still widely used today. The concept of informed consent is governed by certain prerequisites which ensure that the patient makes an autonomous decision regarding their treatment after being presented with the risks and benefits of the available options. In medical negligence claims, the doctor's actions are assessed based on clinical judgement and whether a reasonable doctor in the same circumstances would have acted in the same way resulting in the same outcome. The Montogomery v Lanarkshire case of March 2015 in the United Kingdom for medical negligence[1], saw the court shift the focus away from the clinical judgement of the doctor's alleged negligence, declaring instead that the patient should have been given all options available to her, even if the doctor considered them to be unsuitable for her condition. Medical insurance companies quickly realised how the informed consent model made them vulnerable to medical negligence claims and amended their clauses accordingly. Clinical decisions now require a more personalised approach known as Shared Decision-Making (SDM). This article explores the main ethical principles that underpin SDM, what this means for the practice of dentistry and its effect on the dentist-patient relationship. Future research in this field could assess the success rate of implementation of SDM in different population contexts and geographical settings.

Shared Decision-Making in dentistry

SDM is defined as an approach where clinicians and patients make decisions together using the best available evidence.[2] In a paternalistic approach to decision-making, the patient is presented with the option deemed most suitable by the dentist and treatment is initiated. On the other extreme, in a patient-centred approach, the patient drives his treatment plan and may have unrealistic expectations surrounding his treatment outcome. When the clinical end-result does not meet the patient's expectations, doubt is unfairly cast upon the clinician's competence and there is a breakdown of trust. One of the core duties of a doctor as set out in the Health Professions Council of South Africa (HPCSA) guidelines[3] is to always act in the best interests of the patient. As such, a dentist presents feasible treatment options to a patient after applying his clinical insight and professional opinion to all aspects of the case. However, SDM insists that the patient be made aware of all options, even the non-feasible ones.

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The concept and process of Shared Decision-Making in dentistry

A few different SDM models currently exist, varying only slightly in their methods or the number of steps in their implementation. However, the overall concept remains the same:

1. Evidence-based information is communicated from clinician to patient
2. Factors specific to the patient and their circumstances are highlighted
3. The patient is allowed to deliberate on the available options and return to the clinician with concerns, queries or other possible options for treatment.
4. A final treatment decision is taken only once both clinician and patient are in mutual agreement.

This model is easily and successfully applied to most medical disciplines but there are limitations to the SDM model specific to dentistry.

Patient-specific limitations:
- Literacy level
- Unrealistic expectations
- Financial constraints
- Anxiety
- Perceptions of family and friends placed above their own preferences
- Unwilling to set aside time for multiple appointments

Dentist-specific limitations:
- Continuous culture of learning and application of knowledge
- Maintenance of a high level of competence in clinical skills
- Time constraints that limit lengthy discussions regarding treatment plans
- Financial limitations – Longer appointment times lead to fewer patients seen

Dentistry-specific limitations:
- Cost and quality of different materials
- Rapidly changing technological advances in dentistry
- Necessary equipment can be expensive

Ethical Foundations and considerations of Shared Decision-Making in dentistry

Respect for autonomy – SDM allows more respect for patients' autonomy because they feel more involved in their treatment decisions. Patients are more likely to be satisfied with the end result if their preferences are taken into consideration. As

with informed consent, there can be challenges in assessing a patient's capacity and understanding as dental jargon must be simplified for any individual, educated or not, who is unfamiliar with these terms.

Beneficence and Non-Maleficence – The dentist is obligated to act in the best interests of the patient. This can become difficult when the dentist must balance his professional recommendations while taking patient preferences into consideration. If not done in a diplomatic manner, it can seem that the dentist is trying to force the patient to agree to a specific treatment. These discussions are easier in emergency situations, however in a purely elective procedure it is difficult to balance good clinical judgement with patient autonomy.

CONCLUSION

It is the professional obligation of the dentist to provide patients with all the necessary information regarding their treatment options. However, this ideal is affected by the fact that patients vary greatly in their level of capacity and competence, socio-economic status and personal preferences. There is a risk of patients feeling overwhelmed by the amount of information being given to them especially if there are barriers to communication like language or cognitive impairment. Time and cost restraints are a prominent feature of a dental practice and these are barriers to the successful implementation of SDM in dentistry.

It remains the ethical duty of dental professionals to facilitate informed choices by maintaining a culture of continuous learning in the clinical sphere as well in communication and ethical reasoning. Decision aids and visual tools are an option to clarify concepts to patients but these must also be used in an ethical manner. Most importantly, the dentist must be meticulous about comprehensive documentation in any patient discussion to avoid any legal implications which may arise from the event.

As we move away from the construct of informed consent and towards Shared Decision-Making, it is evident that there is a need for ethical guidelines specific to dentistry that will protect both the dentist and the patient.

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CPD questionnaire

A Review of Chemical Approaches Inherent to Endodontic Disinfection Protocols: Part 1

1. **Select the CORRECT answer: Which characteristics define an ideal endodontic irrigating solution?**
   - A. Endodontic irrigation solutions must have broad-spectrum antimicrobial properties with rapid antimicrobial action.
   - B. These solutions should be biocompatible with the adjacent oral tissues.
   - C. Irrigation solutions must dissolve the organic, inorganic, necrotic tissue and smear layers within the root canal system.
   - D. Irrigation solutions must be easy to use and easy to remove from the root canal.
   - E. All of the above.

2. **Select the INCORRECT statement, one of the following statements is not correct:**
   - A. Mechanical debridement alone is not sufficient to eradicate endodontic microorganisms.
   - B. Complex root anatomies can hinder mechanical instrumentation, making it difficult to debride the root canal system effectively.
   - C. Endodontic irrigant solutions can penetrate complex root canal anatomies and support mechanical debridement for improved disinfection.
   - D. Irrigant activation can never improve disinfection in any anatomical variations such as isthmuses, ramifications, accessory canals, wide oval canals, and the apical areas of the root system.

Impact of different types of smoking on the discolouration of teeth and nanocomposites

3. **Select the CORRECT answer. The main causes for extrinsic tooth staining includes:**
   - A. Tea
   - B. Coffee
   - C. Tobacco
   - D. Medications
   - E. All of the above

4. **Which answer is CORRECT. Since its introduction to the market the number of different flavours of e-liquid have reached**
   - A. 100
   - B. 300
   - C. 1 000
   - D. 7 000
   - E. 20 000

5. **Select the CORRECT answer: Tobacco contains**
   - A. Nicotine
   - B. Hydrogen cyanide
   - C. Carbon monoxide
   - D. Phenols
   - E. All of the above

An evaluation of White Cell count, C-Reactive protein and Procalcitonin as diagnostic and prognostic biomarkers during the management of maxillofacial infections

6. **Select the CORRECT range. What is the normal range of CRP levels in non-infection patients?**
   - A. 0.3 – 1.0 mg/dL
   - B. Less than 0.3 mg/dL
   - C. 1.0 – 10.0 mg/dL
   - D. Less than 50 mg/dL

7. **Choose the CORRECT option. What is the most important initial treatment modality in managing maxillofacial infections?**
   - A. Start the patient on antibiotic cover
   - B. Get a detailed medical and dental history
   - C. Identify and remove the cause of infection
   - D. Support the patient medically (Nutrition, analgesics etc.)

8. **Which option is INCORRECT. Which of the following spaces is NOT regarded as a High-Risk space?**
   - A. Deep temporal/infra temporal space
   - B. Pretracheal space
   - C. Danger space
   - D. Lateral pharyngeal space

Exploring Oral Health Care-Seeking Behaviours: Patient Perspectives on Western and Traditional Health Practices in Rural KwaZulu-Natal

9. **Select the CORRECT statement. Which of the following best describes the focus of the study?**
   - A. Comparing advanced dental technologies used in urban hospitals
   - B. Investigating patient attitudes towards oral health care in rural communities
   - C. Evaluating the nutritional habits of patients in KwaZulu-Natal
   - D. Assessing government funding for dental clinics

10. **Which answer is CORRECT. In the context of oral health care, "traditional health practices" may include:**
    - A. Herbal remedies and spiritual healing
    - B. Dental implants and orthodontic treatment
    - C. Hospital-based surgical interventions
    - D. Use of fluoride-based toothpaste

11. **Choose the CORRECT factor. Which factor may influence patients' preference for traditional health practices over Western care?**
    - A. Accessibility and cultural beliefs
    - B. Lower infection risk
    - C. Greater government regulation
    - D. Shorter treatment duration in hospitals

A 13-Year Follow-Up of a full mouth rehabilitation using a fixed PFM bridge opposing an acrylic veneered implant supported hybrid prosthesis.

12. **Select the CORRECT statement. Telescopic crowns:**
    - A. are not suitable for patients with compromised dentitions
    - B. allowing for the maintenance of teeth
    - C. do not allow for future tooth modifications
    - D. can only be used with fixed restorations
    - E. only a) and c) are correct

13. **Which of the following options is CORRECT. Acrylic veneered prostheses:**
    A. are bulky
    B. have good wear resistance
    C. are poor shock absorbers
    D. are more aesthetic porcelain veneers
    E. need more repair than porcelain veneers

14. **Choose the CORRECT answer. Studies report that acrylic veneers wear at a rate of:**
    A. 0.1-0.2 mm / year
    B. 0.2-0.3 mm / year
    C. 0.3–0.4mm / year
    D. 0.4-0.5 mm / year

15. **Which of these options is CORRECT. Debonding of telescopic crowns:**
    A. maybe due to parafunctional habits
    B. is reported to occur in over 20% of cases after 5 years
    C. maybe due to use of incorrect cements
    D. all of the above
    E. only a) and c) above are correct

The Paradox of Perception – You do not need THE EYES to SEE the person

16. **Select the CORRECT statement. If patients consent to the use of their images:**
    A. One does not need to block out the eyes
    B. They do not need to know where or how the images will be used
    C. They must sign for approval of each specific intended use
    D. They must approve of the images before they are published
    E. Both c) and d) above apply

17. **One of the following statements is INCORRECT. Which of the following statements is not correct?**
    A. Covering the eyes of patients is a legal requirement
    B. A court may request to have unaltered images presented
    C. Publications of images of convicted criminals is allowed
    D. Publications of images of crime victims must ensure anonymity
    E. Publications of images of suspects must ensure anonymity

Evidence-based dentistry: What's new for the clinician

18. **Select the CORRECT answer. What is the primary advantage of the novel apical barrier technique (N-ABT) over the traditional apical barrier technique (T-ABT) in endodontic procedures?**
    A. Higher clinical failure rate due to complexity
    B. Reduced overfilling and more precise material placement
    C. Significantly longer procedure time
    D. Use of calcium hydroxide instead of bioceramic materials

19. **Which of the following answers is CORRECT. According to the study by Wang et al., what was a key procedural difference between N-ABT and T-ABT groups?**
    A. N-ABT used personalized 3D-printed pluggers matching the root canal diameter
    B. T-ABT used CBCT imaging for material volume calculations
    C. N-ABT required more obturation sessions compared to T-ABT
    D. T-ABT employed automated digital obturation techniques

20. **Choose the CORRECT answer. Which outcome was significantly reduced by orthodontic and standard pacifiers in this study?**
    A. Risk of sudden infant death syndrome (SIDS)
    B. Tooth displacement
    C. Incidence of thumb-sucking
    D. Tongue thrust severity

Ethics: From Informed Consent to Shared Decision-Making – what does it mean for dentistry?

21. **Which legal case marked a significant shift in the approach to informed consent in the UK?**
    A. Smith v Jones
    B. Montgomery v Lanarkshire
    C. Brown v Board
    D. Elwyn v NHS

22. **What is the main goal of Shared Decision-Making (SDM) in dentistry?**
    A. To let the dentist choose the best option for the patient
    B. To allow the patient to make the decision alone
    C. To ensure decisions are made collaboratively using evidence and patient values
    D. To reduce legal risks for dentists

23. **Which of the following is considered a patient-specific limitation of SDM in dentistry?**
    A. Rapidly changing dental technology
    B. Dentist's time constraints
    C. Financial constraints and anxiety
    D. High cost of dental equipment

24. **Respect for autonomy in SDM means that:**
    A. The dentist must always decide what is best for the patient
    B. Patients should feel involved and empowered in their treatment decisions
    C. Patients should be left to choose without professional input
    D. The dentist only needs to explain feasible treatment options

25. **Which ethical principles must be balanced when a dentist considers both professional judgement and patient preferences?**
    A. Justice and confidentiality
    B. Autonomy and veracity
    C. Beneficence and Non-Maleficence
    D. Fidelity and utility

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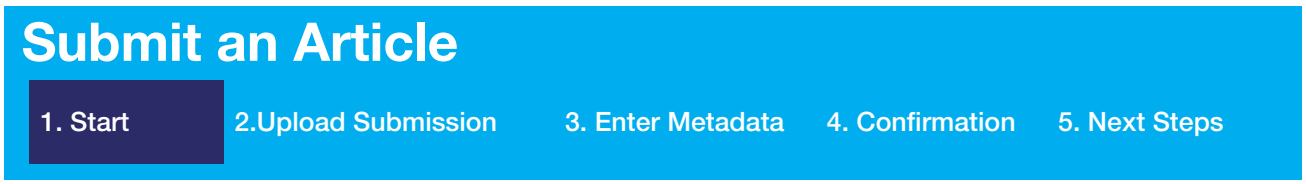

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