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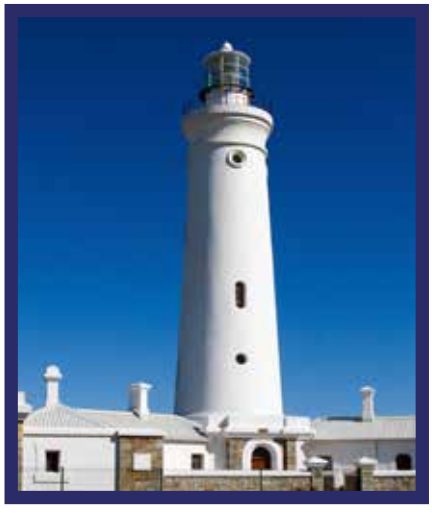

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Enamel, Reimagined: Between Promise, Proof, and the Human Need to Believe

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

I was recently confronted with the question from a curious young patient: "why can't teeth heal themselves the way skin does?"

I suspect it is a question every clinician hears at some point, sometimes from a child bewildered by their first cavity, sometimes from an adult facing years of cumulative enamel loss. And if we are honest, it is a question that unsettles even some of us. Why *can't* enamel regenerate? Why does the hardest tissue in the human body have no capacity for repair beyond remineralisation at its surface? While for some the answer is obvious and any discussion on this is without value, however, what if…

These questions have resurfaced with new intensity following the global excitement around experimental keratin-based coatings that showed enamel-like microstructures forming in laboratory conditions. Media outlets rapidly amplified these findings, and within days, patients were asking whether enamel "regrowth" was finally possible.

Something deeper is at work here. It is not simply the allure of scientific novelty; it is the psychology of hope. Regeneration represents more than a biological breakthrough, it speaks to a universal desire to undo damage, reverse time, and restore what disease or life has taken.

But hope and evidence must sit side by side. Today, regenerative enamel research is real, fascinating, and advancing, but it remains preclinical, with no human trials demonstrating functional enamel regeneration. Studies published to date have shown promising enamel-like mineralised layers using keratin peptides, amelogenin-inspired peptides, biomimetic calcium phosphate systems, and peptide-based remineralisation scaffolds in vitro or in animal models. These findings are meaningful, but they are not yet a clinical therapy.

And this is where dentistry must step in with clarity, calmness, and leadership. This editorial is not about dismissing the promise of regenerative enamel. It is about understanding it scientifically, psychologically, and ethically, so that the profession can guide patients with honesty while embracing innovation with integrity.

Why enamel cannot heal

Enamel is the strongest biological material in the human body, yet paradoxically the least capable of self-repair. Its vulnerability lies in its beauty: a crystalline, highly mineralised, acellular structure.

During tooth development, ameloblasts, create the enamel matrix and then undergo programmed cell death or withdrawal once the tooth erupts. This means that no living cells remain within mature enamel. Unlike bone, dentine, or cementum, enamel has no cellular machinery to initiate repair, remodel structure, or deposit new mineral internally. Surface remineralisation does occur, but only under very specific conditions that include adequate salivary flow, fluoride availability, pH balance, and preserved microstructure. Even then, remineralisation is limited to micrometre-scale repair at the outer enamel surface; it cannot regenerate bulk enamel, recreate prism architecture, or restore structural integrity once lost. In short, enamel does not heal, because it has no cells left with which to heal. This biological reality explains why enamel regeneration research is so compelling. It is not merely a scientific curiosity; it aims to overcome a fundamental limitation of human biology.

Where the Science Actually Stands

Over the past two decades, enamel research has moved from the realm of "interesting possibility" toward genuinely sophisticated biomimetic systems. A comprehensive review by Pandya and Diekwisch maps this evolution clearly: from simple remineralising agents to complex protein- and peptide-based scaffolds that attempt to reconstruct enamel-like architectures rather than merely plug mineral loss.[1]

Broadly, current strategies fall into three overlapping categories: (i) biomimetic mineralisation fronts on enamel, (ii) protein- or peptide-based scaffolds that guide crystal growth, and (iii) matrix systems that stabilise and deliver these peptides in clinically realistic conditions. All of them show promise. None of them yet achieve full, functional enamel regeneration in humans.

a) Keratin-Based Scaffolds and Enamel-Like Coatings

The most recent wave of attention has centred on keratin-based systems, driven by the appeal of using a structural protein derived from hair or wool to repair enamel in a sustainable way. In 2025, Gamea and colleagues reported a keratin-film platform that acts as a biomimetic scaffold for enamel regeneration. In a model of early enamel lesions, processed keratin films assembled into a fibrous network which, upon mineralisation, guided the ordered growth of apatite nanocrystals into an enamel-like layer. The treated lesions showed restoration of both optical appearance and mechanical properties compared with sound enamel.[2]

This is an important step: the work demonstrates that keratin can support oriented, enamel-like mineral deposition and substantially improve hardness and aesthetics at the lesion surface. However, it remains an ex vivo / laboratory system, applied to enamel blocks and sections rather than in vivo human teeth. The newly formed layer is still a surface coating, not a complete recreation of native enamel's full thickness and complex prism decussation. Long-term durability under mastication, resistance to wear, and in vivo clinical effectiveness have not yet been established.

b) Biomimetic Mineralisation Fronts

Parallel work has focused on recreating an "enamel-like" mineralisation front directly on damaged enamel. Shao et al. reported a polymer-induced liquid-precursor–type system that produced a biomimetic mineralisation frontier on etched human enamel, ensuring epitaxial growth of hydroxyapatite crystals that were crystallographically aligned with the underlying tissue.[3]

In that *Science Advances* study, the regenerated surface layer exhibited microstructure and mechanical properties approaching natural enamel, with improved hardness and elastic modulus compared with untreated demineralised controls. However, as the authors themselves emphasise, the effect is still located at the outer surface, with limited thickness at the scale of micrometres, and the work was conducted under controlled laboratory conditions. It is best understood as highly sophisticated repair, not yet full biological regeneration of the original tissue architecture.

c) Amelogenin-Derived Peptides and Hybrid Matrices

A major line of research has used the biology of amelogenesis as a template. Amelogenin, the dominant enamel matrix protein during development, has inspired multiple amelogenin-derived peptides designed to bind to demineralised enamel and guide ordered mineral deposition.

- Kwak et al. demonstrated in 2017 that a leucine-rich amelogenin peptide (LRAP) combined with controlled delivery of inorganic pyrophosphate could regenerate an enamel-like mineral layer on etched human enamel. The regenerated layer showed increased mineral density and hardness, and the crystals were oriented in continuity with the underlying enamel.[4]
- Ruan et al. developed an amelogenin–chitosan matrix that promoted the assembly of an enamel-like layer with a dense interface on demineralised enamel surfaces. The newly formed layer contained fluoridated hydroxyapatite, with ordered structure and improved mechanical properties compared with controls.[5]
- Building on these concepts, Mukherjee et al. incorporated amelogenin-derived peptides into a chitosan hydrogel, creating a delivery system that enhanced peptide stability and allowed sustained remineralisation of incipient enamel lesions. In their in vitro model, peptide–chitosan formulations improved surface hardness and mineral density, and the authors described this as a step toward a clinically viable approach for biomimetic enamel regrowth.[6]

Collectively, these studies show that amelogenin-inspired peptides and hybrid matrices can produce enamel-like mineral layers that are chemically and structurally closer to true enamel than traditional fluoride-based remineralisation alone. They can restore hardness, reduce lesion depth, and align new crystals with the underlying tissue.

What they do *not* yet do is:

- regenerate full-thickness enamel,
- recreate the entire hierarchical prism architecture at millimetre scale, or

- demonstrate long-term in vivo performance under real masticatory load.

d) What This Means for "Regeneration"

Taken together, the current evidence supports a careful, honest summary:

- We can substantially enhance remineralisation of early lesions with biomimetic systems.[2,6]
- We can generate enamel-like mineral layers, with improved hardness and crystal orientation, on previously damaged surfaces.[2,6]
- We can develop novel scaffolds, such as keratin films and peptide–hydrogel matrices, that look increasingly clinically plausible.[2,6]

But we cannot yet regenerate natural, fully formed enamel in humans. Pandya and Diekwisch put it starkly: enamel biomimetics has moved from fiction toward reality, but clinical translation remains constrained by issues of thickness, integration, durability, and delivery.[1]

For now, the science justifies bounded optimism: genuine excitement about what these systems can achieve for early lesions and surface repair, coupled with clear recognition that "regrowth" headlines still outpace what is possible at the chairside.

Hope, Hype, and the Psychology of Regeneration

The intense public excitement around enamel "regrowth" did not emerge from nowhere. It reflects something profoundly human: our longing for reversal and for the chance to undo past damage, to recover what illness, time, or circumstance has worn away. In dentistry, this longing has a particularly sharp edge. Teeth form part of identity, self-esteem, and social presence. When enamel is lost, it is not simply tissue gone; it is a loss people *feel*.

This is why regenerative dentistry captures imagination so powerfully. It straddles a psychological boundary between science and hope. And yet, hope has a way of outpacing evidence. In the days following high-profile enamel studies, social media platforms filled with confident declarations that "dentists will be out of business in five years" or that "tooth regrowth is here." None of these statements were true, but they spread rapidly because they were *emotionally compelling*. Research in science communication consistently shows that emotionally charged, future-oriented messages travel farther and stick longer than sober, incremental truths.[7]

Several well-described psychological mechanisms contribute to this pattern:

a) Optimism Bias

Humans naturally overestimate the likelihood of positive outcomes, especially when those outcomes correct something we regret or fear.[8] Regeneration promises precisely that: the undoing of past dental disease.

Optimism bias is not ignorance; it is a predictable cognitive tendency. Patients interpret early scientific work as eventual inevitability. For clinicians, understanding this helps us respond empathetically, not dismissively.

b) Availability Bias

Information that is vivid, recent, and widely discussed is perceived as more likely or more true.[9] A striking enamel-repair micrograph shared online becomes, in the public mind, evidence of imminent clinical translation. Meanwhile, the dozens of unpublicised studies showing partial, surface-limited remineralisation remain invisible. The result? A skewed perception of scientific readiness.

c) The Halo Effect

When research comes from respected universities or appears in high-impact journals, people assume the findings are further along the translational pathway than they truly are.[10] A beautifully engineered enamel-like layer in *Science Advances* feels like a clinical breakthrough, even when authors carefully stress its limitations. This is not a failure of the public. It is a predictable cognitive shortcut.

d) The seductive precision of scientific imagery

Electron micrographs of enamel-like crystals are visually arresting. They look real, tangible, almost touchable. Communication research shows that detailed images create an illusion of mechanism and closeness to application, even when the underlying science remains early-stage.[11] Microscopy magnifies both structure *and* expectation.

e) The clinician's vulnerability to hope

Dentists, too, are susceptible to these biases, not because we misunderstand science, but because we care about our patients. When a parent asks whether their child's early erosion could be reversed, it is tempting to wish we could say yes. Our professional duty, however, requires us to hold space for both hope and truth.

"Hope is not the enemy. Hype is."

These cognitive tendencies do not mean that patients are naïve or that clinicians should become cynics. They simply remind us that regenerative research sits at the perfect intersection of emotion, identity, novelty, and aspiration. It is the ideal recipe for hype. And hype has consequences:

- Patients may pursue unproven "regeneration" products sold online.
- Expectations for treatment outcomes may become unrealistic.
- Clinicians may feel pressured to offer interventions that do not exist.
- Policymakers may misunderstand the timeline of translational research.

Our task, then, is not to extinguish excitement, but to channel it responsibly. To do so, dentistry must cultivate a communication posture grounded in what behavioural scientists call "bounded optimism": a stance that acknowledges potential while clearly defining limits. This approach preserves trust and protects the integrity of the science.

Clinical Responsibilities in the Era of Enamel Headlines

The moment a striking laboratory image circulates online, dentists feel the consequences almost immediately. Patients arrive at appointments with screenshots of enamel micrographs, short clips from social media, or breathless headlines announcing the "end of cavities." Parents ask whether their teenager's early erosion can be reversed; adults who have lived with worn enamel for decades wonder whether they should postpone necessary care and wait for the breakthrough. In these moments, the clinician becomes the interpreter between scientific nuance and public expectation, and how we communicate matters.

The challenge lies in balancing hope with honesty. Patients gravitate toward certainty even when clinicians intend only to express possibility. A simple phrase such as "there are promising early results" may be heard as "a cure is coming soon." Our responsibility, therefore, is to offer what behavioural scientists

call “bounded optimism”: language that acknowledges scientific potential while clearly defining its current limits. It is the difference between saying, “Researchers can regrow enamel,” and saying, “Researchers are beginning to create enamel-like layers in the laboratory, but there is no treatment available yet.” This distinction strengthens trust because it protects patients from unrealistic expectations while respecting their hope.

Another important responsibility is reframing regeneration within the context of prevention. When stories of enamel regrowth trend, many patients infer that prevention is becoming obsolete, that science will soon correct what behaviour or biology has damaged. In reality, every credible enamel-repair strategy is likely to be most effective on early lesions. If regeneration ever becomes clinically feasible, it will not replace prevention; it will amplify the value of early detection, fluoride, saliva preservation, dietary control, and timely intervention. Patients benefit when clinicians explain that emerging science reinforces, rather than replaces, foundational principles of oral health.

Clarity is also essential when distinguishing “repair” from “regrowth.” Most current technologies strengthen weakened enamel or restore the surface through advanced remineralisation; none rebuild full-thickness enamel tissue. Without careful explanation, patients often conflate these concepts. A simple statement such as “We can strengthen enamel surfaces, but we cannot yet regrow enamel that has been lost” helps anchor expectations realistically.

In parallel, clinicians must serve as a barrier against the commercialization of hype. Whenever research captures public imagination, online markets quickly respond with products claiming to regenerate enamel, often without credible evidence. Dentists are uniquely positioned to protect patients from these claims. Guiding patients away from unproven interventions is not gatekeeping, it is professional safeguarding, preserving both patient welfare and the integrity of the science.

Even so, hopeful questions from patients should not be dismissed. They are opportunities to transform curiosity into understanding. When a patient asks whether enamel can grow back, it is often more helpful to invite them into the biology, to explain how enamel forms, why it cannot regenerate naturally, and what researchers are trying to achieve. Such conversations shift the dynamic from expectation to education, strengthening rapport and reinforcing the clinician’s role as a trusted guide.

Ultimately, counselling patients through the haze of hype is a clinical skill in its own right. It requires calm, clarity, and compassion. Patients do not need mechanistic detail; they need reassurance that dentistry already has excellent and reliable tools to protect their teeth today, and that emerging science, though exciting, is not yet a replacement for proven care. Our responsibility is twofold: to honour the evidence faithfully and to protect our patients from the distortions of excitement. Within that balance lies the clinical leadership that stories of enamel regeneration demand.

The future of practice: how regeneration could reshape dentistry

If regenerative enamel technologies eventually progress from laboratory curiosity to clinical application, dentistry will not simply acquire a new material, it will experience a shift in professional identity. Regeneration is not an incremental innovation like a new composite or adhesive; it represents a conceptual transformation in how we think about disease, prevention, and the role of the clinician.

The first change will be pedagogical. Dental curricula, which already strain to balance foundational science with expanding clinical demands, will need to accommodate new competencies: biomaterials literacy, molecular signalling, scaffold science, and the biology of mineralisation. Students of the future may need to understand not only how to remove decay but also how to activate, stabilise, and monitor regenerative treatments. This shift mirrors what occurred when implant dentistry moved from specialist procedure to mainstream competence; regeneration, if realised, will require similar curricular rethinking, faculty development, and refinement of assessment frameworks.

Clinical practice will change as well. Regeneration would not eliminate operative dentistry but would alter its rhythm. Early detection would become even more central, because regenerative interventions would almost certainly work best in the earliest stages of enamel loss. This places renewed emphasis on risk assessment, behavioural counselling, preventive strategies, and minimally invasive philosophies. Dentists may find themselves spending more time analysing the dynamics of risk and lesion activity, and less time replacing what has already been lost. In many ways, regeneration aligns dentistry more closely with medicine: intervene early, preserve tissue, and respect biology.

The economics of dental care would shift in parallel. If regenerative treatments reduce the need for full-coverage restorations, crowns, or large composite rehabilitations, practice models will adjust. This does not spell obsolescence for dentistry, far from it. It simply changes where value lies. Precision diagnostics, personalised risk profiling, long-term monitoring, and prevention-focused care could become more prominent revenue streams. Practices that embrace a biologically oriented, education-rich model of care may thrive, while those relying heavily on restorative throughput may need to adapt.

Ethically, regeneration pushes the profession toward deeper questions: who will have access to these technologies? Will the benefits be equitably distributed, or will they widen existing disparities between those who can afford advanced care and those who rely solely on public systems? Regenerative dentistry could be a catalyst for renewed discussions about justice in oral health, aligning with global calls for universal coverage, integrated care, and upstream prevention. If the field is to avoid repeating past inequities, these conversations must begin long before any regenerative therapy reaches the marketplace.

There will also be implications for the dentist’s role as a communicator and guide. As regenerative science advances, clinicians will face intensified public curiosity. Precision in communication will matter more than ever: distinguishing between repair and regeneration, between evidence and aspiration, between preliminary findings and proven treatment. The dentist of the future will need to be as skilled in managing expectations as in managing disease.

And finally, there is the matter of professional identity. Dentistry

has long been defined by the restoration of what disease and behaviour have damaged. Regeneration suggests a different narrative: one that centres preservation, minimal intervention, and biological partnership. This is not a loss of craft; it is an evolution of it. Dentistry has always been a discipline where science and artistry meet. Regeneration simply shifts the balance more toward biology without diminishing the clinician's judgment, dexterity, or humanity.

The future, then, is not one in which dentists do "less," but one in which they do differently: more prevention, more thinking, more early intervention, more partnership with patients, and more engagement with the biology that underlies oral health. Regeneration, if it arrives, will not reduce the relevance of dentistry; it will reaffirm it provided the profession is ready to lead with clarity, ethics, and scientific groundedness.

Holding hope, holding truth

There is a quiet intimacy to the work we do as dentists. Every day, we restore small pieces of people's lives: a smile, a confidence, a comfort. We work in millimetres, yet the meaning of our craft is measured in something far larger. Perhaps this is why the idea of regeneration touches us so deeply. It speaks not only to science, but to the human desire to mend what has been lost.

As enamel research advances, it is tempting to imagine a future where we can undo decay with biology rather than burs, where the young patient with early erosion can be offered renewal instead of repair. That hope is real, and it is worth holding onto. But as custodians of a scientific profession, we must hold truth just as firmly. The evidence today is promising, but still young. Regeneration has taken its first steps in the laboratory, not yet in the clinic.

Our role, then, is twofold: to nurture the excitement of discovery without surrendering to the seduction of premature certainty, and to guide our patients with clarity grounded in science, not speculation. Dentistry's integrity has always rested on this balance between innovation and responsibility. If regenerative dentistry is to find its place in our future, it must be welcomed through the same gate.

What lies ahead is not a diminishment of our profession, but an evolution of it. Regeneration, should it arrive, will not replace our work but rather will refine its purpose. It will deepen our commitment to early intervention, prevention, and patient partnership. It will invite us to teach differently, think differently, and care differently. And it will require us, perhaps more than ever, to be the calm voice that interprets discovery with precision and humility.

So let us honour the science without overstating it. Let us welcome the future without abandoning the wisdom of the present. And let us remember that the heart of dentistry has never been defined solely by what we can repair, but by how thoughtfully we help others understand what can be preserved.

Hope is powerful. Evidence is stronger. Between them lies the steady, guiding hand of our profession.

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Personalised Dentistry and Genomics: A Vision for the Future of Oral Health Care

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Mr KC Makhubele – CEO, South African Dental Association

One revolutionary development that sticks out as we consider dentistry's future is the use of genomics in dental treatment. Genetic science advancements are making it possible to move away from a one-size-fits-all strategy and towards one that customises therapy for each patient. This development, sometimes known as precision or personalised dentistry, holds great potential for bettering patient outcomes by providing a route to more focused prevention, precise diagnosis, and customised treatment regimens.

The Rise of Genomics in Dentistry

Understanding the genetic underpinnings of many medical illnesses, including oral diseases, has advanced significantly thanks to genomic research. In the past, dental care has mostly addressed symptoms rather than underlying causes by following standardised treatment methods. Dentists are already starting to determine patients' genetic susceptibilities to particular ailments, like dental caries, periodontal disease, and even some forms of oral cancer, thanks to the integration of genomics (Wong et al., 2021). For example, genetics plays a role in the development of periodontal disease, one of the most prevalent and complicated oral health issues. According to research, some DNA variations can make people more susceptible to periodontal disease, which can result in long-term inflammation, bone loss, and even tooth loss if left untreated (Kornman, 2018). By identifying these signs, early interventions and individualised care strategies may be able to slow the progression of the disease.

Predicting and Preventing Disease through Genetic Markers

Perhaps the most intriguing feature of personalised dentistry is the ability to anticipate danger and take preventative measures before a disease appears. Proactive measures that extend beyond the conventional area of dental care are made possible by genetic markers, which offer insightful information about a patient's risk profile. For instance, more intense preventive measures like fluoride varnishes, sealants, and specialised oral hygiene regimens may be beneficial for patients who have been found to be genetically prone to dental caries. Especially in high-risk patients, this strategy can dramatically cut the incidence of cavities, improving dental health outcomes and possibly reducing treatment costs over time. Likewise, genomics presents encouraging developments for the treatment of diseases of the temporomandibular joint (TMJ). A higher risk of TMJ issues has been linked to abnormalities in specific genes, according to research. Dentists can monitor and treat these cases more proactively by knowing a patient's genetic risk, which could improve the quality of life for patients who suffer from these frequently incapacitating illnesses (Smith et al., 2020).

Personalised Treatment Planning: The Future of Dental Care

Genomic-based personalised treatment planning has the potential to significantly alter the dental care industry. Instead of depending just on general recommendations, treatment plans can be customised to meet the unique requirements of each patient once genetic markers have been found. Individual response profiles may necessitate more regular periodontal maintenance visits, specialised cleanings, and potentially supplementary therapy such as antibiotics or anti-inflammatory drugs for patients with a genetic susceptibility to aggressive periodontitis.

Furthermore, pharmacogenomics—the study of how a person's genes influence how they react to medications—is becoming a crucial tool in dentistry. Drug prescriptions can be guided by pharmacogenomic insights, guaranteeing that patients receive drugs that are both efficacious and compatible with their genetic profiles. Pharmacogenomics is an essential part of individualised dental care since it lowers the risk of negative reactions and increases overall treatment efficacy (Van Dijk et al., 2019).

Ethical Considerations in Genomic Dentistry

Despite the obvious advantages of genetics in dentistry, there are also moral questions. Concerns regarding data security and privacy are raised by the gathering and storing of genetic data, especially when sensitive data like genetic predispositions is involved. As medical practitioners, it is our responsibility to make sure that strong data protection procedures are in place to protect patient privacy and gain their confidence in the responsible use of genetic information. Furthermore, accessibility issues may arise due to the expense of genomic testing. Only those who can afford genetic testing will benefit from these cutting-edge interventions, and if personalised dentistry is not properly managed, it may worsen health disparities. As leaders in the dentistry field, it is our responsibility to promote laws and procedures that guarantee everyone, regardless of financial situation, fair access to individualised care.

Charting a Path Forward for Personalised Dentistry

Although the use of genetics in dentistry is still in its infancy, there is a lot of promise for improvement. By encouraging research, funding training programs, and supporting legislative frameworks that make it easier to incorporate genetics into clinical practice, the South African Dental Association (SADA) is dedicated to advancing personalised dentistry. By doing this, we may set the stage for more proactive, effective, and patient-centered dental care in the future. The application of genetics in dentistry presents an intriguing future for us to envision. We have the chance to revolutionise oral healthcare through personalised dentistry by providing precisely customised therapies that cater to the individual needs of every patient. In addition to improving the standard of care, adopting these innovations brings us one step closer to a future in which everyone can attain ideal dental health. At SADA, we want to remain on the cutting edge of these advancements and make sure that our members have the skills, resources, and encouragement they need to succeed in this new dental care era. Even though personalised dentistry is still in its infancy, it has the potential to completely transform oral health.

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Cephalometric characteristics of South African Black patients presenting at an academic oral health centre

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ABSTRACT

Introduction

Cephalometric analysis is central to the diagnosis, treatment planning and successful management of dental malocclusion and skeletal discrepancies. While interpopulation variations in skeletal morphology have been documented, limited research is available in the South African context. This study contributes to developing literature describing cephalometrics in a South African Black population.

Aims and objectives

The study aimed to assess the cephalometrics of a sample of South African Black adults according to Wits appraisal categories and to examine variations according to sex and age.

Design

This was a cross-sectional quantitative study examining archived lateral cephalograms.

Methods

The study analysed 114 lateral cephalograms (63 females, 51 males). ImageJ software was used for cephalometric measurements. Statistical analysis was performed using PAST statistical programme.

Results

Across Wits appraisal categories significant differences were revealed in the ANB and SNB angles. The extent of mandibular protrusion was greater in males, while the extent of maxillary protrusion was greater in females. In females, where the gnathic index was found to significantly increase with increasing age, the gonial angle significantly decreased

Conclusion

The variations noted in cephalometric analysis of South African Black patients warrants the investigation of contextual consideration for orthodontic assessments and treatment.

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INTRODUCTION

Cephalometric analysis is the primary method employed by orthodontists in the management of facial skeletal morphology and dentoskeletal relationships, aiding in the assessment of malocclusion and other associated skeletal deformities. The occlusion status of patients is assigned to one of three levels of Angle's classification based on the sagittal relationship of maxillary and mandibular first molars resulting in either an aligned maxilla and mandible (Class I malocclussion), a retruded mandible (Class II malocclusion) or a protruded mandible (Class III malocclusion).[1] Prognathism, on the other hand, does not necessarily indicate misalignment or jaw disharmony, and the extent of prognathism may normally vary between individuals and population groups. [2-3]

People of African ancestry have been reported to present with higher degrees of maxillary and mandibular prognathism compared to people of European ancestry. [3-7] Populations of African ancestry with aligned occlusion but with maxillary and mandibular protrusion showed a lower cranial base angle (SNAr) and shorter cranial base (SN distance), when compared to groups of European decent. [7] These features confer a posterior position of the nasion point (N), influencing all measurements related to the sella point (S) or the SN line. [7]

The use of angular measurements that incorporate the relative positions of the jaws to craniofacial landmarks—such as the ANB angle (formed between points A (subspinale), N (nasion), and B (supramentale)) or the SNA and SNB angles (which include the sella)—may introduce interpopulation disparities due to variations in the anatomical positioning of these structures.[8] Additionally, variability appears greater in angular than linear data.[9] The "Wits appraisal" of jaw disharmony is a

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linear measure of the extent to which the jaws are related to each other anteroposteriorly. During cephalometric tracing, the Wits appraisal is measured from points A and B onto the occlusal plane.[8] The occlusal plane is represented by a line drawn through the region of maximum cuspal interdigitation. The points of contact on the occlusal plane from points A and B are termed AO and BO, respectively. By using the Wits appraisal, the possible interpopulation variations in the relative positions of the sella and nasion because of a shortened cranial base can be excluded.

Utilising the Wits appraisal, a positive reading would convey that point BO would be positioned posterior to point AO in skeletal Class II jaw dysplasias. In Class III skeletal jaw disharmonies, a negative reading would convey that point BO is positioned anterior to point AO. Previous reports on small samples[9-10] have indicated that in class I, AO and BO coincided in females while point BO was located 1 mm ahead of point AO in males. Zaffiri et al. (2024) however, found no significant difference between sexes in the Wits appraisal.[11] The Wits appraisal was therefore the primary reference used to classify and describe malocclusion in our study, as it has been reported to provide the highest coefficient of variability for evaluation of jaw relationships.[12-13] Unfortunately, there is paucity in the literature regarding cephalometrics associated with malocclusion (such as SNA angle, SNB angle and ANB angle among others) in Black individuals across the world, and no studies could be found regarding these angles in a South African context.

Table I: Cephalometic landmarks used to quantify prognathism and malocclusion.

Landmark	Abbreviation	Definition
A point	A	The point of the deepest concavity anteriorly on the maxilliary alveolus.[8]
B point	B	The point of the deepest concabity anteriorly on the mandibular symphysis.[8]
Sella	S	The midpoint of the stella turcica.[8]
Nasion	N	The most anterior point on the fronto-nasal suture.[8]
Anterior nasal spine	ANS	Tip of the median sharp bony process of the palatine bone in the hard palate.[8]
Posterior nasal spine	PNS	Tip of the posterior spine of the palatine bone of the hard palate.[8]
Gonion	Go	The point is located at the mandibular angle, where a perpendicular line is dropped from the intersection of two tangents - one along the posterior margin of the mandibular ramus and the other along the inferior margin of the mandibular body. (Figure. 1) [51]
Menton	Me	The most inferior point on the mandibular symphysis (Linjawi et al., 2021).
Prosthion	Pr	Most anterior point in the midline on the alveolar process on the maxilla (Martinez et al., 2017).
Basion	Ba	The lowest point on the anterior rim of the magnum foramen (Martinez et al., 2017).

Additionally, very few studies investigate age-related changes in the cephalometrics of adults. The rising number of adults seeking orthodontic treatment and orthognathic surgery[14] warrants exploration of age-related changes in cephalometrics. Although changes in adult cephalometrics may be subtle, identifying these adult changes can help distinguish between post-orthodontic relapse and normal developmental or maturation processes.[15-16] Understanding adult craniofacial changes therefore, is crucial for effective treatment planning in surgical orthodontic cases.[17] Majority of dental standards have been obtained from adolescent samples.[18-21] This study aimed to determine the cephalometric characteristics according to the Wits appraisal category in South African Black adults referred to an academic oral health centre. Lateral cephalograms were evaluated to assess how cephalometric measurements vary according to sex and age.

MATERIALS AND METHODS

A total of 114 (63 females and 51 males) lateral cephalograms were retrospectively collected from the SMU Oral Health Centre for patients aged between 18 years and 58 years, who were referred for malocclusion and skeletal analysis prior to orthodontic treatment. The maximum age of 58 years was based on data availability and not for any other cut off reasons. Only cephalograms without the evidence of bone trauma, orthodontic braces, tooth loss or tooth restorations were included for analyses. The sample was selected by means of a convenience sampling strategy.

All data acquisition was performed using ImageJ software programmeme.[22] The relevant cephalometric landmarks, planes and abbreviations used for analysis are described in Table I, Table II and Table III respectively. The measurements and the normative values are also described in Table III. Figure 1 illustrates the landmarks taken and Figure 2 illustrates

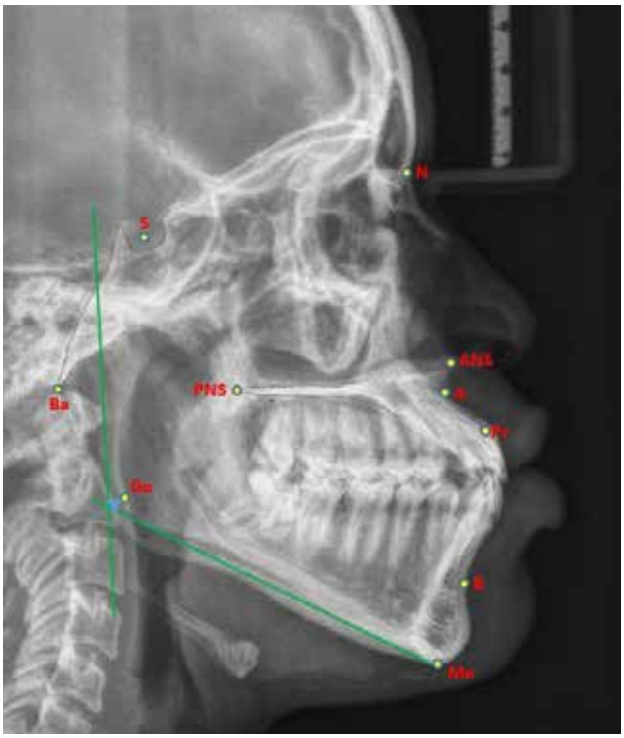

Figure 1: Cephalometric landmarks used to quantify malocclusion. The green lines indicate tangent lines to the posterior margin of the mandibular vertical ramus and inferior margin of the mandibular body, where a perpendicular point was dropped at their intersection to the mandibular angle (to indicate the gonion landmark).[51]

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Table 2: Cephalometric planes

Plane/ Relationship	Description
Stella-Nasion line	The plane created by a line through the nasion and sella.[53]
Mandibular plane	Tangent line drawn at the lower border of the mandible.[51]
Mandibular ramus plane	Tangent line drawn along the posterior margin of the mandibular ramus.[51]
Maxillary (palatal) plane	The plane demonstrated by a line through the anterior and posterior nasal spines.[8]
Nasion A-point plane	The plane demonstrated by a line drawn from nasion to A-point.[53]
Nasion B-point plane	The plane demonstrated by a line drawn from nasion to B-point.[53]
Occlusal plane (O)	An imaginary surface that touches the incisal edges of the incisors and the tips of the occluding surfaces of the posterior teeth.[8]
AO point	Point of contact on the occlusal plane as projected from A point at 90 degrees.[8]
BO point	Point of contact on the occlusal plane as projected from B point at 90 degrees.[8]

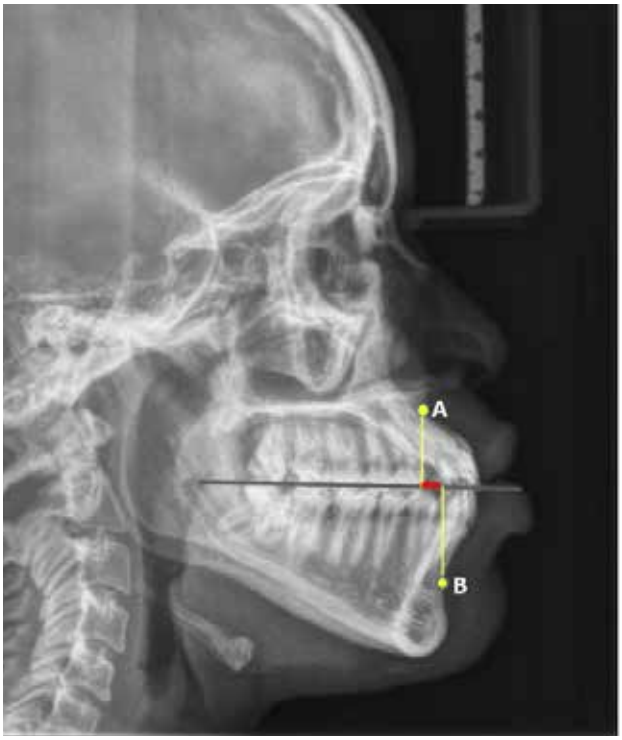

Figure 2: Grey horizontal line = occlusal plane, yellow line from A point to occlusal plane at 90 degrees; yellow line from B point to occlusal plane at 90 degrees; Wits appraisal = red horizontal line

Table 3: Cephalometric measurements derived from the planes

Parameter	Abbreviation	Description	Norms	
			Internationally established	Previously established in South Africa
Sella-Nasion-A point angle	SNA	Main parameter for relative anteroposterior position of the maxilla to the cranial base.[8,54]	82°	
Sella-Nasion-B point angle	SNB	Main parameter for relative anteroposterior position of the mandible to the cranial base.[8,54]	80°	
A point-Nasion-B point angle	ANB	Relative anteroposterior position of the maxilla to the mandible and can be used to determine skeletal class.[33,55]	2°	
Inter-Incisal angle	IIA	The angle between the long axis of the maxillary incisors and the long axis of the mandibular incisors.[8,45]	131°	
Maxillary Incisal Inclination	MxII	The angle between the maxillary plane and the long axis of the maxillary incisors assessing relative maxillary protrusion.[8]	112.5° (females) and 111.0° (males)	
Mandibular Incisal Inclination	MnII	The angle between the mandibular plane and the long axis of the mandibular incisors assessing relative mandibular protrusion.[8]	95.6°	
Gonial angle	GoA	The angle formed at the point of intersection of a line tangent to the lower border of the mandible and another line tangent to the border of the ascending ramus and the condyle (Figure 3). [29,39]		121° and 122°
Wits appraisal		Distance between AO and BO where the reading is positive if BO is behind AO and negative if BO is anterior to AO (Figure 2). [8,10]		0 mm (females) and 1 mm (males)
Gnathic index	GI	Main parameter for relative maxillary protrusion:[35] Ratio of basion-prosthion length to basion-nasion length , calculated with the formula:	98 – 103	

Internationally established norms were obtained from European populations for SNA[28], SNB[28], ANB[28], IIA[28], MxII[44], MnII[44] while the population group for gnathic index[35] was not specified. The previously established South African norms reported were from black populations for gonial angle[36,37], while the population groups for Wits appraisal[10] were not specified.

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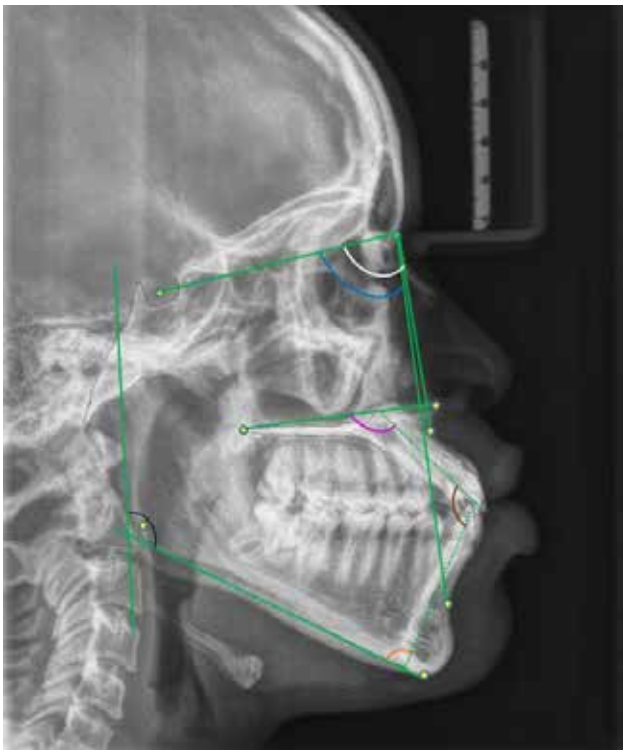

Figure 3: Cephalometric planes and angles measured. The green solid lines indicate planes defined in Table II. The green dotted lines indicate the long axis of maxillary and mandibular incisors. The angle identifiers are as follows as defined in Table III: SNA – white; SNB – blue; ANB -red; MxII – purple; IIA – brown; MnII – orange; GoA - black

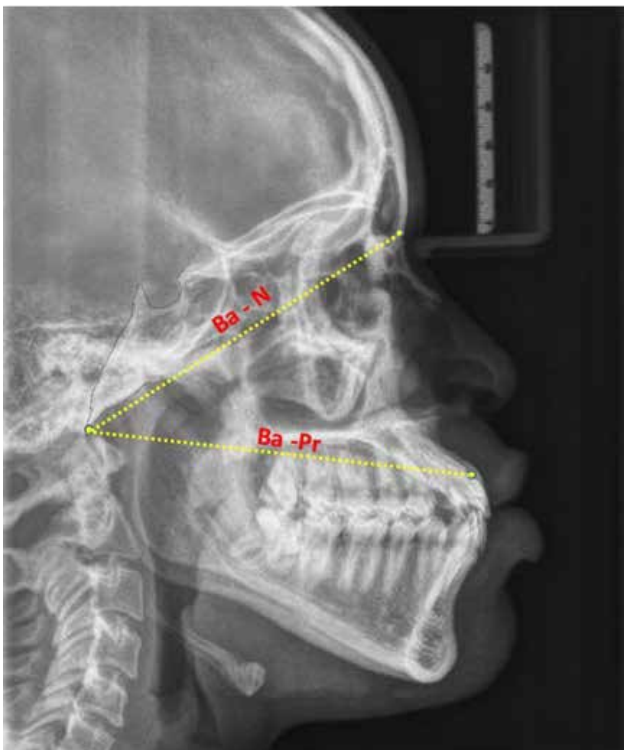

Figure 4: Landmarks for the gnathic index

the Wits appraisal. The angles are further illustrated in Figure 3 and gnathic index in Figure 4. The scale of each cephalogram was calibrated before landmark-based data was collected to determine angles and linear distances. The sample was classified into a negative, positive and zero Wits appraisal categories regardless of sex. The possible sexual dimorphism in the occurrence of zero, negative and positive Wits appraisal was studied.

Table 4: Intra-0bserver error

Measurement	ICC	99% Confidence Interval	
		Lower bound	Upper bound
SNA angle	0.94	0.79	0.98
SNB angle	0.91	0.77	0.95
ANB angle	0.93	0.76	0.98
IIA	0.97	0.86	0.99
MxII	0.91	0.78	0.97
MnII	0.76	0.69	0.83
GoA	0.92	0.81	0.93
Gnathic index	0.98	0.88	0.99
Wits appraisal	0.96	0.85	0.97

Statistical analysis was performed using Paleontological Statistics (PAST) software.[23] First, descriptive analysis was performed on all data. A Shapiro-Wilk test was then used to assess normality.

Based on the results, either parametric (one-way ANOVA with Tukey's pairwise comparisons) or non-parametric (Kruskal-Wallis with Mann Whitney's pairwise comparisons) tests were applied[24] to compare cephalometric parameters between groups (sex-Wits appraisal categories). A p-value of ≤ 0.05 was considered statistically significant. Correlation tests (where r = coefficient of correlation, r^2 = coefficient of determination and p = probability) were performed to assess the relationship between age and various cephalometrics. Pearson's correlation coefficient (r) was used for normally distributed variables, while Spearman's correlation coefficient was applied for non-normally distributed variables.[25] A value of r = +1 indicated a perfect positive correlation, r = -1 indicated a perfect negative correlation, and r = 0 indicated no linear association.[26]

Intra-observer reliability for measurement accuracy was conducted by the principal researcher. Ten percent of the sample (N = 11) was randomly selected from the entire sample and analysed twice by the principal researcher to assess the intra-observer reliability. Measurement repeatability was determined using an intraclass correlation coefficient (ICC: 2, k) classification, where k is 2 since there were two measurements for every variable).[27] This approach determined coefficiency based on analyses performed twice by the researcher.

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Table 5: Univariate analysis of cephalometric dimensions for the entire sample, females and males according to occlusal relationships (Wits appraisal categories).

Groups per Wits appraisal category	SNA (°)	SNB (°)	ANB (°)	IIA (°)	MxII (°)	MnII(°)	GoA (°)	Gnathic Index	Wits appraisal (mm)
Entire sample	**83.58**	**82.65[a]**	**1.38[c]**	**110.57**	**125.42**	**90.02**	**124.42**	**102.30**	**-5.09[h]**
(-)	*5.89*	*4.85*	*5.35*	*7.78*	*6.01*	*7.17*	*6.83*	4.97	*4.45*
N = 53	(68.04-100.19)	(73.15-96.52)	(-18.32-10.44)	(86.89-125.84)	(111.98-136.33)	(76.25-108.01)	(113.53-142.52)	(87.70-116.62)	(-23,34-(-0,52))
Females	**83.71**	**81.28**	**2.86[df]**	**110.42**	**124.58**	**89.7[g]**	**125.74**	**102.55**	**-4.47[i]**
(-)	*5.24*	*4.67*	*4.04*	*7.88*	*6.40*	*7.80*	*6.78*	*4.40*	*2.97*
N = 26	(76.33-99.72)	(73.15-93.04)	(-10.32-9.98)	(96.78-125.84)	(111.98-136.03)	(76.25-107.93)	(114.28-142.52)	(93.85-111.54)	(-13,93 -(-0,77))
Males	**83.46**	**83.98[b]**	**-0.05[de]**	**110.71**	**126.22**	**90.32**	**123.15**	**102.06**	**-5.70[j]**
(-)	*6.57*	*4.72*	*6.11*	*7.83*	*5.61*	*6.65*	*6.75*	*5.54*	*5.52*
N = 27	(68.04-100.19)	(73.39-96.52)	(-18.32-10.44)	(86.89-124.99)	(115.07-136.33)	(77.02-108.01)	(113.53-133.84)	(87.70-116.62)	(-23,34 -(-0,52))
Entire sample	**87.09**	**82.81**	**4.35**	**112.88**	**123.46**	**90.45**	**122.24**	**105.21**	
(0)	*3.96*	*4.05*	*1.69*	*8.34*	*6.22*	*8.16*	*6.19*	*5.62*	-
N = 7	(83.23-94.47)	(78.51-90.84)	(1.66-6.59)	(98.69-121.41)	(116.03-134.45)	(74.19-98.31)	(116.64-133.08)	(98.81-113.44)	
Entire sample	**85.33**	**79.94[a]**	**5.28[c]**	**106.21**	**124.75**	**92.80**	**123.90**	**103.70**	**2.94[h]**
(+)	*4.76*	*4.30*	*3.20*	*8.05*	*6.89*	*6.41*	*5.71*	*4.97*	*2.00*
N = 54	(77.83-99.70)	(72.54-92.54)	(-3.20-13.45)	(90.29-123.09)	(109.73-140.58)	(80.71-107.60)	(106.03-137.11)	(89.83-116.27)	(0.31-7.93)
Females	**85.79**	**79.78**	**5.97[f]**	**104.93**	**125.70**	**93.57[g]**	**125.23**	**103.90**	**3.25[i]**
(+)	*5.15*	*4.22*	*2.89*	*7.77*	*7.28*	*5.94*	*5.20*	*4.79*	*1.76*
N = 31	(77.83-99.70)	(72.54-88.60)	(1.09-13.45)	(90.29-123.09)	(109.73-140.52)	(80.71-104.27)	(115.64-137.11)	(94,70-114,41)	(0.60-7.93)
Males	**84.73**	**80.16[b]**	**4.37[e]**	**107.94**	**123.47**	**91.77**	**122.11**	**103.43**	**2.51[j]**
(+)	*4.21*	*4.48*	*3.43*	*8.28*	*6.27*	*7.00*	*5.98*	*5.31*	*2.26*
N = 23	(80.23-96.76)	(72.77-92.54)	(-3.2-9.32)	(92.34-121.26)	(114.93-140.58)	(81.84-107.60)	(106.03-132.56)	(89.83-116.27)	(0,31-6,93)

Number of individuals = N; mean values are indicated in bold; standard deviation is indicated in italics; range is shown within the round (brackets); repeating alphabet letters in the superscript indicate statistically significant differences (p value < 0.05) between categories/sexes per parameter. Wits appraisal categories are indicated by (+) for positive reading; (-) for negative reading; (0) for readings with zero.

Statistical comparisons involving males in the Wits category of zero (0) could not be made as N = 1 for that category, and thus comparisons with female in the same category (N=6) were not made

RESULTS

The intraclass correlation coefficient (ICC) tests for intra-observer error (Table IV) indicated excellent measurement agreement, with 95% confidence intervals of good to excellent, except the mandibular incisal inclination (MnII), which showed good measurement agreement (ICC – 0.76) and a 95% confidence interval of moderate to good.

In the entire sample, parametric data included the Sella-Nasion-B point angle (SNB), inter-incisal angle (IIA), maxillary incisal inclination (MxII) angle, MnII angle, gonial angle and gnathic index on which one-way Anova with Tukey's pairwise comparisons tests were applied. Non-parametric data included the Sella-Nasion-A point angle (SNA), A point-Nasion-B point angle (ANB), and Wits appraisal, where the Kruskal-Wallis with Mann-Whitney's pairwise comparisons were applied. In the sex group comparisons, parametric data included the SNA angle, SNB angle, IIA, MxII angle and gonial angle, whereas the ANB angle, MnII angle, gnathic index and Wits appraisal were non-parametric.

The summary statistics for the cephalometrics of each group (entire sample, females and males) per Wits appraisal reading category (negative (-), positive (+) and zero (0)) are shown in Table V. There were no statistically significant variations noted in the parameters between males and females of the same Wits appraisal reading (female negative vs male negative; female positive vs male positive), except for the ANB angle which was significantly larger in females than males of the negative Wits appraisal category (Table V). Sex comparisons could not be made in the zero Wits appraisal category as there was only one male in that category.

There were no statistically significant differences for SNA, IIA, MxII, GoA or gnathic index between Wits appraisal categories in the entire sample, within sex groups or between

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sex groups. The SNB angle was significantly larger in the negative compared to the positive Wits appraisal categories for the entire sample and when comparing negative males to positive males. ANB was significantly smaller when comparing the negative Wits appraisal category to positive Wits appraisal category in the entire sample and when comparing negative females and males to positive females and males respectively. For MnII, negative category females were statistically smaller than positive category females. The gnathic index was larger in positive Wits appraisal groups when compared to the negative groups but not statistically significantly so. The mean Wits appraisal values were far smaller (< 0 mm) in the negative groups, while they were greater than 0 mm in the positive groups. Sex variations in the mean Wits appraisal showed smaller values in males when compared to females.

Females displayed larger SNA angles and smaller SNB angles in all categories while males displayed larger SNB angles and smaller SNA angles in the negative Wits appraisal group. Sex variations showed that the SNA was larger in females compared to males in all groups and the SNB was larger in males than females in all groups. ANB in males of the negative Wits appraisal category was significantly smaller than in females of the negative Wits appraisal category.

In the entire sample, significant weak positive correlations were observed for SNA (r = 0.18; r2 = 0.03; p = 0.05), gnathic index (r = 0.21; r2 = 0.04; p = 0.03) and Wits appraisal (r = 0.18; r2 = 0.04; p = 0.04), while significant weak negative correlations with age were noted for the gonial angle (r = -0.19; r2 = 0.04; p = 0.04). Age correlations in the entire sample did not follow a homogenous pattern and therefore correlations were evaluated separately for each sex. Age correlations were weak in both sexes, but weaker in males than females. In females, the gonial angle decreased significantly with age (r = - 0.33; p = 0.01), while the gnathic index increased significantly with age (r = 0.36; p = 0.00). These same parameters (gonial angle and gnathic index) in males were weaker and negative when compared to females, and they were not significant.

Furthermore, age correlations were performed for Wits appraisal categories and all correlations were weak and insignificant, except the gonial angle, which had a significant weak negative correlation (r = - 0.26; r2 = 0.07; p = 0.04) in the Wits category of both zero and positive combined (due to the small sample size in the category of zero, cephalometrics of that group were combined with those of the positive group when correlating age).

DISCUSSION

The results of this study present cephalometric data specific to Black South African orthodontic patients, emphasising characteristic features associated with malocclusion.

The negative Wits appraisal category in Table V represented class III with mean Wits of -5.09 mm and mean ANB of 1.38°. As expected for skeletal class III, the mean SNB angle of 82.65° and the mean gonial angle of 124.42°, were greater than the norms which is consistent with mandibular protrusion.[28-34] The gnathic index of 102.30 coheres with the position of a maxilla in normal occlusion35, while the SNA of 83.58° would be associated with a protrusive maxilla (SNA > 82°).[28,34]

The positive category, associated with skeletal class II (ANB > 4°; Wits: 2.94 mm) showed a relative protrusion of the maxilla, which was further corroborated by a larger SNA and gnathic index than those in normal occlusion.[28,34-35] The mean SNB of 79.94° in the positive group seemed to indicate a normal mandibular position and was significantly smaller than the SNB in the negative Wits appraisal category. The mean gonial angle of 123.90° in the positive group, although smaller than the one in the negative group, was still greater than the norms (> both 121° and 122° as established by Oettlé et al., (2009)36 and Pillay at al., (2017)[37] respectively). Reasons for this difference could include the different modalities used, where dried skeletal collections were used in a study by Oettlé and colleagues (2009)[36] and panaromic radiographs in a study by Pillay and colleagues (2017), [37] whereas lateral cephalograms were used in this study. While it has been reported that cranial dimensions from radiographs were generally larger than those on cadaveric data,[38] there should not be any differences between the gonial angles measured on panaromic radiographs versus lateral cephalograms.[39] Other factors that may account for differences in gonial angle include variations in age ranges, dentition status, and the representation of the sexes across the different studies.

Our findings of a protrusive maxilla in class II malocclusions are not surprising. In a study by Rosenblum (1995),40 maxillary protrusion was found in 56% of class II malocclusion samples, while it was as a result of mandibular retrusion in 27% of the sample, and the other 17% had neither maxillary protrusion nor mandibular retrusion. In an adult Indian sample,[41] Sinha and colleagues (2018) noted that 27% of class II malocclusion samples presented with maxillary protrusion and 68% comprised mandibular retrusion (retrognathism), and the smallest portion of the sample (5%) had both a protrusive maxilla with a retrusive mandible.

Only 7 individuals in the entire sample had Wits appraisal readings of zero, which is categorised as class I malocclusion. Cephalometrics in this category in our study were associated with both a protrusive maxilla and protrusive mandible. For maxillary protrusion, these were marked by the SNA of 87.09° (which was > 82°) and gnathic index of 105.21 (which was > 103). For protrusive mandible, an SNB of 82.81° (which was > 80°) and gonial angle of 123.90° (which was > 122°).

An older study by Bacon et al., (1983)[4] reported similar findings for black individuals with class 1 malocclusion, where their SNA angle of 88° and SNB angle of 84° indicated a combination of protrusive maxilla and mandible. This finding of maxillary and mandibular protrusion[4] was concluded to be normal in black individuals especially when compared to white individuals, who in their study did not demonstrate distinguished protrusion of the jaws. These findings were corroborated by the study of Dandajena and Nanda (2003),[42] who studied an adult black Zimbabwean sample, and found that class I malocclusion individuals presented with both maxillary and mandibular prognathism.

Sex variations in these Wits appraisal categories showed that there were no statistically significant variations (negative versus negative; positive versus positive) except for the ANB angle. The ANB angle (a marker for relative maxillary protrusion) was larger in females than males in both the positive and negative Wits appraisal categories and significant (p = 0.04) in the female negative category (2.86°) than the male negative category (-0.05°). A greater ANB angle in females would also imply a more pronounced relative maxillary protrusion in class II malocclusion compared to

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males. Sex variations displaying a greater ANB in females was also noted in American White populations (orthodontic setting, pre-treatment).43 The greater ANB in females emphasise the notion of a relatively more forward projecting maxilla in females as opposed to males.

The larger SNB angle, indicative of mandibular protrusion, was greater in males than in females across both Wits appraisal categories. Independent of the Wits appraisal category, the distance between AO and BO was more positive in females than in males in both categories: -4.47 mm vs. -5.70 mm and 3.25 mm vs. 2.51 mm. Although not statistically significant, these trends further support the observation of a more protrusive mandible in males than in females across categories and would contribute to a more pronounced class III malocclusion in males. A more protrusive maxilla in females compared to males would contribute to a more pronounced class II malocclusion in females.

In class II malocclusion the SNA angle is expected to be larger than the SNB angle.32,34,40-41 This pattern was also noted in our study across all positive categories. The pattern of the SNB angle being larger than the SNA angle in class III malocclusion cases has been frequently reported in the literature.29,31-33 The mean values of a larger SNB angle than SNA angle in class III categories was only noted in males (N = 27). For females in the class III malocclusion category (N = 26), with mandibular protrusion (SNB: 81.28°), the SNA angle could exceed the SNB angle if the nasion is situated more posteriorly (see Figure 3). A posteriorly positioned nasion is associated with a shorter anterior cranial base as previously described in individuals of African descent.[7]

In the literature,[32] the mandibular incisal inclination (MnII) angle was smaller in class III malocclusions compared to classes I and II. Our study followed a similar pattern (Table V). Beyond the markers of malocclusion discussed in the Wits appraisal groups, our groups consistently showed features of both maxillary and mandibular prognathism. The MxII angles (Table V) were all larger than the established norms[44] of 112.5° for females and 111.0° for males and are indicative of maxillary prognathism in our samples.[29]

The smaller MnII angle in our study compared to the normal pre-established values44 (< 95.6°) indicates the presence of mandibular prognathism especially in the negative categories where they are even smaller than those in the positive categories. A smaller MnII angle in mandibular prognathism (84°) was also noted by Chang et al., (2006)[29] when compared to the normal established values in their study (98°).

The normal interincisal angle (IIA) according to Steiner (1959)[28] is 131°. The IIA noted in our study across all groups were far smaller than Steiner's normative value. According to Wei (1969), a smaller IIA indicates an anterior projection of either the maxilla, mandible or both.[45]

When sexes were evaluated separately, all cephalometric parameters showed weak correlations with age. The gonial angle in females indicated a significantly smaller angle with aging as also previously reported (Oettlé et al., 2016).[46] Although the correlations were weak, they were however stronger in females than those of males. The gnathic index had a significant positive correlation in females, which might be associated with enhanced maxillary prognathism with aging. The gonial angle and gnathic index decreased with age in males (although not statistically significant). Although a decrease in gonial angle has been reported in the literature,[47] varying reports on the correlations with aging have been found in the literature.[48] Unfortunately, the presence or absence of teeth is not always documented, which appears to be the primary factor preventing a decrease in the gonial angle with continued mastication as one ages.[46] There was no literature found which reported gnathic index correlations with age. The parameters which showed statistically significant increases with aging (SNA and gnathic index) are associated with more prognathic jaws especially of the maxilla while that which showed a statistically significant decrease with aging (gonial angle) is associated with a more retracted mandible.

The results of this study reflect a sample referred to a single academic institution and does not necessarily reflect facial skeletal dimensions of all Black South Africans. Further studies including other groups could enhance the applicability of the findings and norms that represent the general population could then be developed. As no single parameter should be relied on entirely for diagnostic purposes and for assessing orthodontic progress,[9,49] the determination of other cephalometrics associated with each Wits appraisal category are proposed towards deriving specific cephalometric norms for Black South Africans.

Findings from this study will be applicable in orthodontics for case related diagnosis, treatment design and growth estimation within the adult categories[28] and therefore improving management of malocclusion in the Black South African population group.[50]

CONCLUSION

In this study cephalometrics of positive and negative Wits appraisal categories, respectively corresponding to Class II and Class III malocclusion in South African Black adult lateral cephalograms are presented. Our groups consistently showed features of both maxillary and mandibular prognathism across malocclusion categories. In the comparison between sexes, males presented with a more protrusive mandible (a more pronounced class III malocclusion), while females presented with a more protrusive maxilla (a more pronounced class II malocclusion) which progressed with age. Future studies could expand the limited Class I malocclusion sample and establish reference values for normal occlusion individuals.

ETHICAL CONSIDERATIONS

Ethical approval from the Research Ethics Committee at Sefako Makgatho Health Sciences University (SMUREC/M/274/2023:PG) has been obtained for this study.

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CONFLICTS OF INTEREST:

None.

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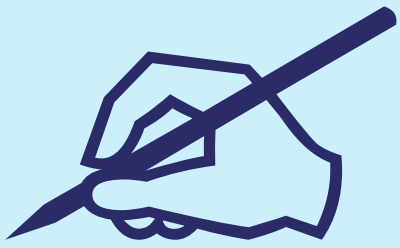
CPD questionnaire on page 510

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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Teething problems with the implementation of the HPCSA core competency framework in an undergraduate dentistry curriculum

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KNM Masike,[1] M Volschenk[2]

ABSTRACT

Introduction

The Health Professions Council of South Africa (HPCSA) adopted and contextually adapted the CanMEDS competency framework, with a view to prepare undergraduate students for the dynamic healthcare needs of patients and communities they serve. However, limited guidance on integration of this framework into existing curricula leaves educators uncertain about its implementation. Given the critical role of faculty engagement in educational reform, it is crucial to understand dentistry educators' perceptions of this framework.

Aims

This study explored dentistry educators' experiences with incorporating the HPCSA core competency framework into an existing undergraduate dentistry curriculum.

Methods

Qualitative methodology within an interpretivist paradigm was utilised. Data were generated by means of semi-structured interviews, then coded and thematically analysed.

Results

Three main themes and four sub-themes were deductively developed, revealing diverse perceptions regarding the teaching and assessment of the HPCSA core competencies. Participants foregrounded barriers and enablers influencing the effective teaching and assessment of these competencies and emphasized the need for faculty development initiatives.

Conclusion

Integrating the HPCSA core competency framework into an existing dentistry curriculum posed 'teething' problems. Ideally, the implementation of new core competency frameworks should form part of a curriculum renewal process and faculty development offerings that prioritize pedagogical conceptual change.

Keywords

CanMEDS roles, competency-based medical education, constructive alignment, core competencies, curriculum renewal, faculty development, pedagogical conceptual change, undergraduate dentistry curriculum

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1. Kebiditswe Masike 90%,
2. Mariette Volschenk 10%

INTRODUCTION

Global calls for contemporary health professions education to be more responsive to the evolving health needs of society[1-3] have catalysed the wide-spread adoption of competency-based educational frameworks at both undergraduate and postgraduate levels. Competency-based Medical Education (CBME) involves an outcomes-based approach to the design, implementation, assessment, and evaluation of health professional education programmes, using an organizing framework of predefined abilities or competencies derived from an analysis of societal and patient needs.[4] Although CBME has become a preferred pedagogy for equipping health professional graduates with the requisite competencies to deliver 21st century health care in increasingly complex contexts,[1,5,6] Harden[7] cautions that this educational approach is not a 'magic bullet' that by itself can address all the problems facing health professions education. Instead, its success is determined by the way in which it is implemented and the extent and quality of faculty engagement with the process.

South Africa joined the global CBME movement in 2011 when the Undergraduate Education and Training (UET) subcommittee of the Health Professions Council of South Africa's (HPCSA) Medical and Dental Professions Board (MDB) embarked on the process of contextually adapting the Canadian Medical Education Directions for Specialists (CanMEDs) competency framework[8] as an organizing framework of Core Competencies for Undergraduate Students in Clinical Associate, Dentistry and Medical Teaching and Learning Programmes in South Africa.[9,10] This framework, implemented in 2014, requires a competent healthcare professional to be proficient in the seven distinct, yet integrated roles of healthcare practitioner, communicator, collaborator, leader, health advocate, scholar and professional.[8,10]

It is important to acknowledge that the underpinning epistemology and philosophy of CBME differ significantly from the more traditional biomedical approach followed in most undergraduate health professional education programmes in the South African context, including dentistry programmes. Not only are health professions educators expected to

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adopt new and alternative teaching and assessment practices,[6] but the focus on outcomes in the form of observable competencies requires that teaching strategies and assessment tasks are constructively aligned[11] with the competency outcomes for each of the seven HPCSA core competency roles. Since the concept of CBME may be new to many South African health professions educators, they will first need to familiarize themselves with the selected competency framework and alternative educational approaches and consider the ways in which their specific programme outcomes will support the desired competency development.[7]

Whilst the HPCSA core competency framework clearly delineates the key and enabling competencies to be fostered in health professional graduates,[12] limited guidance and support have been provided thus far for the health professions educators who are required to integrate the competency framework into undergraduate curricula at the various South African Universities. This raises concerns about the preparedness of dentistry educators for implementing the HPCSA core competencies in their relevant undergraduate curricula.[13]

At a South African university where dentistry educators are tasked with integrating the HPCSA core competency framework into undergraduate dentistry programmes, the framework has been made available to all academic staff and students on the institution's online curriculum mapping system, the Learning Opportunities, Objectives and Outcome Platform (LOOOP).[14] However, the dentistry educators at this institution have not received formal training on teaching and assessing the newly adopted HPCSA core competencies in undergraduate curricula, limiting their ability to comprehend the alignment that LOOOP is designed to facilitate. Consequently, the teaching and assessment of these competencies are not fully effectuated when students graduate, potentially compromising the preparedness of future dentists to effectively address the oral health needs of the communities they serve.

Educators often struggle to translate calls for curriculum transformation into their own curricula and adapt their teaching practices accordingly.[15] Since faculty engagement and support play a pivotal role in the success of any type of educational reform,[8] it is important to understand how dentistry educators conceptualize the HPCSA core competency framework and perceive its implementation in their own curricula.[16] Currently, there is limited research on how South African dentistry educators understand the teaching and assessment of the HPCSA core competencies. There is also a paucity in the literature on dentistry educators' perceptions of implementing CBME in the South African context. A recent study conducted at a South African university revealed significant uncertainties among dentistry educators around alignment of the HPCSA core competency framework with the undergraduate dentistry curriculum, foregrounding the need for greater clarity and guidance in teaching and assessing these competencies.[17]

AIM AND OBJECTIVES

The lack of clear guidelines on integrating the HPCSA core competency framework into undergraduate dentistry programmes in South Africa prompted the exploration of dentistry educators' perceptions on the teaching and assessment of these competencies in undergraduate dentistry programmes at the study site. The objectives were to: a) explore and describe dentistry educators' perceptions and understanding of teaching and assessing the HPCSA core competencies in an undergraduate dental programme; b) identify potential barriers and enablers to teaching and assessing these competencies; and c) provide recommendations for faculty development initiatives aimed at enhancing the teaching and assessment of the HPCSA core competencies in undergraduate dentistry curricula.

METHODOLOGY

This was an exploratory study, utilising a qualitative methodology within an interpretivist paradigm. This approach facilitated the co-construction of knowledge between the researcher and participants, thus allowing for a deeper understanding of participants' realities, meaning making and perceptions to emerge.[18,19]

The target population for this study comprised of all full-time and part-time dentistry educators at the selected study site (n=127). Participants were purposively selected based on the following inclusion criteria: being a full-time educator on the undergraduate dentistry programme with at least three years of teaching experience, facilitating learning in both clinical and classroom environments, and holding a dentistry qualification. These criteria were deemed essential for the study as the HPCSA core competency framework had been adapted in South Africa four years prior to conducting the study. It was assumed that participants meeting these criteria would provide rich insight into their perceptions and experiences of teaching and assessing the HPCSA core competencies within the context of undergraduate dentistry education.

Following ethical and institutional approval (S18/05/111), the primary researcher approached eligible participants on an individual, face-to-face basis to inform them about the study. Thereafter a detailed email invitation was sent to each prospective participant. Ten (n=10) educators agreed to participate in the study. The primary researcher conducted face-to-face, semi-structured individual interviews to explore participants' perceptions and understanding of teaching and assessing the HPCSA core competencies within their respective modules. The interview schedule was developed based on the study objectives and existing literature on CBME.

Interviews were conducted, audio-recorded and transcribed verbatim by an independent transcriber with the written, informed consent of each participant. Participation was voluntary and participants could withdraw from the study at any stage without any negative consequences. To ensure confidentiality, each participant was assigned a unique number so that no data could be linked to individual participants in any of the research reports.[17] An iterative process of data analysis was undertaken, guided by Braun and Clark's[20] six phases of thematic analysis. These involved familiarising oneself with the data, generating initial codes, searching for themes, reviewing themes, refining and naming themes, and producing the final report.

FINDINGS

Participant demographics

Ten (n=10) full-time dentistry educators who taught across undergraduate dental programmes at the selected study site participated in this study. Most participants (n=9) held

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RESULTS

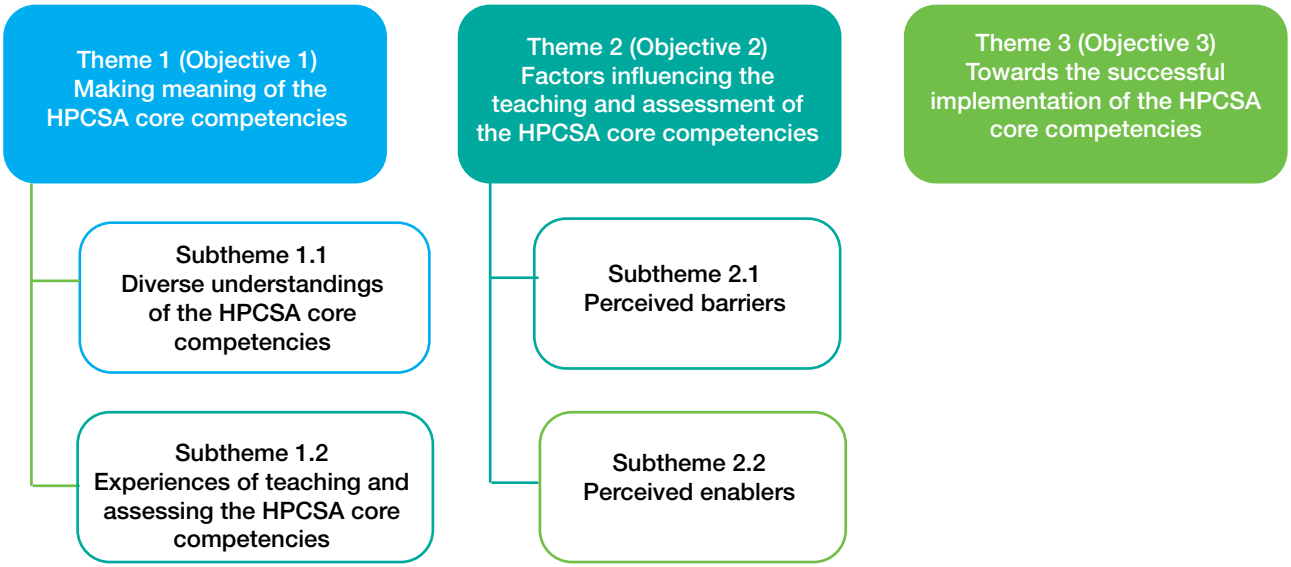

Figure 1: Themes and Sub-themes

a Bachelor's degree in Dental Surgery (BDS/BChD), while one (n=1) held a Bachelor's degree in Oral Hygiene. One (n=1) participant completed an additional Bachelor's degree in Dental Therapy. Participants' teaching experience varied between 4 and 18 years.

THEMES

The qualitative data analysis offered valuable insights into the range of understandings that dentistry educators held about the HPCSA core competency framework, as well as their perceptions of teaching and assessing these competencies in an undergraduate dental curriculum. Three themes and four sub-themes were deductively developed and categorized according to the study objectives (see Figure 1).

Theme 1: Making meaning of the HPCSA core competencies (Objective 1)

Participants' responses revealed a range of perceptions and understandings of the HPCSA core competencies and what the implementation of this framework might mean for their teaching practice going forward. This influenced their engagement with the teaching and assessment of the relevant competencies in their respective modules.

Sub-Theme 1.1: Diverse understandings of the HPCSA core competencies

Most participants demonstrated some degree of background knowledge about the HPCSA core competency framework, recognising it as having been "*developed in Canada*" and "*adopted by the HPCSA*" *[P1].* While participants understood the framework as a set of competency roles, many struggled to recall the specific roles by name: *"Could you just refresh my memory on those competencies?" [P9]* and *"I'm not sure what those competencies are. Maybe if you can just give me a guide... Oh yes, I remember now, yes, to be managers and all that" [P5].* A few participants were completely unaware of the framework's existence prior to participating in this study: *"I am hearing about this for the first time now. I didn't even know there was something like that" [P4].*

Uncertainty about the meaning and content of individual competency roles left many participants feeling overwhelmed by the expectation to implement this new framework within their own modules: *"There are so many things there ... it leaves some parts open to interpretation as to what is 'Professional' and what is 'Ethical' …" [P10].*

Participants' understandings of the HPCSA core competencies ranged from a broad perspective that viewed these competencies as extending *"beyond just clinical skills" [P2],* to a narrower focus that limited the competencies to a few clinical procedures: *"I think there are two basically. It's extractions, you must be confident in doing extractions, and normal restorations" [P3].* The data further revealed conflicting perspectives on whether an integrated or standalone approach should be followed when implementing the competency framework. One participant expressed the belief that *"this must be a module on its own, the core competencies. It must just stand there on its own, they deliver it, they assess them on it." [P6].*

While most participants viewed the seven HPCSA core competencies as equally relevant and important for preparing graduates for practice, some expressed the belief that *"you can't really teach and assess all of those aspects",* specifically *"at pre-clinical level" [P7].* However, there was consensus that it was the university's responsibility to ensure that dentistry students acquire all the HPCSA core competencies prior to graduation: *"My understanding is that before the graduates leave university, they must be having all the seven core competencies that are identified in the Health Professions Council… I think it's a university's responsibility to make sure that every little core competency has been attended to, and they are sure that our students are capable" [P6].*

Sub-theme 1.2: Experiences of teaching and assessing the HPCSA core competencies

Although the HPCSA core competency framework was outlined in the curriculum documents and learner guides, its teaching and assessment were not yet actively implemented across all curricula at the study site. Consequently, most

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participants viewed the implementation of the competencies at this institution as a predominantly theoretical exercise. One participant responded: *"How well we are implementing it, I don't know. Theoretically, yes, we have. You know, in our study guides … we were asked to update our study guides to include those core competencies in each of our learning objectives, in our course guides, our learner guides" [P9].* Another participant expressed concern that, while educators were incorporating the new competencies into their study guides, they were not overtly teaching them, ultimately leaving it to chance that students would develop the necessary competencies by the end of the course: *"You put it in your study guide, and you hope at the end of the course the students actually come up with that competency"[P9].* This challenge extended to the assessment of the new competencies: *"Unfortunately, I don't think we have anything in place to assess, not only advocacy, but in actual fact, all the key competencies"[P2].*

Participants who attempted to teach and assess all seven HPCSA core competencies often felt overwhelmed and eventually focused on only one or two competencies within their respective modules: *"…it was a little bit tricky to cover all of them. So, I found myself using one or two of those competencies more, and not using others at all" [P9].* Moreover, participants shared varied experiences teaching specific competencies. For example, one participant recognised their limitations in teaching the Collaborator and Leader/Manager roles: *"I realise that I am lacking on collaborator and leadership" [P10].* Another participant shared their deliberate approach to teaching the Leader/Manager role: *"…we involve the student, and at particular days, there will be one or two who will be at that particular day, will be managing the going out, what we do at the project and stuff. So, I think in that fashion, we are trying to empower them with those skills of management." [P8].* In contrast, participant six foregrounded the challenges they experienced in fostering leadership among students:*"… when we assign one student to be a manager or a leader, you find that they are pushing each other. No one wants to take responsibility to lead, and which is one of the core competencies..." [P6].* Regarding the Health Advocate role, one participant suggested that it is best learned in a community setting rather than within a university learning environment *"As a health advocate, that is the link between the health practitioner and the community, but some specialties… are in-house professionals, they are not going to the communities… I find it difficult to say how they advocate for the patients who are in the community… we are not really exposed to what the patients are going through and where they are coming from" [P6].*

Theme 2: Factors influencing the teaching and assessment of the HPCSA core competencies (Objective 2)

This theme highlighted educators' perceptions of factors that may have either a negative or positive influence on the teaching and assessment of the HPCSA core competencies.

Subtheme 2.1: Perceived barriers

Factors relating to general curriculum implementation and evaluation processes, as well as poor communication between curriculum developers and educators were regarded as major barriers to the effective implementation of the HPCSA core competencies at the study site: *"… they will just submit this document and keep quiet about it. How are they sure that we are imparting this knowledge to the students as it is now? The next thing that they are likely going to do is to come and amend maybe the communication, not knowing whether it has worked, or it did not work. So, that is my challenge" [P6].* Poor engagement of educators in the curriculum review processes contributed to the poor integration of the core competencies into teaching and assessment practices: *"I think the problem is that most of these exercises like the curriculum review, curriculum development, it is looked at as an elitist kind of activity, whereby a few individuals, based on what, I don't know, are actually meant to participate in, and because of that, there is actually no buy-in from the rest of the staff…"[P2].*

The fact that participants were not previously exposed to this competency framework in their own training or clinical practice seemed to pose another barrier to their engagement with the teaching and assessment of the new competencies: *"I think lack of experience in some of these roles that we are focusing maybe on a few, not incorporating all of them" [P8].* This challenge was exacerbated by the fact that participants have not yet received any training on the pedagogical principles and practical implementation of the new competency framework: *"I have never been particularly taught or trained on these core competencies" [P7].* Participants' sense of confidence with teaching and assessing these competencies was further affected by their primary identification with the clinician role. They regarded themselves first and foremost as dentists, who were required to incorporate the added role of teacher; a role that they mostly felt unprepared for. *"We actually are dentists who are teaching, so we didn't go through the teaching course" [P5].*

Ultimately, time and *"excessive workload" [P10],* significantly affected participants' capacity to engage with the implementation of the new core competency framework: "… *firstly you need to spend a lot of time developing it if you want it to be done properly. So, you need to have the time to do it. You need to have the resources to do it" [P7].*

Sub-theme 2.2: Perceived enablers

Participants were not able to identify many enablers towards successfully implementing the HPCSA core competency framework in their curricula. Some participants believed that an additional qualification in education may better prepare educators to implement the framework in an evidence-based manner: *"…if you have someone that has a qualification in education, they may be able to come up with ideas. They may have the literature to back them up. You know, what they learnt, it will be easier to facilitate or to incorporate these competencies into our curriculum" [P9].* One participant suggested that programme evaluation and feedback may guide dentistry educators to improve on certain aspects of teaching and assessing the new competencies: *"So perhaps an evaluation of that would be great, for someone to tell you, well, you could do better on a certain aspect of it." [P7].*

Theme 3: Towards the successful implementation of the HPCSA core competencies (Objective 3)

Participants made various recommendations for ways in which the successful implementation of the HPCSA core competency framework could be supported.

Some participants believed that it was the responsibility of the HPCSA, as the regulating body, to not only provide guidelines for the implementation of the core competency framework, but also offer training on appropriate teaching

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and assessment strategies: *"… perhaps some sort of a workshop from the HPCSA" [P9].*

The need for faculty development initiatives that would equip dentistry educators with the necessary knowledge and skills to teach and assess HPCSA core competencies was expressed by all participants: *"I'm sure a lot of staff members would be interested in being trained on that, so that we know that we are actually doing it properly [chuckles], because we sometimes think, or we assume that we are doing it and doing it correctly, and hope that we are"[P7].* Workshops and dialogical engagement were regarded as important forms of faculty development: *"If we can have some workshops where people come and say this is what I am doing, this component on this role, this is how, you know, just people coming and sharing in a workshop…then we talk about all those roles… staff development in this particular area will be really beneficial for all staff members..."[P8].*

One participant foregrounded the need for the core competencies to be integrated as curriculum outcomes during future renewal processes, instead of being superimposed on existing curriculum content: *"A suggestion is that when the curriculum review is in place, this document is not supposed to be by-the-way. It must form part of their curriculum, and have the measures in place, how we are going to assess, to make sure that everything that is here is being implemented" [P6].*

DISCUSSION

This study aimed to explore the perceptions and understanding of dentistry educators about the teaching and assessment of the HPCSA core competency roles in undergraduate dentistry programmes at a South African University.

Participants in this study were required to implement a new competency framework that differs significantly from the current curriculum without receiving clear guidance. We found that participants were not adequately prepared to teach and assess the HPCSA core competency framework. Lack of guidance resulted in diverse understandings of the framework among participants. Their conceptions ranged from incorporating the framework into learner guides with the assumption that students will somehow learn the core competency roles before graduating, to teaching and assessing only core competency roles that they regarded as applicable to their respective discipline and omitting those that proved problematic without seeking assistance and guidance.

Participants expected the University and the HPCSA to provide clear guidance on the integration of the HPCSA core competency framework into the existing undergraduate dentistry curriculum. While our study findings affirm the need for clarity and guidance in supporting dental educators to implement this framework,[16] we argue that the dentistry educators play a crucial role in the implementation process. Without their full support and understanding of these competencies, the constructive alignment of the framework's intended outcomes may be compromised.[21]

Dentistry educators in this study encountered various barriers when attempting to integrate the HPCSA core competency framework into their curricula, ultimately limiting their effectiveness in teaching and assessing these new competencies. Their challenges ranged from a lack of exposure to the core competency framework, and limited teaching experience, often tied to their primary professional identity as clinicians,[22,23] to inadequate curriculum revision and insufficient monitoring of the success or failure of curriculum changes, a process commonly known as curriculum renewal.[24] Since evaluation safeguards constructive alignment,[25] continuous evaluation, revision and responsiveness[24] to curricular changes should be embedded in the curriculum renewal process. This will assist curriculum designers and reviewers to identify and address challenges encountered by all stakeholders, thereby better supporting dentistry educators in their teaching needs.

We contend that participants' limited engagement in teaching and assessing the core competency roles within their respective modules, is deeply rooted in their primary professional identity as clinicians. Their traditional approaches to teaching along with perceptions that these core competencies extend beyond the biomedical aspects of patient care, further reinforce this disconnect. Our study findings align with previous studies that highlight how most health professions educators are not formally trained to teach.[22,23,26] Consequently they often prioritize their primary disciplinary identity, feeling more knowledgeable and confident[27] delivering biomedical content to improve patient health[28,26] as they have invested significant time in acquiring clinical skills rather than teaching expertise.[29-31]

Participants acknowledged gaps in their understanding of the HPCSA core competency framework and recommended faculty development initiatives to bridge these gaps. Hedge[32] emphasises that transformation in health professions education can be effectively facilitated through faculty development programs aimed at fostering pedagogical change among clinicians involved in teaching. We concur, and argue that some degree of pedagogical conceptual change is required to support dentistry educators in effectively teaching and assessing the new core competencies..

Rooted in cognitive psychology, conceptual change refers to the alteration of deeply held conceptions that are "in some way central and organizing in thought and learning[33]". In education, the notion of conceptual change is used to understand the challenges individuals encounter when shifting from one framework to another.[34] Pedagogical conceptual change theory applies this notion to educators' conceptions about teaching,[35] facilitating shifts in their underlying beliefs about teaching, and enabling the translation of new pedagogical knowledge into teaching practice.[36,37] In essence, pedagogical conceptual change equips educators with "new ways of both seeing and doing things[38]" in their teaching contexts. Nevertheless, we caution that even with changes in their pedagogical conceptions, some dentistry educators may still feel uncertain about enacting those conceptions. Research suggests that educators require detailed guidance in implementing new teaching and assessment approaches.[13] This is an important consideration, because the cycle of pedagogical conceptual change is not complete until educators have acted on their revised conceptions in meaningful ways.[36]

The pedagogical conceptual change process affords educators an opportunity to identify and reflect on gaps in their teaching conceptions and recognise their need for professional development.[39] We propose that faculty

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development initiatives for curriculum renewal should incorporate a focus on fostering pedagogical conceptual change in order to bridge the gap between dentistry educators' existing teaching philosophies and the philosophy of the new competency framework: support dentistry educators in making sense of, and internalising new conceptions of teaching and assessment,[40,41] and introduce strategies that facilitate the practical application of alternative teaching and assessment models. By adopting this approach, faculty development programs can enhance educators' ability to integrate core competencies into dental curricula, ultimately improving teaching and assessment practices in health professions education.

CONCLUSION

In this study, we explored dentistry educators' perceptions and understanding of teaching and assessing the HPCSA core competency framework in an undergraduate dentistry curriculum. Our findings revealed several 'teething' problems encountered by dentistry educators during implementation. These challenges foregrounded the need for adequate preparation to effectively translate the new core competencies into teaching practice.

We argue that introducing a new competency framework into an existing curriculum without clear guidelines and structured curriculum renewal processes, is likely to result in various misconceptions. In such instances, dentistry educators may rely on their prior experiences of teaching biomedical competencies to interpret and apply the new framework, potentially leading to inconsistencies in the teaching and assessment of the new competencies. We assert that successfully embedding these competencies requires a degree of pedagogical conceptual change, allowing dentistry educators to make meaningful sense of the teaching and assessment of the HPCSA competency framework.

Furthermore, we advocate for continuous curriculum renewal that considers and emphasises the evolving roles and responsibilities of dentistry educators,[42] before a new framework is introduced. We call on dentistry curriculum developers and the UET subcommittee of the HPCSA to recognise the critical role that educators play in implementing curriculum renewal initiatives. In doing so we urge them to provide clear guidance when introducing a new competency framework, to improve the quality of educators' engagement within institutions, and prioritize faculty development programs that focus on fostering pedagogical conceptual change. Such initiatives may better equip dentistry educators to understand, adopt and implement the new core competency framework, transforming their perspectives and practices.

This study contributes to the growing body of literature on the implementation of the HPCSA core competency framework in transforming South African undergraduate dentistry curricula. It underscores the importance of faculty development initiatives that foster pedagogical conceptual change and provide adequate guidance and support, ensuring that educators are well-prepared before a new competency framework is introduced.

DECLARATION

Author[1] conducted the study in partial fulfilment of a Master's degree in Health Professions Education from Stellenbosch University.

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AUTHOR CONTRIBUTIONS

Author[1] conducted the study in partial fulfilment of a Master's degree in Health Professions Education from Stellenbosch University. She collected and analysed the data and subsequently prepared the manuscript. Author[2] acted as primary research supervisor, assisted with verifying the data analysis, and commented and contributed to various sections of the manuscript. Both authors reviewed and approved the final article.

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Cultural Beliefs and Oral Health Practices in Rural KwaZulu-Natal: Bridging Tradition with Modernity through Perspectives of Traditional Health Practitioners

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ABSTRACT

KwaZulu-Natal (KZN), the second largest province in South Africa, is home to the Zulu nation, whose culture is deeply rooted in ancestral traditions, including health practices. Oral health, although essential to overall health, is often influenced by cultural beliefs and practices in rural communities. While modern oral care such as brushing with fluoride toothpaste and visiting a dental professional regularly is widely promoted in urban areas, rural areas in KZN still rely on indigenous methods for maintaining oral hygiene and treating dental problems. These traditional practices reflect both practical solutions and spiritual beliefs. This qualitative study explored how rural KwaZulu-Natal's oral health practices are shaped by cultural traditions, the role of traditional health practitioners (THPs), and modern dentistry and the challenges of integrating the two.

Methods

Purposive sampling included 42 participants from 5 KZN district municipalities who were selected by the Traditional Healers' Research Officer of the province. Selecting participants was based on the criteria of being a registered THP under a recognised organisation, namely *Traditional Healers' Organisation (THO)*, *Vukuzenzele* and *Nupatsa*.

Results

The vast majority of traditional health practitioners revealed that oral diseases can be caused by spiritual and physical forces. This means that a disturbance of spiritual ease can manifest physically through disease. Furthermore, they advocated that in order to strengthen the care of oral diseases, it could be managed by both dental professionals and traditional healers concurrently although different interventions were necessary.

Conclusion

By valuing and integrating traditional practices, rural communities in KZN can achieve oral health outcomes while preserving their rich cultural heritage, demonstrating the confluence of tradition and modernity which can lead to innovative and culturally competent oral health solutions. This collaboration will not only enhance accessibility and acceptability of oral health programs but also foster mutual respect and understanding between diverse oral health paradigms.

Keywords

Traditional health practitioners, cultural belief, oral diseases, oral health.

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INTRODUCTION

The healthcare system in South Africa (SA) faces significant challenges in meeting the needs of its population, particularly in KwaZulu-Natal (KZN), which is burdened by a quadruple disease load of Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome (HIV/AIDS), Tuberculosis (TB), chronic illnesses, and injuries.[1] The shortage of healthcare workers, unevenly distributed between the public and private sectors, exacerbates these challenges.[2] In the public sector, urban areas have more healthcare workers compared to rural regions.[3] With a population exceeding 10 million, only 15% of KZN residents have medical insurance, granting them access to private healthcare services, while the remaining 85% rely on public health services.[4,5] This disparity creates additional vulnerabilities for those in rural and disadvantaged communities, where access to healthcare, including oral health services, is limited. While rural communities in KZN have access to dental care, these are often infrequent and insufficient to meet the population's needs. Many rural residents face barriers such as long travel distances, lack of transportation, and financial constraints, which prevent them from accessing regular dental checkups.[6] Consequently, individuals often seek oral healthcare only when experiencing severe pain, leading to late presentations of oral diseases.

This situation is further complicated by cultural beliefs. The majority of the population in KZN is the Zulu nation,

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whose societal perceptions, culture and practices are highly influential in shaping local health behaviors, representing a known but underexplored barrier to accessing healthcare services in rural areas.[7]

Rural communities tend to have more traditional beliefs, where culture dictates not only social and economic organisation but also health and well-being. Health is viewed holistically, with physical, spiritual, and ancestral well-being interconnected. Communities often place trust in natural, herbal remedies and the guidance of Traditional Health Practitioners (THPs) (Faith healers- abathandazi, diviners- izangoma and herbalists- *izinyanga).*[8] According to the Zulu culture, there are two views of the causes of disease. Good health is usually associated with principled ancestral recognition; it is believed that good health is a blessing for good behaviour, upholding norms and values of the traditions of society.[9] Therefore, when the ancestors are distressed, people manifest with disease. Oral health is not seen in isolation, but as part of one's overall health, influenced by factors including diet, hygiene practices, and spiritual balance. Hence, if someone experiences dental problems such as toothaches or abscesses, it might be interpreted not just as a medical issue but as a sign of spiritual imbalance or a disconnection from their ancestors [10,11]. The second view is that disease is caused by evil or bad spirits from spell casting or witchcraft, particularly disease that defies scientific treatment.[12]

In SA, 80% of black South Africans seek assistance from THPs for health-related conditions.[12] There are currently over 200 000 THPs compared to 25 000 physicians.[12] Although they have no formal medical training, THPs are highly regarded as being capable for treating health-related issues in their communities, as they are easily accessible and affordable,[12] making them the first point of access for health-related issues.[13,14] Many South Africans consult THPs before or alongside conventional healthcare providers.[9]

The use of THPs in management of general health and oral health care is well established in other African countries.[14, 17] The World Health Organization (WHO) reports that 80% of Africans rely on Traditional Medicine (TM) for their healthcare needs.[18,19,20] THPs in Nigeria are known to treat most oral health related conditions with plants and herbs.[21] They further play a pivotal role in addressing early diagnosis of the oral manifestations of HIV/AIDS.[22]

While there is extensive evidence on the role of THPs in managing oral diseases in African countries, there is limited knowledge about their role in SA. Given the high prevalence of oral diseases, such as dental caries and periodontitis, in rural KZN, effective and efficient oral health programs are essential to strengthen oral healthcare.[23] This study aimed to explore how rural KwaZulu-Natal's oral health practices are shaped by cultural traditions, the role of traditional health practitioners and modern healthcare, and the challenges of integrating the two.

METHODOLOGY

Study design

This study was an exploratory, cross sectional study, conducted among THPs to explore cultural beliefs on oral health related conditions among rural communities. Furthermore, it investigated the role THPs could play in strengthening oral health care and improving the quality of life in rural KZN through focus group discussions.

Setting

The study was conducted in five of the eleven district municipalities of KZN; eThekwini, Harry Gwala, ILembe, Umgungundlovu and Ugu districts. The study was approved by the Human and Social Sciences Research Ethics Committee of the University of KwaZulu Natal (HSSREC/00000951/2020). The researcher adhered to the ethical principles as per the University guidelines. Gatekeeper permission to conduct research with THPs was obtained from the KZN THP facilitator at the KZN Department of Health office.

Sampling and selection criteria

A purposive sampling technique in the form of expert sampling was used in this study, where participants were selected by the Traditional Health Practitioners' Research Officer in KZN. As part of the inclusion criteria, THPs had to be registered under a recognised organisation, such as Tra*ditional Healers' Organisation (THO)*, *Vukuzenzele* and *Nupatsa*. Initially the study was to be conducted in the 11 district municipalities of KZN, however, due to the lockdown restrictions imposed by the COVID-19 pandemic, only participants from 5 district municipalities volunteered to participate in the study. The researcher explained the purpose of the study to the Chairperson of the THP organisation in each district and asked him/her to invite THPs to a focus group discussion. The final sample size was made up of 42 THPs.

Data collection

Data was collected from participants using focus group discussions. Informed consent and permission to record the entire session was obtained from all participants. Five focus group discussions were conducted in the community halls of each of the districts using an interview schedule with semi-structured questions which afforded THPs the discussion on their viewpoints on oral health care in rural communities. The average number of participants in each group were eight. The questions were asked in IsiZulu, as all participants were Zulu speaking and the participants' responses were also in IsiZulu. Each participant was given an opportunity to express his/her views, with participant anonymity being maintained by using code names. The code names were dependent on the sequence of data collection per district, as well as the number of participants per group. The focus group discussions were conducted with strict adherence to the COVID 19 protocol.

Data analysis

All the focus group discussions were transcribed verbatim and translated into English. The data from this study was analysed using the qualitative method. This method is described as the analysis narrative through converting raw data into partially processed data where it is then observed, coded and interpreted. [24]

The content of the data from the focus group discussions were recorded, documented, filtered and summarized to report the main aspects of the respondents' accounts. The data obtained from various respondents was compared with each other and classified into 'themes' that emerged in the data set. Data codes were then created based on the identified themes.

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The data was then reviewed and a final coding framework was decided upon. This process was applied to each individual transcript until the analysis was complete. The data was analysed by the researcher and the contributing authors separately and then together, the notes were compared for common themes that emerged until consensus was reached.

RESULTS

Out of the 42 participants, 27 were females (64%) and 15 were males (36%), with an average age of 48. A notable (29%; n=12) of participants had completed up to grade 8 as their highest level of education, while 24% (n=10) were graduates of higher education institutions. Among these graduates, one held a Master's degree and another a PhD. All participants were religiously affiliated, with 86% (n=36) identifying as Africanists and 14% (n=6) as Christians. Regarding employment, all participants practiced as THPs on a full-time basis: 62% (n=26) were *izangoma* (diviners), 12% (n=5) were *izinyanga* (herbalists), and 26% (n=11) were *abathandazi* (faith healers).

In many rural communities, THPs play a crucial role in diagnosing and managing oral diseases. In this study, nearly all participants (95%; n=40) reported being consulted for oral health-related conditions. The THPs indicated that the most common conditions they were consulted for included toothache, tooth decay, gum diseases, oral cancer, mouth ulcers, tooth abscesses, and tonsillitis.

Three key themes emerged from the data analysis: These included the *cultural beliefs and oral health, perceived challenges confronted by THPs, possible collaboration of THPs with dental professionals.*

Theme 1: Cultural Beliefs and Oral Health

This theme highlights the underlying cultural beliefs that influence oral health practices in rural communities. All participants believed that there is a connection between tooth pain and its potential spiritual implications. They believe that toothache is a means of communication of the ancestors to the living as affirmed by some of the participants: *"Toothache could mean that the ancestors are communicating through that pain." (F2)* and *"Very often it is a communication stream from the ancestors." (G3) The following are the sub-themes that illustrate this belief:*

1.1 Failure to seek permission from the Ancestors for a tooth extraction

Most of the participants believed that individuals must seek permission from the ancestors before having a tooth extraction, and failure to do so results in a difficult extraction or post-extraction complications:

"The pain after an extraction can be due to a traumatic dental extraction experience, which often happens when an individual doesn't report to their ancestors before having the dental extraction done." (H1)

"Even a painful socket after the extraction can be caused by spiritual forces because a person had an extraction done when it was not meant to be done before finding out what the ancestors want. Not practicing whatever the ancestors require of you causes disease." (B3)

1.2 Toothache, a reprimand for moral misdeeds

The THPs believed that when one suffers from toothache, one is being reprimanded by the ancestors for moral wrongdoing. The pain may be seen as divine warning or a result of not respecting one's elders or ancestors as noted by the following:

"Often our clients cannot locate the pain. The ancestors communicate via mouth pain but at times the pain can be due to a person's ill behaviour and the ancestors are trying to discipline them." (A4)

"Mouth diseases could be punishment for not doing right with your ancestors, of warning in order to alert you that something is lacking or of conflict in your spiritual well-being." (F1)

"The mouth sores persisted and I ended up mixing my own concoctions and begging the ancestors to show me a sign. Eventually I received a sign that she was using the wrong surname (her father's surname) yet her parents are not married. This angered the ancestors." (J1)

1.5 Teeth and Rites of Passage

Some THPs associated toothache with a rite of passage or an indicator of maturity. In some rural communities, there are certain prayers or rituals that have to be performed in the transition from childhood to adulthood and when they are not undertaken, the person experiences toothache:

"Teeth represent growth, therefore mouth related conditions could be a sign of positive developments that require a certain prayer or practice that will ensure success in the upcoming stages of life." (G1)

"Teeth are part of our spiritual identity, each eruption date signifies a developmental stage spiritually, that require practices of growth and special prayers need to be carried out for each stage of growth." (F1). "If these processes and prayers are not carried out then troubles start". (A1)

"Toothache can mean that a certain ancestor used to suffer from the same diseases of the mouth and requires some sort of prayer from the suffering individual." (G3)

Physical and spiritual forces responsible for toothache

All participants reported that toothache cannot be caused only by spiritual forces but also physical forces too.

"A traditional healer can spiritually investigate holistically as to what caused the physical force to transpire and manifest as a disease." (D2) "Once the reason has been found then the traditional healer and the patient deal with the root cause spiritually." (B1)

"It can't always be spiritual, for example bad breath can be caused by a problem in your gastrointestinal tract or some form of oropharyngeal disease." (B2)

Treatment of dental diseases

All the study participants agreed that dental conditions cannot be treated only by THPs.

"As much as we play a healing role in the elimination of pain, we still believe that dental professionals also have a role to play. For example, we don't remove teeth or do fillings, or

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cleanings. However, we do have our own plants that we use for cleaning." (E1)

"Sometimes a person can go to the clinic and the extraction can be difficult, and some may even refuse to extract after the tooth has broken. We are able to give them concoctions that can loosen the tooth and manage pain until they go to someone else for an extraction if need be." (F3)

"There is no guaranteed healing/ cure from one practice both THPs and dental professionals are capable in their own ways." (D4)

"I also think both practices are good in their own rights. At the end of the day we are not in competition with each other, the purpose is to serve the people and save lives." (G4)

Theme 2: Perceived Challenges confronted by THPs

This theme highlights some of the perceived challenges experienced by THPs.

2.1 The need for THPs in the Modern Age

As the world advances technologically, participants had a contradictory perception to the need for THPs in the future. Almost all participants (95%) believed that they will survive in the future:

"Technology is ever developing and it is possible to develop healing through technology. Traditional healing taps into all aspects of human existence; physical, psychological, spiritual and otherwise. Therefore, the demand for THPs will definitely increase in the near future." (B1)

"There will definitely be an increase in the future. New diseases are being discovered, substance abuse is rife and the quality of the food we eat is now becoming poorer, this means more illnesses that need Traditional Healing." (F3)

"The demand will increase because traditional healing is a natural and a special gift regardless of physical advancements and changing times." (A4)

"THPs are born every year, they are spiritually chosen. That will never change, so the demand for THPs in the near future will rise." (E3)

However, a few participants (5%) believed that the demand for THPs will decrease in the future for the following reasons:

"There will be a decrease in demand of THPs in future, because our government does not include THPs in the national health system. Also, we never have workshops where we are taught to advance ourselves educationally and technologically." (D2)

"We are neglected and out casted, that's why you will find that most rural THPs are still very backward in terms of technology." (A2)

2.2 Bogus Traditional Health Practitioners

The participants believed that they are threatened by fake traditional healers:

Social media is a threat because it allows bogus healers to thrive." (F1)

"Some bogus healers can simply Google different types of traditional medicines and start calling themselves healers, jeopardizing the entire body of authentic THPs." (D1)

"There are far too many chance takers who offer magical healing through dark spirits. Unfortunately, these so-called healers attract scores of patients as most people are looking for instant success." (A5)

2.3 Lack of internet access

Participants believed that the lack of internet access in rural areas can be challenging for them:

"Access to online consultations may also cause a decline in demand as we have THPs who are highly gifted but are unable to use the internet due to a lack of education and poor signal in most rural areas." (H2)

Theme 3: Possible collaboration of THPs with dental professionals

This theme highlights that the possibility of THPs and dental professionals working together with dental professionals in managing their clients' dental problems:

3.1 Acknowledging the role of dental professionals

As much as THPs consult and treat clients with dental problems, they acknowledge the need for dental professionals to treat dental conditions:

"Some illnesses are beyond my understanding and may need a dental professional even after I have tried several attempts to relieve the person from pain. As THPs, we ought to know our boundaries as much as dental professionals should know theirs. No one is better than the other, we just need to accept each other and help ill people." (H1)

"Some of our clients start by seeing dental professionals, others start by seeing a THP and then we ask them to have the tooth removed by dental professional after certain procedures have been carried out by us. It's not a problem because the patient has that right." (C3)

"Dental professionals know the detailed structure of the tooth more than I do. So, it's ok if my clients see them before or after me. I don't have a problem with that." (D3)

"There are procedures which we cannot do and do not conduct, such as cleaning, fillings, dental extractions etc. We only stick to what we know and prefer the professionals to deal with the rest." (A5)

3.2 Willingness to collaborate with dental professionals:

The results show that participants were willing to collaborate with dental professionals in the holistic management of their clients:

"I actually informally refer my patients to the dental clinics after working out the root cause and fixing it." (G4)

"Whenever I treat an illness, I prefer sending my patients back to the doctor even if they feel ok, just to have tests done that will ensure that they are fully healed physically." (D4)

3.3 Perceived barriers to collaborate with dental professionals:

As much as THPs are willing to collaborate with dental

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professional in the management of oral diseases, they also perceived barriers in doing so, such as not being recognized by the government or being looked down upon by dental professionals or not having their clients being referred back to them:

"The non-recognition by the government of THPs." (F1)
"Traditional healing plays a vital role in healing holistically, even though we are often looked down upon by western health care workers." (C5)

"What we have realized is that we refer to the conventional health system and we hardly get referrals back." (D1)

THE WAY FORWARD

The participants were asked about their perceptions regarding collaboration with dental professionals in order to improve oral health in rural KZN. The following are some of their suggestions:

"Dental professionals should be more accepting to the patients' belief systems, be more open minded and not just rely on textbook information." (A2)

"THPs can be invited to dental workshops, and dental professionals can be invited to THP workshops. This can help in exchanging knowledge and benefit the patient." (C2)

"Dental professionals shouldn't look down on us, they shouldn't isolate us from helping people because we tend to treat the same patients anyway. They shouldn't judge us by the level of our education. What they don't know is that tooth extractions can be deadly if caused by spiritual forces, we see this in our communities. This can have a bad effect on the dental professional's spiritual being in the long run." (A3)

"Cross referrals are important. Post treatment evaluation is rare by the dental professionals, because some of their clients come to us afterwards. Just because these clients do not go back to them doesn't mean that the patient was completely healed or that dental professionals are the only capable body of treating oral diseases." (B3)

"We do understand that some of the herbs and traditional medicines do not respond to toothache hence the importance of dental professionals. Pain medication doesn't work too at times when you have toothache and we are accepting to that. We seek that acceptance and acknowledgement from dental professionals." (G3)

"I would like dental professionals to respond by accepting the existence of THPs and have a round table discussion with us which will ensure that in the end, the patient is healed and equipped with knowledge." (B4)

"Dental professionals should also consider referring their patients to THPs as much as we also refer to them." (G4)

"Oral health awareness programs should also be done in deep rural areas. We would also like seminars and workshops where we are also given the platform to present what we know about the disease of the mouth and oral health."(D4)

"We would also like our traditional medicines to be tested and accepted, not stolen and repackaged." (E4)

"We can think we are doing a good job but if we're not getting positive feedback from health professionals and other organisations, it worries us." (D4)

"We would like the dental professionals to respond by firstly acknowledging that their patients have different belief systems, secondly by acknowledging that THPs exist and do treat some oral health related conditions. Lastly, and most importantly would be by creating a platform where both the dental professionals and the THPs can have knowledge-sharing discussions for the benefit of the patient whose total health comes first, that's if we put business aside and practice the National Department of Health's 'Batho Pele' principle." (A5)

DISCUSSION

There is a huge disparity in oral health between rural and urban areas in KZN. Rural communities face considerable challenges in accessing dental care, compounded by cultural beliefs and mistrust in healthcare systems. This study found that Traditional Health Practitioners (THPs) are often consulted for dental problems, indicating that people in rural areas may turn to THPs for a spiritual diagnosis and seek answers from their ancestors for their pain. This finding is similar to a study conducted by Wright in 2008 who noted that cultural beliefs are often interwoven with spirituality, where health is not merely a physical state but a reflection of a person's relationship with their ancestors and the natural world.[11] This is further supported by Sithole & Odhav in 2011, who found that some rural people believe that toothaches could be caused by ancestral spirits or witchcraft, requiring spiritual interventions and herbal remedies.[10]

African traditional health practice is a holistic healthcare system, viewing illness as having both natural and spiritual causes. Treatment aims to restore physical, mental, and spiritual well-being. This study found that THPs treat their patients spiritually and offer TM when necessary, similar to findings by other researchers, who noted that TM aims to restore the patient's overall well-being through alternative health practices.[13]

Participants in this study highlighted ongoing challenges faced by THPs, particularly the lack of legal recognition and explicit legislation governing their profession.[13] In this study, THPS felt threatened by bogus healers using internet (Google) to get information to treat people. Traditional healers are practitioners who use indigenous knowledge, spiritual practices, and natural remedies. They are often revered within their communities for their deep knowledge of medicinal plants, spiritual healing techniques, and holistic approaches to health.[26] They typically undergo years of training, often inheriting healing knowledge passed down through generations.[27] The authenticity of a traditional healer is generally determined by their training, community reputation, and experience. In contrast, bogus healers are individuals who claim to possess healing abilities but lack the necessary training and genuine expertise. They are often motivated by financial gain, and their practices can be unproven, misleading, or harmful as observed by other researchers.[28, 29]

The increasing reliance on modern medicine and technological innovations in healthcare has led some to question the necessity of THPs in the future. In this study, while most believed that there will still be a demand for THPs in the future, some were pondering the need for them. A

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study by Andaleeb and Yousaf suggests that technological advancements may threaten the role of traditional healers, particularly in urban and technologically advanced regions where access to modern healthcare is easily available.[27] On the other hand, many argue that the need for THPs will not disappear in the future, but rather, they will continue to play an important role, particularly in rural areas and within communities that maintain a strong cultural connection to traditional practices. Traditional healers often offer more holistic, culturally relevant, and personalised care, addressing not only physical but also mental, emotional, and spiritual aspects of health. [28]

This study found that THPs were willing to collaborate with dental professionals in combating the high prevalence of oral diseases. WHO emphasizes the importance of integrating traditional medicine with conventional healthcare systems, especially in rural or underserved regions where traditional healers are often the primary source of medical care.[29] Many governments have initiated policies to encourage collaboration between traditional healers and formal health sectors, acknowledging that these practices can coexist and even enhance each other's impact on public health. The South African government has acknowledged the contributions of traditional healers and supports collaborative work between the two health practices.[30] One such collaboration includes the work done by THPs who visited the patients to fast track and monitor distribution of HIV and TB treatment in rural communities.[31]

This study showed that THPs regularly refer their clients to dental professionals recognising their limitations in managing dental diseases. This finding is supported by previous study which found that THPs referred their patients to local oral health clinics if the treatment offered was non- effective.[32] While some studies found that competing and contradictory treatments can coexist without conflict, [33] others noted that conventional health practices were not ready to work with THPs due to differences in scientific concepts, sources of knowledge, and lack of policy. [34]

Respecting the cultural context of KZN, there is a growing need for dental professionals to collaborate with THPs to improve oral health outcomes in rural communities. Supporting collaborative work between these two health practices reflects an understanding that modern and traditional medicine can complement each other in promoting public health.

CLINICAL IMPLICATIONS

Dental professionals can collaborate with THPs to spread messages about the benefits of regular dental visits while respecting the use of traditional remedies. Such collaboration can help bridge the gap between modern and traditional practices, making health interventions more effective and widely accepted.

It is crucial to design oral health education programs that recognise and respect cultural values. For example, instead of discouraging traditional practices outright, health educators can work with communities to promote safe and effective oral care methods that blend traditional and modern practices.

CONCLUSION

Oral health in rural KZN is shaped by a blend of traditional practices and modern healthcare strategies. While cultural beliefs remain strong, there is a growing need for integrating the two practices. By respecting and understanding cultural perspectives, dental professionals and THPs can collaborate to promote better oral health outcomes for rural communities in KZN.

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A Comparison of Three Types of Orthodontic Study Models

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ABSTRACT

Plaster study models have been the gold standard for many years but have many disadvantages. Intra-oral scanners and three-dimensional printers have provided alternatives in the form of digital and printed study models. Their accuracy for clinical use requires further validation.

The aim of this research was to compare the accuracy of digital and printed study models with plaster study models. The objectives were to compare the accuracy of measurements obtained from digital and printed study models with those of plaster study models, to establish which type of study model yielded the most accurate measurements in comparison to plaster study models and to identify disadvantages associated with the use of these types of study models.

A study sample of 50 patients attending a private orthodontic practice for treatment participated. Patients' participation was voluntary and informed consent was obtained from all patients.

Dental impressions were taken from each patient and cast into plaster study models. Digital impressions using the 3Shape TRIOS® intra-oral scanner were taken for each patient and digital study models were generated and used to print study models using the Next Dent 5100 for Ceramill® 3D printer. Measurements were taken from each study model and respectively compared for accuracy.

Only four of the 28 sets of observations were statistically significantly different, namely: mesio-distal widths of teeth 15 and 26, the inter-canine widths in the maxillary arches and the inter-molar widths in the maxillary arches.

The researchers concluded that the measurements taken from digital and printed study models are as accurate as those taken from plaster study models and are accurate enough to be used in a clinical environment.

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Key words

Digital study models, plaster study models, printed study models, intra-oral scanner, three-dimensional (3D) printer, accuracy, measurements, orthodontics

Introduction and Literature Review

An orthodontic diagnosis and treatment plan are formulated once a thorough assessment of the patient and the patient's presenting problems have been addressed[1]. Clinical examinations of patients consist of extra-oral and intra-oral examinations. Diagnostic tools that are vital to formulate a diagnosis include: a study model assessment, extra and intra-oral photographs, radiographs and cephalometric analysis. [1]

Study models are an imperative part of orthodontic diagnosis and treatment planning[1]. They are used to measure overjets and overbites, tooth size, arch lengths [2], Bolton analysis[3] and can be used to predict the sizes of unerupted permanent teeth.[4] Study models are also needed to evaluate space analyses, arch form, symmetry, and curves of Wilson and Spee.[5]

Plaster study models have been accepted to be the 'gold standard' for study model analysis[6]. Measurements taken using a digital or analogue calliper have been considered reliable.[7] Plaster study models are considered an accurate representation of patients' occlusion, and this claim is further validated by the well-fitting orthodontic appliances that are made using these study models.[8] The advantages include that they are easy and cheap to produce.[9] The method of conventional impression taking is well tolerated and accepted and therefore still favoured by many practitioners.[10] Plaster study models are subject to breakage and damage,[7] can be misplaced[6] and are also time-consuming to measure.[11] For legal purposes, study models are required to be stored for a certain number of years and the storage of plaster study models is problematic due to their weight and size.[7]

The introduction of intra-oral scanners, digital models and three-dimensional (3D) printers has presented practitioners with a more modern and user-friendly approach to orthodontic treatment planning.[12] According to Reuschl *et al.* (2016), digital study models may replace the need for their plaster equivalents.[13] Digital study models may also be used to print physical study models using a three-dimensional (3D) printer.[14] The ability to print study models from digital impressions allows practitioners to make use of intra-oral scanners and still have physical models to analyse.[15]

Cadent was the first dental equipment manufacturing company that introduced an intra-oral scanner called iTero™ in 2008[16]. A digital intra-oral scanner is made up of three main parts: a wireless workstation, a handheld wand that

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has a built-in camera or sensor, and a computer monitor[16]. Intra-oral scanning is a direct method of obtaining digital study models by scanning patients' mouths using an intra-oral scanner.[17] Digital impressions eliminate many of the disadvantages associated with conventional impression taking.[18] These impressions are converted to digital study models.[18] Using software packages, practitioners can take linear measurements, conduct a space analysis and assess arch form, length and crowding.[14]

Advantages of using an intra-scanner include: the elimination of the many disadvantages associated with conventional impression taking and plaster study models.[14] Digital study models can be visualised three-dimensionally before scanning has been finalised[19]. Re-scans can be done immediately if the image captured is unsatisfactory and can be undertaken without repeating the entire impression taking process.[19] Improved patient experiences at the dentist or orthodontist are an advantage of this technology, as conventional impression taking can be an unpleasant experience for many patients[14]. Disadvantages include scanning difficulties in the posterior mandibular molar area due to the movements of the tongue and the limited area the intra-oral scanner head can access.[20] The price of training, software updates and subscriptions can make the purchase of an intra-oral scanner very expensive.[21]

Plaster study models have been accepted to be the 'gold standard' for study model analysis.[22] Measurements taken using a digital or analogue calliper have been considered reliable.[23] Plaster study models are considered an accurate representation of patients' occlusion, and this claim is further validated by the well-fitting orthodontic appliances that are made using these study models.[18] The advantages include that they are easy and cheap to produce.[19] The method of conventional impression taking is well tolerated and accepted and therefore still favoured by many practitioners.[20] Plaster study models are subject to breakage and damage,[7] can be misplaced[6] and are also time-consuming to measure.[11] For legal purposes, study models are required to be stored for a certain number of years and the storage of plaster study models is problematic due to their weight and size.[7]

The formation of digital study models depends on the technology used for each brand of intra-oral or desktop scanner and its associated software. Computer aided design/computer aided manufacture (CAD/CAM) technology made it possible for the dental arch to be scanned three-dimensionally.[14] CAD/CAM technology can scan plaster study models to convert them to digital study models or is available as a computer software programme that can manipulate digital study models.[4] Digital study models are created and stored as Standard Tessellation Language (STL) open format files.[14] Digital study models have numerous advantages. Digital files are stored electronically and do not require physical storage space.[22,23] The digital files can be sent worldwide instantly for laboratory work, consultation, referral or educational purposes,[7] eliminating the need for transport.[24] They are not subject to physical damage or loss as plaster study models are.[23] The software that is part of the intra-oral scanners allows practitioners to analyse, measure and manipulate digital study models and design orthodontic appliances and virtual set ups.[25,26,8,5] One of the most significant disadvantages of digital study models is the fact that practitioners cannot physically hold, view or feel the study model.[27] The accuracy of measurements can be affected by difficulty in distinguishing landmarks on the digital study models.[2] Practitioners need to orientate themselves and practise locating certain planes and landmarks on digital study models.[6] Storing digital study models requires maintenance, as digital files need to be backed up regularly and files must be password protected to ensure patients' records are kept confidential.[6] Several studies found the accuracy of measurements between plaster and digital study models similar and concluded that digital study models are accurate enough to replace the need for plaster study models: any differences found were not statistically significant.[4,5,28]

Digital study models are the blueprints for printing 3D study models using a 3D printer.[29] The additive method of 3D printing is also known as rapid prototyping,[29] and study models are produced using this method[15]. The digital study model is created by CAD software and translated to an STL file[30]. This file is processed by slicing the model[30] and the model is built in incremental layers, followed by post curing[15]. Advantages of 3D printed study models include the fact that the study model is a physical one[15], and this option caters to practitioners who want to physically hold and manipulate a study model[31]. Physical study models are also needed to construct orthodontic appliances[15]. A significant disadvantage of printed study models is that materials shrink during the building process, or study models shrink after the post curing process[15]. Keating *et al.* (2008) also reported that the researchers of their study claimed difficulty in measuring printed study models, as the translucency of the clear epoxy-based resin made it challenging to identify certain landmarks. The lack of detail in cervical margins of teeth in study models was also problematic.[11] 3D printing technology is also very expensive and not many practitioners can afford this type of equipment.[32] The complexity of the technology and equipment will require expert help.[33] Several studies that compared measurements taken from printed study models were as accurate as those taken from plaster, acrylic and digital study models. [15,33,28]

AIM AND OBJECTIVES

The aim of this research was to compare the accuracy of measurements taken from digital study models obtained from an intra-oral scanner, and printed study models, printed from digital study model files by a 3D printer, with measurements taken from plaster study models.

The objectives were:

- To compare the accuracy of measurements obtained from digital and printed study models with those taken from plaster study models.
- To establish which type of study model yielded the most accurate measurements in comparison to plaster study models.
- To identify possible disadvantages and errors that can be made using any of the three types of study models.

METHODOLOGY

The design of study was a comparative descriptive study with a study population consisting of 50 patients that attended the private practice of an orthodontist specialist for treatment. The study population consisted of 37 female patients and 8 male patients.

Inclusion criteria were as follows: impressions were only taken from patients who required it as part of their treatment and patients who had permanent teeth 1- 6 were used as the

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mesio-distal widths of these teeth needed to be measured and compared.

Exclusion criteria included: patients who did not require impressions or study models, who had missing permanent canines and first permanent molars, those with mixed dentition and fixed orthodontic appliances.

Ethics approval was granted from the University of the Western Cape Senate Biomedical Research Ethics Committee (BM 18/3/20). Patients' participation was voluntary and informed consent from all participating patients was obtained before participation commenced. In the case of minor patients, informed consent from a parent or legal guardian was obtained.

Conventional dental impressions using Kromogel® Advance alginate were taken for all participating patients and plaster study models were cast from these impressions. Digital impressions of patients' mouths were taken using the TRIOS® 3 3Shape intra-oral scanner and its software generated digital study models. The Next Dent 5100 for Ceramill® 3D printer, a digital light processing 3D printer, printed study models from the digital study model files. The following measurements were taken from both arches for each type of study model: the mesio-distal tooth widths of permanent teeth 1-6, the inter-canine widths and the inter-molar widths. An electronic digital calliper was used to measure the plaster and printed study models. Ortho Analyzer™, the software that is part of the TRIOS® 3 3Shape intra-oral scanner, was used measure the digital study models. Each study model was numbered for reference and confidentiality purposes and all data was recorded on Microsoft Excel spreadsheets.

Parametric techniques were employed to compare the accuracy of measurements taken from the plaster, digital and printed study models. Descriptive analyses and Tests Within-Subjects Effects, pairwise comparisons and interclass correlation techniques were conducted.

RESULTS

The descriptive data for the three sets of study models are presented in Table 1.

Tests Within-Subjects Effects

Tests of within-subjects effects evaluation was done to determine whether any significant differences in measurements taken from all three models exist. The

Table I: Descriptive analyses for plaster, digital and printed study models.

	Min	Max	Mean	Std deviation		Min	Max	Mean	Std deviation
Tooth 11					**Tooth 21**				
Plaster	8,04	10,3	8,8432	0,53635	Plaster	7,91	10,6	8,796	0,58888
Digital	8,06	10,36	8,8284	0,53236	Digital	7,79	10,65	8,7828	0,6106
Printed	8,11	10,2	8,823	0,51241	Printed	7,88	10,4	8,8222	0,56025
Tooth 12					**Tooth 22**				
Plaster	0	8,04	6,6858	1,11203	Plaster	5,31	7,92	6,8458	0,56001
Digital	0	7,92	6,667	1,1102	Digital	5,36	8,04	6,8676	0,56639
Printed	0	7,94	6,72	1,1078	Printed	5,55	7,93	6,8374	0,54643
Tooth 13					**Tooth 23**				
Plaster	5,36	8,72	7,7526	0,52373	Plaster	5,04	8,41	7,646	0,56753
Digital	5,58	8,61	7,7708	0,55042	Digital	5,1	8,55	7,6368	0,60315
Printed	5,31	8,52	7,7322	0,54313	Printed	5	8,56	7,6108	0,58542
Tooth 14					**Tooth 24**				
Plaster	5,8	8,41	7,1702	0,52058	Plaster	6,2	8,36	7,2146	0,52455
Digital	5,76	8,59	7,2028	0,55259	Digital	6,11	8,34	7,2066	0,50777
Printed	5,93	8,31	7,1474	0,55738	Printed	6,31	8,31	7,1844	0,53207
Tooth 15					**Tooth 25**				
Plaster	0	7,55	5,8126	2,21732	Plaster	0	7,64	6,3144	1,68402
Digital	0	7,65	5,876	2,24907	Digital	0	7,81	6,3456	1,69978
Printed	0	7,51	5,7626	2,20355	Printed	0	7,67	6,2986	1,6795
Tooth 16					**Tooth 26**				
Plaster	8,46	11,57	10,1678	0,66645	Plaster	9,04	11,94	10,2006	0,64745
Digital	8,57	11,58	10,2013	0,62009	Digital	9,04	11,69	10,241	0,63078
Printed	8,31	11,57	10,1366	0,67484	Printed	9,07	11,56	10,1208	0,63905
Tooth 41					**Tooth 31**				
Plaster	4,58	6,2	5,3034	0,37656	Plaster	4,72	6,16	5,3852	0,36212
Digital	4,32	6,16	5,2513	0,38446	Digital	4,5	6,37	5,3534	0,40656
Printed	4,67	6,24	5,2813	0,36626	Printed	4,67	6,11	5,3942	0,35292

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Tooth 42					**Tooth 32**				
Plaster	5,05	6,7	5,9074	0,39044	Plaster	5,16	6,72	5,9706	0,3801
Digital	5,21	7	5,9536	0,41511	Digital	5,16	6,9	6,0064	0,41034
Printed	5,8	6,85	5,9372	0,39626	Printed	5,21	6,73	5,9938	0,36033
Tooth 43					**Tooth 33**				
Plaster	2,6	7,89	6,808	0,74369	Plaster	6,02	8,53	6,8962	0,551
Digital	3	8,08	6,8108	0,72847	Digital	5,81	8,5	6,8954	0,52706
Printed	2,99	7,97	6,8517	0,69999	Printed	6,1	8,55	6,9286	0,54456
Tooth 44					**Tooth 34**				
Plaster	6,14	8,45	7,2288	0,55231	Plaster	6,33	8,51	7,2666	0,53929
Digital	6,26	8,43	7,2184	0,51859	Digital	6,29	8,47	7,2584	0,56018
Printed	6,21	8,47	7,2276	0,52867	Printed	6,45	8,64	7,2736	0,5069
Tooth 45					**Tooth 35**				
Plaster	0	8,06	6,8462	1,49907	Plaster	0	8,23	7,0352	1,8748
Digital	0	8,24	6,884	1,49471	Digital	0	8,35	7,0478	1,8164
Printed	0	8,33	6,8244	1,50101	Printed	0	8,8	6,9954	1,12612
Tooth 46					**Tooth 36**				
Plaster	9,14	12,26	10,9822	0,6646	Plaster	9,69	12,46	10,9948	0,65135
Digital	9,18	12,4	10,9817	0,67049	Digital	9,89	12,5	10,9974	0,65073
Printed	9,28	12,31	10,982	0,68685	Printed	9,7	12,58	10,9998	0,64605
ICW MX					**ICW MND**				
Plaster	30,89	42,52	34,6868	2,50635	Plaster	21,63	30,95	26,7506	2,52553
Digital	30,94	42,49	34,6948	2,52393	Digital	21,62	31,1	26,7188	2,49033
Printed	31,46	42,56	34,8476	2,5597	Printed	21,29	31,8	26,784	2,54398
IMW MX					**IMW MND**				
Plaster	30,11	56,98	51,111	3,95632	Plaster	39,49	59,11	45,443	3,43002
Digital	30,23	56,96	51,1384	3,94939	Digital	39,4	59,33	45,4092	3,4493
Printed	30,35	56,88	51,222	3,91223	Printed	39,38	58,95	45,4168	3,3776

significant value for sphericity assumed is set at p=0.05. If the significant value found between all three measurements for each type of model is $p \leq 0.05$, a statistically significant difference between the measurements exist. According to the data analyses; only four sets of measurements were found to be statistically significantly different in each type of model; namely mesio-distal widths of teeth 15 and 26, that had significant values of 0.001 and 0.000 respectively, the inter-canine widths in the maxillary arches that had a significant value of 0.001 and the inter-molar widths for the maxillary arches that had a significant value of 0.025.

Pairwise comparisons

The significant values of sphericity assumed of the tests within-subjects effects were $p \leq 0.05$ for the mesio-distal widths of teeth 15 and 26, the inter-canine widths in the maxillary arches and the inter-molar distances in the maxillary arches. These values indicate that statistically significant differences between these measurements taken from the 3 types of study models exist. In this instance, pairwise comparisons determine where the significant differences exist. This test directly compares the study models against each other. In the case of the mesio-distal widths of tooth 15, both digital and printed study model measurements are statistically significantly different from the plaster study model measurement with significant values of 0.033 and 0.033 respectively. In the case of the mesio-distal width of tooth 26, the printed study model measurement is statistically significantly different from the plaster study model measurement with a significant value of 0.011. The digital study model significant value was 0.064, which makes it not statistically different from the plaster study model measurements. The significant value for the inter-canine widths in the maxillary arches taken from printed study models was 0.002, making it statistically significantly different from the plaster study model measurements. The digital study model significant value was not statistically significantly different from the plaster study model inter-canine widths in the maxillary arches. The significant values for the inter-molar widths of both digital and printed study models were 0.126 and 0.016; making the measurements from the printed study models statistically significantly different from the plaster study model measurements. Out of the 4 sets of observations discussed above, it must be noted that the printed study models were the models that were statistically significantly different from their plaster counterparts, with the exception of the measurements taken for the mesio-distal width of tooth 15, where both digital and printed study model measurements differed significantly from the plaster study model observations.

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Inter-rater reliability

Fifteen study models of each study model type were randomly selected, and these were measured by a second operator (KJ). Comparing the results of the second operator to those of the researcher is necessary to establish the reliability and reproducibility of these results obtained from the study models.

An interclass correlation technique is used to measure inter-rater reliability of quantitative data. The total measurements of each model were analysed for inter-rater reliability. The interclass correlation values of the study models are tabulated below in Table 2.

Table II: Inter-rater reliability of study models

Study model	Interclass correlation value
Plaster	0.825
Digital	0.861
Printed	0.880

Based on the 95% confidence interval of the interclass correlation estimate, these values fall within the 'good' category of reliability. Results between the values of 0.75-0.9, are classified as having a 'good' reliability. Those that are greater than 0.9 are classified as being of excellent reliability[37].

DISCUSSION

Plaster study models have been well established as the 'golden standard' of study models[8,6,13, 9, 24, 22]. Measuring study models using electronic digital callipers have also been considered the most validated method of measuring study models.[7, 22, 34, 24, 13, 6, 8] There are many disadvantages associated with plaster study models and conventional impression taking, and the rise of digital technology and 3D printing in dentistry has given dental practitioners alternate techniques to obtain dental impressions and study models.[35] Plaster study models require storage and are susceptible to loss and physical damage[24]. The use of digital study models eliminates these disadvantages and numerous studies have shown that they are a reliable and clinically acceptable alternative to its plaster counterparts.[6, 28, 24, 22, 7] A major disadvantage is that a digital study model is not a physical object and cannot be physically manipulated or held.[27] Printing study models using 3D printers allows practitioners to obtain a physical representation of digital study models. Several studies have concluded that although the difference between measurements taken from plaster and printed models is statistically significant; the results are acceptable within in a clinical environment [15,21,28].

The manner study models are routinely measured impact the resultant measurements. The operator measuring the study models is required to position the tips of an electronic digital calliper on very specific landmarks to render a result; and the result is displayed on the screen of the electronic digital calliper and recorded.[36] When computer software is used to measure digital study models, the practitioner must click on specific landmarks and the software calculates the resultant measurement.[36] Intra- or inter-operator reliability needs to be accounted for both methods of measuring as a certain degree of variability will occur.[36] In this study, the study models' interclass correlation values based on a 95% confidence index was classified as 'good' reliability, as the values fall between the range of 0.75-0.9. Although these results do not reflect an 'excellent' reliability; these results could be due to difficulties in identifying certain landmarks and inexperience of the researcher in using OrthoAnalyzer™. While this is relevant statistically, clinically it is acceptable. Reuschl *et al.* (2015) concluded that although landmark identification will differ between practitioners; the differences are not clinically relevant and that measuring digital models using computer software is accurate enough to be used instead of measuring plaster study models with callipers.[13]

The results of this research are similar to previous studies that researched the accuracy of digital and printed study models for orthodontic practice. Hazeveld *et al* (2014) compared plaster study models and three types of study models printed by three different rapid prototyping techniques, namely: 3D printing, jetted photopolymer and DLP. They measured the clinical crown heights and mesio-distal widths of teeth of all permanent teeth, 1-6, in each arch and found a statistically significant difference in one measurement only, the clinical crown heights of the teeth from the 3D printed models[15]. However, these studies compared digital study models that were obtained by an extra-oral scanner.[6,7,13,35] This research used an intra-oral scanner to obtain the digital study models that were used for comparison.

Abizadeh *et al* (2012) compared measurements from plaster and digital study models and found that significant differences between the two types of study models existed but these differences were clinically irrelevant. They also found that the repeatability of digital study models when compared to their plaster equivalents to be acceptable to use in a clinical environment[6]. Saleh *et al* (2015) also concluded that the reproducibility of digital and printed study models to be favourable in comparison to plaster study models[28].

CONCLUSION

The researchers of this study have concluded that measurements taken from digital and printed study models are as accurate as those taken from plaster study models and are therefore accurate enough to be used in a clinical environment.

DISCLOSURE

The authors declare no conflict of interest.

The authors of this study did not receive any financial benefits and have no financial interests in the companies whose equipment and materials are included in this research.

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A Review of Computer Aided Design and Computer Aided Technology (CAD/CAM) in Complete Denture Fabrication: Part 2

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ABSTRACT

The field of removable prosthodontics is on the brink of a transformative era, propelled by the continuous evolution of digital technology. Integrating artificial intelligence, machine learning, and 3D printing promises to revolutionise denture fabrication, offering unprecedented customisation and efficiency. As these technologies become more accessible and widely adopted, they are set to establish new benchmarks in quality and patient satisfaction. The future of removable prosthodontics is bright, marked by the seamless integration of these innovations, underpinned by robust research and collaboration among dental professionals. This convergence is poised to deliver superior clinical outcomes, elevate patient satisfaction, and drive continuous advancements in the art and science of denture fabrication.

Introduction

In recent years, digital technology has begun to reshape prosthodontics, mainly by integrating computer-aided design and computer-aided manufacturing (CAD/CAM) systems into the dental workflow. These systems enable clinicians to create digital impressions, which can be manipulated in a virtual environment before being used to fabricate accurately fitting dentures. Adopting CAD/CAM technology has reduced the number of clinical appointments required for denture fabrication, has the potential to minimise errors, and accelerates the production process while maintaining or possibly improving the quality of the final prosthesis.[1] The transition from traditional to digital impression and manufacturing techniques represents a significant shift in prosthodontics that aims to enhance precision, efficiency, and patient satisfaction. However, integrating digital technologies into routine clinical practice is still in its early stages, and long-term studies are needed to assess their impact on treatment outcomes.[2]

Digital denture fabrication is typically divided into several key stages, each contributing to the final product's accuracy and outcome. These stages include:

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Digital impressions

Unlike traditional impression methods that rely on physical moulds, digital impressions are obtained by scanning the patient's edentulous arches. This process is more comfortable for the patient and produces highly accurate digital models.[3] One of the primary challenges in the digital workflow is the accuracy of digital impressions, particularly when capturing the soft tissues of the edentulous arch. While intraoral scanners have improved precision, they still face difficulties accurately capturing mobile and delicate tissues, such as the vestibule, soft palate, and sublingual areas. These are crucial for ensuring the proper fit and retention of dentures.[3]

Inaccurate digital impressions can lead to several complications, including poor peripheral seal and inadequate retention, which can cause discomfort and functional issues for the patient. Although traditional impression techniques using border-moulded trays effectively capture these details, the fully digital workflow often omits these steps, leading to potential inaccuracies in the final prosthesis.[1] To overcome this challenge, further advancements in intraoral scanning technology are needed. Additionally, hybrid approaches that combine digital scanning with traditional impression techniques may offer a viable solution until fully digital methods can match the accuracy of conventional approaches.[4]

Digital Design and Occlusal Plane Determination

Once the digital impressions are captured, they are imported into CAD software, where the denture design takes place. This stage involves several critical tasks, including tooth arrangement, gingival contour customisation, and occlusal plane adjustment using virtual articulators.[5] The fit and retention of digital dentures are crucial factors that directly influence patient comfort and satisfaction. Poorly fitting dentures can cause various issues, from discomfort and pain to difficulties in speaking and eating. Digital workflows, particularly those that incorporate high-precision milling and scanning technologies, have been shown to produce dentures with superior fit and retention compared to traditional methods.[5] However, some challenges remain, mainly when digital workflows omit critical steps such as trial placements or clinical remounts. These omissions can result in occlusal errors only identified after the final denture is delivered, necessitating additional adjustments, time, and costly remakes.[3] An accurate occlusal relationship is essential for the functioning of complete dentures. Inaccuracies in the vertical dimension of occlusion or centric relation can lead to problems such as open bites, excessive wear, discomfort, and dislodgement during chewing. Digital workflows have the potential to enhance the accuracy of occlusal relationships, thanks to the precision of digital design tools and virtual articulators.[1] In addition, systems like *3Shape's Dental Designer* and *Exocad's DentalCAD* offer advanced tools for occlusal analysis, including virtual articulators and facebow

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Process	Description	Advantages
Milling [4]	Milled dentures are carved from pre-polymerised polymethyl methacrylate (PMMA) blocks. This process produces dentures with excellent strength, stability, and longevity. The milling precision ensures that the denture fits the patient's oral cavity with minimal adjustments.	• **Strength:** The milling process creates a dense, homogenous material that is highly resistant to fractures. • **Precision:** The high level of accuracy ensures a close fit to the oral tissues, enhancing comfort and retention.
3D Printing [4]	3D printing allows for greater flexibility in design and customisation. Dentures can be printed layer by layer using materials such as biocompatible resins, which can be customised in colour and texture.	• **Customisation:** Layer printing allows for intricate designs and aesthetic enhancements, such as varying gingival shades • **Efficiency:** 3D printing can significantly reduce the time needed to produce a complete denture, making it a cost-effective option for clinicians and patients.

Table 1: Description of milling and 3D printing, including the advantages of each [4].

transfers, which help ensure that the occlusal relationships are accurately captured and maintained throughout the fabrication process.[3, 5]

Fabrication:

The digital file of the finalised design is then sent to a milling machine or 3D printer to fabricate the denture. Each of these two production methods has certain advantages, as described by Avellino et al. (2024) and depicted in Table 1.[4]

The materials used in digital denture fabrication, particularly those for 3D printing, still face challenges in balancing strength and aesthetics. While milled PMMA offers excellent strength and durability, 3D-printed resins have historically been less robust, leading to concerns about the long-term performance of these dentures, especially in patients with high occlusal loads.[6] 3D printing offers customisation and aesthetic capabilities, making it an attractive option. However, achieving the same level of aesthetic detail and translucency possible with traditional materials or milled PMMA is challenging, mainly when using resin-based printing; therefore, 3D-printed dentures may require additional finishing and characterisation to meet aesthetic standards.[7] Another challenge with 3D printing is the need for post-production processing. After printing, dentures often require additional cleaning, curing, and sometimes surface finishing to ensure they meet clinical standards. These extra steps can add to the overall production time and may introduce variability in the final product depending on the quality and consistency of the post-processing procedures.[6]

Given the distinct advantages of both milling and 3D printing, many dental professionals are now adopting hybrid workflows. For example, a denture base might be milled for strength and stability, while the teeth or aesthetic components are 3D printed for greater customisation and detail. This approach uses the strong points of both methods to produce functional and aesthetically pleasing dentures.[5]

One of the benefits of digital dentures is the reduced number of patient visits required. Traditional denture fabrication typically involves multiple appointments; digital workflows streamline this process, often reducing the treatment time by half or more [1]. This can be seen with systems like AvaDent's Digital Design (MNF) and 3Shape's Dental Design (MNF). As a result, patients can receive their final dentures in a shorter time. The advocates of this process also purport that these dentures require fewer follow-up appointments for adjustments.[3]

Denture materials

The materials used to fabricate digital complete dentures are critical to the prosthesis's overall success. To meet patients' functional and aesthetic demands, these materials must balance strength, durability, aesthetics, and biocompatibility. Table 2 below highlights the primary materials used in denture fabrication, highlighting the associated advantages and disadvantages.

Biocompatibility ensures dental materials are safe for long-term use in contact with oral tissues. Milled Polymethyl Methacrylate (PMMA) has a long history of reliable and well-established biocompatibility. Similarly, 3D-printed resins demonstrate good biocompatibility when processed correctly, although care must be taken to address potential issues such as porosity and surface hygiene.[6, 8]

The Future of Digital Denture Fabrication

Long-term studies on the durability and performance of digital complete dentures are still relatively limited. However, early results suggest that digitally fabricated dentures are comparable to traditional dentures in wear and tear, with many patients reporting satisfactory long-term outcomes. Nevertheless, ongoing monitoring and follow-up are essential to ensure that any issues are promptly addressed and that the dentures continue to perform well over time.[6]

Adopting digital denture technology requires significant equipment, software, and training investment. The high initial costs of purchasing CAD-CAM machines, 3D printers, and intraoral scanners can be a barrier for many dental practices, notably smaller or independent ones.[8] In addition to the financial investment, a steep learning curve is associated with mastering digital workflows.[6]

Artificial intelligence (AI) and machine learning are poised to revolutionise digital denture fabrication by enabling more accurate and efficient workflows. AI algorithms can assist in the design phase by predicting optimal denture shapes based on patient-specific data, automating the identification of undercuts, and even simulating the final fit and function of the denture before it is fabricated.[6]

Machine learning can also improve the accuracy of digital impressions and occlusal records by analysing vast amounts of data from previous cases to refine scanning techniques and prediction models. This could lead to more consistent and reliable outcomes, reducing the need for adjustments and improving patient satisfaction.[5]

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Table 2: Materials used to make complete dentures and the advantages and disadvantages of each

Material/Process	Description	Advantages	Disadvantages
Polymethyl Methacrylate (PMMA)[3]	It is the gold standard for denture bases due to its favourable mechanical properties, ease of manipulation, and aesthetic versatility. In digital denture fabrication, it was used predominantly as pre-polymerised blocks for milling.	• High stability and resistance to polymerisation shrinkage • Precise fit and structural integrity	- Can be time-consuming and generate material waste during milling
Milled PMMA[4]	They are milled from solid blocks of pre-polymerised PMMA, offering high mechanical strength and excellent dimensional stability. Ensures a tight fit against the mucosa, enhancing retention and patient comfort.	• Superior aesthetic outcomes with customisable colour to match gingival tissue • Smooth surface finish for a natural appearance	- Time-consuming process - Generates material waste - Higher production costs
3D-printed Resins[6]	It allows for the creation of dentures through additive manufacturing, layer by layer. It offers flexibility and customisation in design, enabling complex geometries. It is generally more cost-effective due to reduced material waste.	• Cost-effective and efficient production • Customisable for intricate designs and aesthetics	- Historically lower mechanical strength compared to milled PMMA - May require additional finishing for aesthetics - Porosity and surface roughness can lead to hygiene issues
Hybrid Materials[3, 5]	It combines milled PMMA bases with 3D-printed components (e.g., denture teeth) to leverage the strengths of both materials. It offers a balance of strength, stability, and customisation.	• Combines strength and aesthetics • Allows for highly customisable and detailed designs	- May still involve the disadvantages of both milled and 3D-printed processes (e.g., waste, time-consuming production)
Emerging Materials[4, 5]	New materials like modified PEEK are being explored for improved mechanical properties and biocompatibility. PEEK is a high-performance polymer offering strength and flexibility and is a potential alternative to metal frameworks for those with metal allergies.	- PEEK: High strength, flexibility, and biocompatibility - Potential for lighter, more comfortable dentures	- Still in the early research stages - Long-term viability not yet established

CONCLUSION

Digital technology, particularly CAD/CAM systems, has revolutionised prosthodontics by introducing a level of precision and efficiency previously unattainable with traditional prosthesis fabrication methods. Literature suggests that digital impressions and computer-aided design, and manufacturing have improved patient satisfaction through better fit and reduced clinical chair time.[2, 9] However, challenges such as the cost of technology and the need for specialised training underscore the importance of ongoing research and professional development to integrate these tools into routine clinical practice successfully.[10] Digitally aided production of complete dentures could result in a better fit and more durable and aesthetically pleasing prostheses. Additionally, they may benefit from improved strength due to the milling and 3D printing techniques, a more streamlined fabrication process, more time and cost-effectiveness, and enhanced patient satisfaction.[1] The materials used in digital denture fabrication, particularly milled PMMA and 3D-printed resins, play a crucial role in the success of the final prosthesis. Ongoing research into advanced materials, such as modified PEEK and hybrid composites, promises to enhance further the durability, aesthetics, and biocompatibility of digital dentures.[3-6] However, challenges remain in the widespread adoption and standardisation of digital denture technologies, including issues related to the accuracy of digital impressions, occlusal relationships, and material limitations.

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Multidisciplinary Management is crucial in Pierre-Robin syndrome: A Case Report

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ABSTRACT

Background

Pierre-Robin syndrome (PRS) is a congenital disorder in which affected individuals present with micro/retrognathia, difficulty feeding, cleft lip/palate, glossoptosis and difficulty breathing. PRS affects between 1 in 8 500 to 1 in 20 000 births. The nature of the congenital defects results in patients presenting with numerous complications including malnutrition, aspiration pneumonia, recurrent local infections, dental abnormalities, respiratory problems as well as aesthetic and functional defects.

Case report

A 3-year-old female patient who was diagnosed with PRS at 6-months of age was referred to the Department of Operative Dentistry by the Department of Orthodontics with a main complaint of dental pain as well as the existing cleft palate.

Discussion

The clinical needs for the alleviation of pain, surgical closure of clefts to facilitate nutritional intake, surgical intervention to prevent respiratory obstruction as well as the dental abnormalities which need to be managed and restored are all highlighted in this case presentation. Furthermore, the need for lifelong therapy, encouragement, monitoring and nurture within a supportive, stimulating environment are essential to improve the overall quality of life for patients with PRS.

Conclusion

The objective of documenting this case report is to demonstrate the diverse scope and nature of the health care team responsible for providing adequate treatment, rehabilitation and surgical intervention in the patient who has PRS. The need for holistic management through multidisciplinary collaboration is emphasised for patient and practitioner education.

Keywords

Pierre-Robin syndrome, congenital, micrognathia, glossoptosis, enamel hypoplasia, rampant decay, malocclusion, airway obstruction.

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1. Dr J Bull – Consulting clinician who retrieved the case information, obtained photographs, contributed to conceptualisation, prepared treatment plan and assisted with the writing and editing (30%).
2. Dr BK Bunn - Conceptualisation, writing, editing and submission (30%).
3. Dr P Gwengu – Assistance with development of treatment planning, writing and editing (30%).
4. Dr CS Lebaka – Surgical closure of palatal cleft, patient consultation and editing (10%).

INTRODUCTION

Pierre-Robin Syndrome (PRS) is a congenital disorder with an incidence of between 1 in 8 500 to 1 in 20 000 births.[1] Individuals afflicted with this disorder characteristically present with retro-or micrognathia, cleft palate, glossoptosis, difficulty feeding and recurrent respiratory infections.[1] This may often lead to malnutrition and underdevelopment. Cleft palate increases the risk of food aspiration which is frequently complicated by pneumonia.[1, 2]

Embryologically, defective caudal hind brain development has been observed in patients with PRS. Recent studies have shown dysregulation of the genes SOX9 and KCNJ2 as a result of a familial translocation between these two genes, the outcome of which is under expression of the respective gene products.[2, 3] The gene products produced by these genes are functionally involved in craniofacial development.[4] The defect is not routinely detected on ultrasonography prior to birth and may not be initially diagnosed in the first few days of the child's life, however, the diagnosis becomes apparent shortly thereafter following failure to latch and difficulty feeding as a result of the cleft palate. Furthermore, many affected babies will begin to struggle with respiration or develop bronchopneumonia following aspiration.[1] Many babies are successful at breastfeeding small volumes on demand. This may delay diagnosis but also critically lowers the pH of the Stephan curve rendering the patient high risk for the development of caries. Enamel hypoplasia has frequently been documented in patients with PRS.[5]

Retro-micrognathia is clinically identified by an underdeveloped mandible located in a retruded position. Clefting of the palate most often presents as a wide u-shaped defect which may involve both the soft and hard palates. This results in a visible oro-antral communication and nasal septum. Glossoptosis refers to upper airway obstruction due to the posterior displacement of the tongue because of the underdeveloped mandible.[3] Despite the physical, psychological and functional problems in patients with PRS, in most cases there appears

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to be intact intellectual ability.[3] The treatment journey is prolonged, and patients are susceptible to a multitude of complications along the way. These include poor aesthetics, functional defects (dental, speech, swallowing, recurrent upper aerodigestive infections), malnutrition, psychosocial effects, psychomotor delay, loss of autonomy as well as postoperative complications including the possibility of hearing loss.[1-3, 6-8] Therapeutic intervention requires the involvement of a diverse range of health care professionals from the earliest treatment regimen to lifelong management. This case report aims to facilitate awareness for the need of a diverse multidisciplinary approach in the management of PRS as well as stability and support at home. Patients require a lot of attention and a stimulating environment to thrive. Successful management of patients with PRS may be evaluated by their overall quality of life and most are able to attain relatively normal functionality as well as being able to establish positive social relationships in later life.[3]

CASE REPORT

A 3-year-old female patient was referred to the Department of Operative Dentistry by a clinician in the Department of Orthodontics. The patient had been diagnosed previously with PRS at the age of 6-months due to both micro-retrognathia and a cleft palate (Figure 1A). The patient was referred for oral prophylaxis and dental assessment prior to scheduled cleft palate repair surgery.

Figure 1A: Intra-oral clinical photograph in which extensive enamel hypoplasia and rampant dental decay of the maxillary deciduous teeth are identified. Furthermore, the u-shaped cleft involving both the hard and soft palate is conspicuous. The cleft is associated with an oro-antral communication with visibility of the nasal septum centrally.

The patient is the only child that is cared for by a single parent (mother) at home. She has not yet attended any preparatory school. She was recently referred to a dietitian as well as to a speech therapist. She appears to be cognitively unimpaired although she rarely interacts and, seldom speaks. She communicates with limited speech in her home language with her mother and grandmother and she can fully comprehend conversations and follows instructions, however, she would benefit from a more socially stimulating environment. Her main complaint was pain in the upper anterior region as well as the existence of "a hole in the upper back part of the mouth".

Medical History

The patient was confirmed to be healthy, and she was reportedly able to be breastfed normally with no reported incidences of milk aspiration into the nasal cavity. The mother confirmed that there was no familial history of PRS or of isolated cleft palate. The mother informed the clinicians that the patient consumes the same meals as the other family members including porridge and protein such as beef, chicken and eggs.

Dental History

Dental extractions were performed in the past with no complications. Teeth 51 and 52 were previously extracted (Figure 1 B). This dental history is quite relevant for the case as the possibility of hazardous in-office tooth extractions was anticipated due to the presence of an oro-antral communication associated with clefting of the palate in addition to breathing difficulties because of glossoptosis. Other precautionary measures included consideration of complications associated with the administration of general anaesthesia which could be due to airway limitations in PRS cases.[9] There is no history of thumb sucking or of dependence on a pacifier.[10]

Due to the lack of co-operation during examination in the dental chair, a more comprehensive dental examination was scheduled intra-operatively under general anaesthesia in March 2024.

Figure 1B: Intra-oral clinical photograph highlighting the extensive enamel hypoplasia and rampant dental decay of the maxillary deciduous teeth. The site of the previously extracted 51 and 52 has healed adequately.

Treatment procedures and planning

At the patient's first consultation, a work-up for the surgical repair of the cleft palate under general anaesthesia was discussed. This was a joint sitting involving the maxillofacial surgeon and a dental clinician. A comprehensive examination of the dentition and the cleft palate was performed to facilitate surgical planning.

Extra-oral examination

General appraisal showed the patient to be of small posture yet was well nourished. There was distinct retro-micrognathia. There was no evidence of temporomandibular joint abnormalities or of lymphadenopathy. There was no clinical evidence of jaundice, anaemia, cyanosis, clubbing of the fingernails or of oedema. Radiological examination was not undertaken due to the extensive radiation dose and the difficulty for such a young patient to maintain a still position in addition to the patient being unco-operative.

Intra-oral examination

A fistula distal to tooth 62 was identified (Figure 2A and Figure 2B). In addition, carious involvement of all teeth was evident. The entire dentition was coated with soft adherent plaque. The patient had poor oral hygiene and a low dental IQ which was also facilitated by her mother who reported that she was unable to brush her daughter's teeth because of discomfort due to the palatal cleft. An underdeveloped mandible was also observed which will likely result in future malocclusion and

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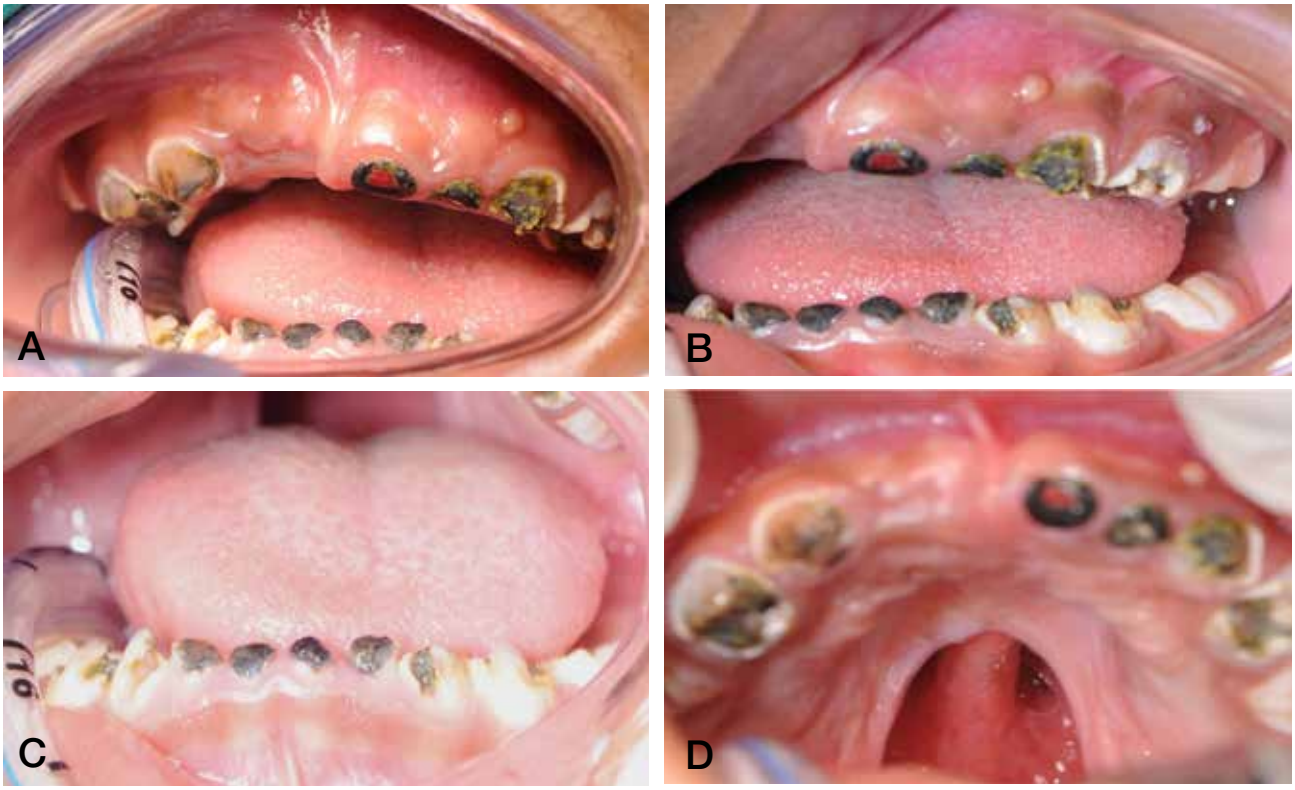

Figure 2A: A clinical intra-oral photograph in which the rampant decay of the maxillary and mandibular dentition can be seen. The labial frenum is also prominent. A parulis (gumboil) is in the region of the apex of tooth 62. **Figure 2B:** A clinical intra-oral photograph in which the maxillary and mandibular teeth are visualised from the left aspect. The friability of the enamel due to hypoplasia and the severity of the caries is also highlighted. The parulis associated with tooth 62 is present on the buccal aspect. **Figure 2C:** Clinical intra-oral mandibular anterior occlusal photograph demonstrating the marked glossoptosis in this patient as well as the carious involvement of the mandibular teeth. **Figure 2D:** Intra-oral maxillary occlusal photograph in which the carious maxillary teeth and cleft palate are depicted.

the need for interceptive orthodontic treatment. Furthermore, the patient exhibited mouth breathing.[9]

The intra-oral findings in this patient were photographed by the Audio-Visual Department with the written consent of the patient's mother. Examination showed the presence of multiple carious teeth, poor oral hygiene, visible soft plaque and fiery red gingiva (Figures 2A to 2C). Clefting of the palate was noted to extend posteriorly from the incisive foramen with partial involvement of the hard palate and more extensive involvement of the soft palate. The cleft corresponds with a "Kernahan striped-Y" classification of 7-8-9.[10] A conspicuous oro-antral communication with visibility of the nasal septum was present (Figure 2D). The documented dental features described in association with PRS include delayed eruption, hypodontia, enamel hypoplasia, abnormal tooth morphology, missing teeth, supernumerary teeth and malocclusion.[11]
Surgical closure of the cleft palate was performed by the maxillofacial surgeon in order to restore anatomy, minimise growth disturbances, to facilitate feeding and speech whilst preventing food aspiration and upper aerodigestive tract infections.[6] It was acknowledged that this was a delayed surgical repair as it is recommended in the literature that surgical repair of the hard and soft palate be performed between the ages of 9 and 12-months by means of an intravelar veloplasty procedure.[6]

The advantages of this clinical procedure when performed at an earlier stage of life include minimisation of growth disturbances whilst being relatively easy to perform and is associated with fewer postoperative risks for fistula development.[6]
It was also anticipated that this surgical procedure may, however, be more complicated when wide clefts are repaired and with loss of palatal length due to this late intervention.[12] The surgery was also planned over two phases because of the long duration of treatment, high volume of blood loss and extensive trauma which resulted from the procedure. It was therefore decided to perform dental extractions and treatment in a subsequent procedure under general anaesthesia.

The first phase of the surgical cleft repair was reportedly successful. The patient had good muscle strength and a good prognosis (Figure 3 and Figure 4). A small palatal communication might remain after surgical healing, and this is often a complication which is noted to occur in 9,7% of cases.[6]

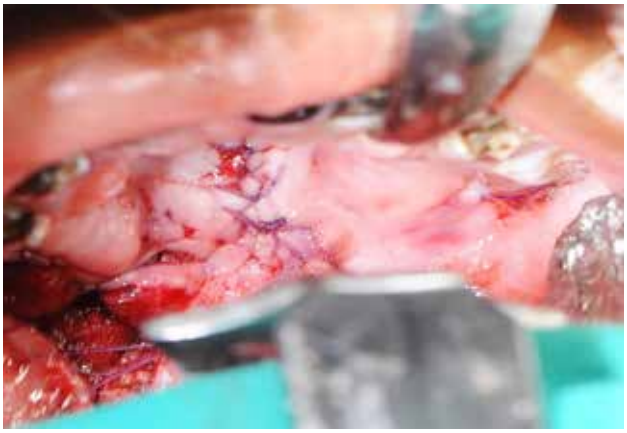

Figure 3: Intra-operative clinical photograph depicting cleft palate repair surgery using the intravelar veloplasty repair technique.

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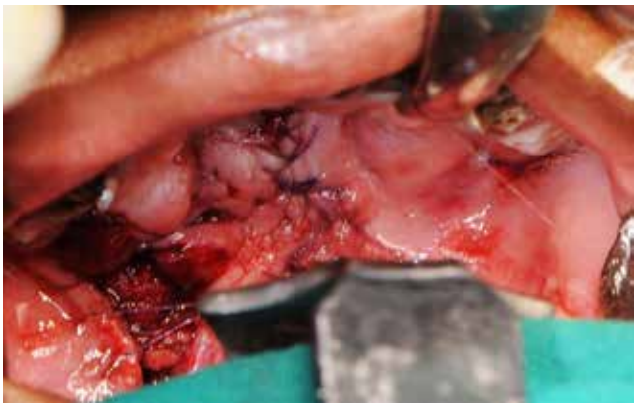

Figure 4: Post-operative clinical photograph showing closure of the palatal cleft.

Figure 5A: The pre-operative view of the carious left maxillary teeth.

Figure 5B: Intra-operative view of the same teeth. Figure 5C: Post-operative clinical photograph showing extraction sockets of tooth 61 and tooth 62 as well as fissure sealant application on tooth 65.

A team approach was used to decide on the second phase surgery following appropriate healing at which time the dental management will be performed. The dental treatment plan included extraction of tooth 61 and tooth 62 (Figure 5A to 5C). Composite restoration (3M Composite) of carious teeth was performed provided there was no evidence of pulpal involvement (Figures 6A to 6C and Figures 7A to 7C). These teeth were also covered with flowable composite without raising the occlusal surfaces. Fissure sealants were also placed on the occlusal surfaces of all d's ("Twinky Star") as seen in Figure 5C. Dental prophylaxis was undertaken to remove all adherent plaque. The use of fluoride varnish was applied to strengthen and support the remaining enamel.[13] Topical fluoride application was done where possible with re-application at future in-chair follow-up appointments for better results. The placement of stainless-steel crowns on the d's is preferable but in this case, it was not performed due to time constraints.

Close regular monitoring and follow-up is crucial for evaluation of the permanent dentition for early recognition of enamel hypoplasia. There is a dire need for parental education and support. The mother of the patient must be able to assist with tooth brushing and to be vigilant about good oral hygiene. Psychomotor delays should be evaluated at follow-up visits to facilitate early referral if required.[14]

Figure 6A: Pre-operative photograph demonstrating the carious involvement of the teeth in the third quadrant.

Figure 6B: Intra-operative photograph of the caries removal in teeth 73, 74 and 75. Figure 6C: Post-operative photograph showing composite restorations on the lower left teeth 73,74 and 75.

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Figure 7A: Pre-operative photograph showing the extent of the decay involving the teeth in the lower right quadrant.

Figure 7B: Intra-operative photograph demonstrating caries removal from teeth 83, 84 and 85. **Figure 7C:** Post-operative clinical photograph showing composite restorations on the lower right teeth 83, 84, and 85.

DISCUSSION

PRS is a rare congenital craniofacial deformity characterised by retro-micrognathia, glossoptosis and cleft palate.[1-4, 12, 13] The disorder may occur in isolation or as part of a wider Mendelian syndrome such as Stickler's Syndrome, Velocardiofacial Syndrome, Marshall's Syndrome, Foetal alcohol Syndrome or Treacher-Collins Syndrome.[1, 2, 4] Such cases are not always hereditary. Recent studies have shown the genes SOX9 and KCNJ2 are dysregulated as a result of a familial translocation between the two genes which may interfere embryologically with caudal hind brain development.[1, 3] The defects associated with PRS occur aetiologically during the 8th to 11th weeks of intra-uterine life. At this stage, the relatively large tongue in these patients fails to descend adequately which prevents the lateral palatine shelves from fusing together in the midline. Patients with PRS are diagnosed with the condition shortly after birth and experience lifelong complications. The most immediate concerns are difficulty breathing and difficulty feeding. Immediate intervention regimens include supine positioning of the patient for feeding and to minimise the potential for airway obstruction by posterior displacement of the tongue or aspiration of food. Patients may require insertion of a nasogastric or orogastric tube or placement of a surgical gastrotomy.[8, 14] The use of an obturator or modification of the nipple for bottle feeding may also be required. There is significant risk of death due to bronchial aspiration or respiratory difficulties. This may be minimised by use of a laryngeal mask, prolonged intubation, a tongue-lip adhesion surgery, mandibular distraction osteogenesis and tracheotomy[1, 8, 14] Recurrent local infections complicate nutritional status which is further exacerbated by a cleft palate. Contemporary therapy combining tongue-lip adhesion and mandibular advancement is thus the most recommended surgical intervention. Surgical intervention is generally postponed until after 18-months of age and in consultation with the entire health care team. Most patients with PRS do not have impairment of intellect and can easily grow up to live relatively normal lives. They do, however, require continuous support as well as psychological follow-up for the remainder of their lives. The only residual complaints in most patients is slight hypernasality although the overall quality of life of a patient may be dramatically affected by the aesthetic outcome of all therapeutic interventions as this may affect the patients autonomy, self esteem and ability to socialise.[1, 3] There remains a need for patient and parent education to ensure that there is continuity of therapy with members of a diverse multidisciplinary health care team to optimise the aesthetic, functional, social and psychological outcomes for each individual patient.

CONCLUSION

The aim of this case report is to emphasise the diversity of the multidisciplinary treatment team needed in the adequate management of a patient diagnosed with PRS. The multitude of complications associated with PRS are both life threatening and may be lifelong. Caretakers and parents must be made aware of the need to be diligent, ensure a stimulating and nurturing environment and to continually provide support of both a physical and psychosocial nature.

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

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

1. DOES PROPER FLOSSING PERFORMANCE TRANSLATE INTO EFFECTIVE PLAQUE REMOVAL?

The ritual of brushing our teeth is a cornerstone of daily life, a universally acknowledged pillar of health and social propriety. Yet, for many, this routine focuses solely on the readily accessible surfaces of the teeth, overlooking the critical, hidden landscapes that lie between them. This neglected frontier—the interdental spaces—is where the most common and destructive oral diseases often begin their insidious work. Interdental hygiene, the practice of cleaning between the teeth, is therefore not merely a supplementary step but a fundamental necessity for comprehensive oral health. The evidence supporting this claim is robust and compelling, rooted in a clear biological understanding of oral disease. The sticky, bacterial biofilm known as plaque accumulates relentlessly in these toothbrush-defying spaces, serving as the primary instigator for gingivitis, the inflammation of the gums characterised by redness, swelling, and bleeding. If left unchecked, this condition can progress to periodontitis, a severe and destructive form of gum disease that erodes the very bone supporting our teeth, ultimately leading to tooth loss.

Regarding floss, a systematic review indicated a trend towards reduced plaque levels after one month when flossing was added to toothbrushing, but this did not reach significance (standardised mean difference (SMD) –0.42, 95% CI –0.85 to 0.02; seven trials, 542 participants; $p = .06$). Already at the three-month interval the additional effect of flossing decreased markedly (SMD –0.20, 95% CI –0.36 to –0.04; five trials, 594 participants, $p = .016$), and at six months, flossing was no longer found to have any measurable benefit (SMD –0.13, 95% CI –0.30 to 0.05; $P = .53$; three trials, 487 participants). If dental flossing can only remove plaque to a limited extent, this also explains the findings of a network meta-analysis that assessed the comparative efficacy of various interdental oral hygiene aids focusing on gingival inflammation. Among 22 trials evaluating 10 different types of devices, ranking probabilities indicated that floss had a near-zero probability of being the best interdental cleaning aid. However, the authors emphasized that the unfavourable results for flossing may be due to its technically demanding applicability and that, when used properly, for example in a professional context it could contribute to the prevention of plaque-associated diseases.

Observational studies show that many subjects have considerable difficulty in using dental floss correctly which impacts on its efficacy. Jung and colleagues (2025)[1] reported on a study that sought to answer the question as to whether the limited effect of dental floss described in the literature is due to inadequate instruction and technical performance or actual uselessness.

Methodology

This clinical trial investigated flossing performance through video observation and monitored plaque levels using an intraoral scanner.

Participants were eligible for inclusion if they were at least 18 years old, had a sufficiently healthy dentition, provided written informed consent, and were willing to take part in the study. Exclusion criteria were mental and/or physical disability that could limit the subject's oral hygiene performance, as well as allergies or intolerances to the dental materials used. Further exclusion criteria based on anatomical characteristics or factors interfering with standardised plaque assessment and oral hygiene procedures for all teeth: gingivitis with swelling and bleeding (< grade 3 of the Modified Gingival Index, tooth mobility > 1 (Grace & Smales Mobility Index), recessions with an extension of more than one third of the root length, cavitated carious lesions, gap dentition, absence of permanent teeth (with the exception of third molars and missing premolars due to orthodontic treatment with gap closure), fillings or crowns involving the proximal surfaces with defects that impede the use of dental floss and represent plaque retention sites, fixed orthodontic appliances.

At the first appointment, all included participants were asked to continue their habitual oral hygiene, but to suspend interdental hygiene measures until the next appointment. At the second appointment (T1) one week later, participants first brushed their teeth using their own toothbrush unsupervised. In a dental chair, plaque in both jaws was then disclosed with a foam pellet mixed in water that showed up discoloured plaque. Intraoral scans of both jaws (scan 1) were then performed.

The participants then went into another room equipped with a filming device. The video camera was mounted behind a semi-transparent mirror, which was taped with a transparent colour filter foil to make any red stains on the teeth as invisible as possible. This was to prevent the flossing performance from being affected by the perception of stained plaque. A dispenser with dental floss (Oral-B Essential Floss Mint waxed) was provided and participants were asked to floss in the way they thought was right and how they usually flossed at home (habitual flossing). Flossing performance was filmed unobserved and without a time limit. The remaining plaque was then recorded with intraoral scans (scan 2) after re-staining as described above.

The participants then watched an instruction video that showed in close-up how the floss is correctly guided over the contact point, applied to the mesial and distal tooth surface

of the interdental space and moved in vertical direction. In addition, a systematic procedure was demonstrated, starting in the interdental space of the first and second molars in the upper jaw on the right and then successively reaching every subsequent interdental space up to the interdental space of the two molars in the lower jaw on the right. The participants were asked to practice flossing as instructed for one week.
At the third appointment (T2), the instructed flossing performance were recorded as well as one scan before flossing (scan 3) and one after flossing (scan 4) as described above.

The videos were analysed after all participants had completed all sessions using special software (Interact). All videos were coded exhaustively meaning that every second of the recorded session was annotated for relevant behaviours in slow motion using continuous temporal behavioural sampling. The interdental spaces mesial and distal of the Ramfjord-teeth (16, 21, 24, 36, 41, 44; in total 12 interdental spaces) were analysed.

Criteria of proper flossing performance were taken in part from the Flossing Dexterity Index. These included the number of interdental spaces reached, the movements performed in the interdental spaces, and the adaptation to the mesial and distal sides of the interdental space. An interdental space was defined as reached when the floss passed the contact point, correct movement was coded when vertical movements were performed and correct adaptation when the floss was placed mesially and distally against the tooth surfaces. This was coded dichotomously (yes/no) in each case. A score was calculated from the percentage (decimal numbers) of interdental spaces reached, flossed with vertical movements and with correct adaptation. To describe the overall performance, the individual scores are added together to the flossing performance score (FPS; maximum score 3 = all interdental spaces flossed with correct adaptation and vertical movements). In addition, the duration of flossing was coded and is given in seconds. Duration as well as FPS is given as median [95% CI].

The scans of the upper and lower jaw of a participant of all four time points were aligned processed using MeshLab software. A region of interest (ROI) was constructed and then visually assessed with the following scores: 0: no stained plaque visible, 1: < 50% of the ROI covered with stained plaque, 2: ≥ 50% of the ROI covered with stained plaque. Four areas of each Ramfjord tooth (mesial and distal each oral and vestibular) were assessed. A Proximal Surface Plaque Index (PSPI) was calculated as the mean of all scores. Plaque removal was calculated as difference between PSPI before and after flossing, thus, higher values for this difference indicate more plaque removal, i.e., less plaque remaining after flossing.

Results

The group studied consisted of 37 subjects (30 female, 7 males; 23.1 ± 3.2 years), no drop outs occurred.

The flossing performance score (FPS) for habitual flossing was 2.0 [1.48; 2.54] which increased significantly after instruction (2.83 [2.45; 2.95]; $p < .001$). The score reflects the quality of flossing based on three criteria: percentage of interdental space reached and percentage of interdental spaces with correct floss adaptation and with vertical flossing movements; each rated on a scale from 0 to 1, adding up to a sum sore between 0 (totally imperfect) and 3 (perfect flossing). Almost all participants had reached all interdental spaces already at T1, but the correct technique was only implemented to a limited extent. For habitual flossing, the score for correct adaptation was 0.42 [0.18; 0.73] and for vertical movements 0.64 [0.0; 1.0], both of which improved significantly after instruction (0.92 [0.83; 1.0], $p < .001$ and 1.00 [0.83; 1.00]; $p = .012$; respectively). However, even after instruction, there were still 8 subjects who did not implement the vertical movement in any interdental space and 5 subjects were only able to present the correct adaptation of the floss in less than half of the interdental spaces.

The time for habitual flossing was 60.3 [48.6; 75.6] s and increased to 89.2 [67.0; 108.7] s after instruction ($p < .001$).
The Proximal Surface Plaque Index (PSPI) was 1.29 [1.00; 1.42] before habitual and 1.33 [1.13; 1.46] before instructed flossing with no significant difference between them ($p = .182$). Oral sites had higher PSPI values than buccal sites at all time points (all $p < .01$). Overall, the plaque removal (difference PSPI before/after) was 0.17 [0.04; 0.25] for habitual and 0.21 [0.13; 0.25] after instructed use ($p = .112$). Flossing significantly increased the number of plaque-free areas ($p < .001$ for both habitual and instructed flossing) and reduced the number of areas with a score of 2 ($p < .001$ for both habitual and instructed flossing). In contrast, there was no significant change in the number of areas with a score of 1 ($p = .726$ for habitual and $p = .177$ for instructed flossing)
Flossing performance was not related to plaque scores (difference PSPI before/after) as there was no significant relationship between FPS and PSPI scores after flossing and also no significant relationship between FPS and plaque removal. Similar was true for the time spent for flossing (habitual flossing: $R^2 = 0.011$, $p = .544$; instructed flossing: $R^2 = 0.001$, $p = .825$). However, there was a significant relationship between the PSPI score before flossing and plaque removal and a strong relationship between PSPI scores before and after flossing.

Conclusion

The researchers found that even with correct technique, flossing did not substantially reduce plaque levels.

Implications for practice:

The results align with previous studies questioning the efficacy of flossing and highlight the need for further investigation into interdental cleaning approaches.

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2. POLYWAVE LIGHT-CURING UNITS (LCUS) COMPARED TO MONOWAVE LCUS FOR THE POLYMERIZATION OF RESIN-BASED COMPOSITES IN RESTORATIVE DENTISTRY: A SYSTEMATIC REVIEW

The performance of resin-based composites, a cornerstone of restorative procedures, heavily depends on the efficiency of light-curing units (LCUs) used for polymerization. Traditionally, monowave LCUs have been the standard, emitting a narrow spectrum of blue light primarily optimized for activating camphorquinone (CQ), the most common photoinitiator in composites. While effective for CQ-based materials, monowave LCUs have limitations in polymerizing composites containing alternative photoinitiators, such as TPO and Ivocerin, which require activation at shorter wavelengths.

Since the advent of light-activated resin composites, light-curing unit (LCU) technology has evolved from quartz-tungsten halogen (QTH) lamps to second- and third-generation light-emitting diode (LED) systems. Third-generation polywave LCUs, incorporating both blue (~450–470 nm) and violet (~400–420 nm) LEDs, were developed to overcome the spectral limitations of monowave devices and enable the activation of a broader range of photoinitiators—including camphorquinone (CQ), TPO, and Ivocerin. This broader emission spectrum makes polywave LCUs particularly relevant for advanced composite systems such as bulk-fill and aesthetic materials formulated with alternative photoinitiators that improve curing depth and aesthetics.

Thus, Polywave light-curing units (LCUs) have become increasingly important in restorative dentistry due to their ability to emit a broader spectrum of light compared to traditional monowave units. This allows them to efficiently activate a wider range of photoinitiators in modern resin-based composites, leading to superior clinical outcomes in many scenarios. Key features of Polywave LCUs include:-

Wider Spectral Output: Polywave LCUs emit light in the 380–550nm range, covering both blue and violet wavelengths. This enables them to activate not only camphorquinone (CQ, absorbs 430–500nm) but also alternative photoinitiators such as TPO, Ivocerin, BAPO, and MAPO, which require violet light.

Improved Polymerization Efficiency: Studies consistently show that polywave LCUs achieve a higher degree of conversion (DC), improved microhardness, and greater depth of cure than monowave units, particularly for composites containing TPO or Ivocerin. For instance, the degree of conversion was reported to be 83.7–92% for polywave LCUs versus 70–81% for monowave ones, and depth of cure reached up to 4.3mm compared to 3.6mm for monowave units.

Enhanced Mechanical Properties: Polywave curing produces stronger and more durable restorations with higher bond strength, especially in bulk-fill or photoinitiator-diverse composites, thereby increasing the longevity and clinical performance of restorations.

Versatility: Because they activate a variety of photoinitiators, a single polywave LCU can be used with a broader range of resin materials, making them highly practical in clinical settings.

However, they do have some important limitations and considerations that clinicians must take note of:-

Thermal Risks: Polywave LCUs tend to produce higher temperatures during curing (temperature rise up to 12°C has been noted), which can pose risks to pulp vitality. Protocol optimization is required to mitigate this effect.

Beam Homogeneity: Due to the arrangement of blue and violet LEDs, the spectral output may not be perfectly uniform, potentially resulting in uneven polymerization if the LCU is not properly positioned.

Colour Stability: No consistent advantage is seen for colour stability, as results vary based on the specific composite formulation. The impact on aesthetics and long-term shade retention may differ with different materials.

Not Always Superior for CQ-only Composites: For composites with only camphorquinone as photoinitiator, both polywave and monowave units tend to perform equally well. The polywave advantage is most apparent for photoinitiator-rich composites.

Fernández Godoy and colleagues (2025)[1] reported on a systematic review that sought to compare the performance of polywave and monowave light-curing units (LCUs) in the photoactivation of resin-based composite materials, with a specific focus on three key polymerization parameters: degree of conversion (DC), microhardness, and depth of cure (DoC). The null hypothesis of this review is that there are no significant differences in polymerization performance between polywave and monowave LCUs with respect to DC, microhardness, and DoC.

Methodology: The methodology adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was registered in PROSPERO, ensuring methodological transparency, reproducibility, and systematic rigor.

This review aimed to evaluate how polywave light-curing units (LCUs) compared to monowave LCUs in terms of polymerization efficiency, specifically assessing the degree of conversion (DC), microhardness, and depth of cure (DoC) in resin-based composite materials.

The **PICO** question was as follows: The **population** of interest comprised resin-based composites containing either conventional photoinitiators, such as camphorquinone, or alternative photoinitiators, such as TPO and Ivocerin. The **intervention** under analysis was photoactivation using polywave LCUs, while the **comparator** was photoactivation using monowave LCUs. The primary **outcomes** included DC, microhardness, and DoC, measured through standardised in vitro laboratory methods such as Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy, Vickers or Knoop hardness testing, and assessments based on ISO 4049 protocols. Only in vitro experimental studies that directly compared the polymerization performance of polywave and monowave LCUs were eligible for inclusion.

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A comprehensive literature search was conducted across five major electronic databases: PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, and EMBASE. The search strategy was constructed to identify studies evaluating the comparative performance of polywave and monowave LCUs in restorative dentistry, with no restrictions applied regarding language. The search included articles published up to December 2024.

In addition to the electronic database search, a manual screening of the reference lists of all included articles and a targeted hand search of relevant journals were conducted. Furthermore, grey literature sources including Google Scholar and institutional repositories were consulted. However, no additional eligible studies were identified through these manual or grey literature searches.

The study selection process was conducted in two phases by two independent reviewers (AC and RC) using pre-defined eligibility criteria. Firstly, titles and abstracts were independently screened for relevance. Records that clearly did not meet the inclusion criteria were excluded. Then, full texts of potentially eligible studies were retrieved and independently assessed by both reviewers. In cases where discrepancies arose during either phase, these were resolved through discussion. If consensus could not be reached, a third reviewer (EF) was consulted to adjudicate and make a final decision.

For inclusion, studies were required to compare the performance of polywave a nd monowave light-curing units (LCUs) in restorative dentistry and to report quantitative assessments of at least one of the following polymerization outcomes: degree of conversion (DC), microhardness, or depth of cure (DoC). Only studies that employed standardised evaluation techniques were included.

Studies were excluded if they lacked detailed information on light-curing parameters, such as irradiance, exposure time, or wavelength range. Studies that were narrative reviews, conference abstracts, non-peer-reviewed literature, and studies investigating non-dental applications of LCUs were also excluded.

Two independent reviewers extracted data from the included studies using a standardised Excel spreadsheet. Given that all included studies were in vitro experimental investigations, the Risk of Bias for Dental Materials (RoBDEMAT) tool was applied to evaluate internal validity. This instrument, specifically designed for preclinical research in dental materials, assesses multiple domains including randomization (when applicable), blinding of evaluators, sample size justification, appropriateness of statistical analyses, standardization of specimen preparation, and reproducibility of testing conditions.

Each study was rated across these domains and assigned an overall risk of bias classification: low, moderate, or high. The results were summarized in tabular format. Studies with high risk of bias were subjected to additional scrutiny to assess their potential influence on the strength and consistency of the review's findings.

Due to the substantial methodological heterogeneity among the included studies particularly in terms of composite formulations, photoinitiator types, curing protocols, and measurement techniques—a meta-analysis was not feasible. Instead, a narrative synthesis was conducted. Studies were grouped and analysed according to the three primary outcomes: degree of conversion (DC), microhardness, and depth of cure (DoC). Within each outcome category, results were stratified based on key variables such as composite type (e.g., bulk-fill vs. conventional), photoinitiator system (e.g., camphorquinone, TPO, Ivocerin), and the characteristics of the LCU used (e.g., irradiance, spectral emission). Heterogeneity was qualitatively evaluated by comparing study methodologies, experimental conditions, and reporting formats. Where applicable, ranges and percentage differences between polywave and monowave LCUs were reported to highlight trends and variations across studies.

Results

From an initial pool of 1,326 articles identified through electronic database searches (PubMed, Scopus, Web of Science, Embase, and Cochrane Library), 26 studies that met the inclusion criteria were selected for final analysis.

The included studies primarily focused on the in vitro performance of polywave and monowave light-curing units (LCUs) in the polymerization of resin-based composites. Among the 26 analysed studies, 14 specifically evaluated the degree of conversion (DC), 12 assessed microhardness, and 10 investigated depths of cure (DoC) using ISO-based or indirect methods.

Colour stability was found to be more influenced by the resin formulation—particularly the presence of hydrophilic monomers like TEGDMA—than by the spectral output of the light-curing unit. Marginal adaptation was shown to be influenced by both the composite formulation and the spectral compatibility of the curing unit Additional parameters explored included colour stability, heat generation and marginal adaptation.

Most studies exhibited low risk of bias for control group presence, standardization, testing procedures, and outcome reporting. However, recurrent issues were observed in domains related to randomization (D1.2), sample size justification (D1.3), and operator blinding (D3.2), which were frequently marked as "not reported" or "insufficient." These methodological deficiencies indicate a variable internal validity among studies and justify the cautious interpretation of aggregated findings.

Conclusions

Polywave LCUs show advantages in curing composites with alternative photoinitiators like TPO and Ivocerin, particularly in bulk-fill and high-viscosity materials, while monowave LCUs remain suitable for CQ-based resins. Nevertheless, their clinical use requires protocol optimization to manage irradiance variability and mitigate thermal risks.

Implications for practice

This review highlights the importance of matching the spectral output of light-curing units (LCUs) with the photoinitiators used in composite resins. Polywave LCUs showed superior outcomes in degree of conversion, microhardness, and depth of cure especially in composites containing TPO or Ivocerin. However, their higher thermal emission and beam non-uniformity may pose clinical challenges. Selecting an appropriate LCU should consider the composite's photoinitiator system and cavity depth to avoid under-curing and ensure restoration longevity. These findings support a more tailored, evidence-based approach to light-curing in contemporary restorative dentistry.

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Oral Medicine: Ethical Implications and Considerations

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S Mulder van Staden

INTRODUCTION

With the ever-increasing environmental exposures of the oral cavity to pathogens and potential carcinogens associated with habits (e.g. smoking, vaping, waterpipe, etc.) clinicians should remain vigilant in order to ensure the practice of ethical principles of care.[1]

Many Oral Health Care Workers (OHCW) – such as Dentists and Oral Hygienists – may experience uncertainty as to how to navigate the discussion when an oral presentation is noted that warrants further investigations. It is imperative that the OHCW remain objective, clear, concise and ensure dignity and truthfulness remain intact during these discussions with the patient. The predicament that may present is how can the OHCW motivate a patient for referral for special investigations (such as histopathological assessment), without offering the patient a diagnosis, instilling excessive fear or insufficient urgency to act.

CLINICAL CASE SCENARIOS

Patient A presents with a lesion on the palate that is small and flares up from time to time. The patient does not experience any pain.

Patient B presents with a white lesion in the cheek and has not noticed it until the examination by the dentist.

Patient C presents with a chronic lesion on the tongue. The patient presented with a history of receiving treatment several years ago for this same area from a non-dental specialist and with a diagnosis of a "benign lesion previously determined".

Patient D present with active oral lesions originating from a notifiable transmittable disease such as a sexually transmitted infection (STI) e.g. Syphilis.

DISCUSSION

The OHCW should never make a perceived diagnosis for any of the case scenarios above, in order to prevent a discussion with the patient or to avoid disclosure of the findings of the oral examination. The OHCW has an obligation to disclose all the findings of the oral examination to the patient. The patient has the right of autonomy on their treatment and it is important for the OHCW to involve the patient in decision making process[2]. The potential difficulty faced by the OHCW (in the roles of a General Dentist or Oral Hygienist) is that in most cases they are the first point of contact and examination. The OHCW needs to emphasize the importance to the patient for seeking specialist care for the relevant special investigations and subsequent treatment based on the histopathological diagnosis. This discussion regarding the importance for referral needs to be completed without leading the patient towards a diagnosis or creating a perception regarding the prognosis. There are patients that will give push-back to not pursue a consultation with a specialist. This is especially true for case scenario C – as previous investigations were performed, or due to an absence of symptoms associated with case scenarios A and B. The patient's autonomy to not seeking treatment has been reported to be influenced by a fear of the biopsy results (65% of cases)[3] and the anxiety of the patient regarding the biopsy with the specialist (23% of cases).[3] Due to these and other personal situations (such as financial constraints), the patient may hesitate to disclose, could result in the refusal to seek further treatment and will present the OHCW with ethical difficulties. OHCW have a natural pre-disposition towards the corner stone of ethics namely beneficence. This is to act in the best interest of the patient at all times.[2] The clinician is additionally faced with the non-maleficence of "doing no harm". [2] The inkling of the OHCW for case scenarios B and C of the possible serious differential diagnosis and realising the sequelae of non-treatment, should never prompt the clinician to overstep and offer a possible diagnosis to convince the patient to present for a referral. Definitive diagnosis and treatment option discussion may only occur after biopsy and histopathological investigations. Even in case scenario A, where there is no pain and palatal lesions are not regularly seen, the patient must be referred to ensure beneficence and non-maleficence is duly enforced.

Cases where patients present with a diagnosis, that may bear considerable health implications for an uninformed partner or spouse (such as case scenario D), may leave OHCW feeling conflicted as to their responsibilities to the exposed individual. There are many reasons why a patient may refuse disclosing their diagnosis to a third party. In a study[4] it was reported reasons for patients not disclosing a STI diagnosis as inadequate access to education, concern of stigma associated with diagnosis, fear of accusation of infidelity, threat of violence from the partner and the risk of dissolution of the relationship. The burden of responsibility for OHCW is limited to informing the patient of their STI diagnosis and the importance of disclosing this information and notifying their sexual partners.[4] This approach is potentially in conflict with other ethical considerations, such as the harm that may come to an uninformed partner. OHCW may also feel conflicted as they are unsure whether a partner notification will take place at all. An OHCW may only make a disclosure regarding a diagnosis without patient consent, when it involves disclosures

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in public interest that outweigh the patient's interest to confidentiality[5] for example in cases of human retroviral disease (HIV) exposure where serious harm or death are consequences of non-disclosure and failure to receive prophylactic treatment.

In most cases the OHCW-patient relationship is established and this ensures the patient is confident in maintenance of their dignity and the OHCW maintaining truthfulness (veracity). This "comfort" enhances the shared-decision-making discussion and will allow the patient to ask questions without prejudice and be involved in the referral process to a specialist, while stating the importance of the patient seeking the further care. When there is no patient-OHCW relationship present, this shared-decision-making discussion will be more challenging to the OHCW. It is the obligation of the OHCW to educate regarding referral, provide the patient with a referral letter and note in the patient records a referral was provided.[6]

When the shared-decision-making process breaks down and the patient remains adamant that they do not want to seek further treatment, the OHCW should make detailed notes on the discussion[7] and the copy of the referral letter that was not accepted should be noted in the patients file.[6] Ideally, take a metered photo record with a periodontal probe of the respective lesion, should the patient consent for record purposes. The OHCW may not proceed to discuss the scenario with their usual specialist referral pathway; as the patient has declined further treatment by exercising their autonomy.[5] The OHCW must retain the patients' rights to confidentiality and privacy until the patient chooses to pursue a consultation with the specialist with the provided referral letter. Upon subsequent dental visits the OHCW is required to continuously record the presentation of the lesion, and renew the consent for the photographic record. The OHCW must re-motivate, encourage and provide a newly dated referral letter towards the patient for visiting the specialist for biopsy and histopathological assessment.

Some patients would want to have clarity at the oral examination visit, if there is a chance for the lesion present to be malignant. From previous literature, it was reported as common practice for OHCW to estimate the patients' expectations, reaction and the way they would like to receive the diagnosis of a malignant nature[8] even before a histopathological diagnosis is confirmed. The OHCW should always maintain beneficence, however remain mindful that the clinical presentation of oral lesions is only one aspect of assessment and the diagnosis and severity (i.e. degree of dysplasia) can only be determined histopathologically. The clinician that decides to make the diagnosis, without histopathological assessment or proceeds to biopsy the lesion themselves, will be evaluated on the same level of standard of care as a specialist, should any law-suits and Ethical Regulatory Body inquiries transpire.[6] HPCSA guidance is set out in Ethical Rule 21, Performance of Professional Acts, stating that a practitioner shall only perform a procedure that is deemed to be out of scope, or the when the clinician is not adequately qualified or experienced, in the event of an emergency.[9] The discussion of a differential diagnosis by a non-treating OHCW that could lead to a perceived diagnosis discussion, must be managed carefully with respect and dignity towards the patient. Therefore, the non-treating OHCW, should try to maintain a neutral position, considering the patients' fear of a malignant diagnosis and re-assure them until the definitive histopathological diagnosis is confirmed by the specialist.

CONCLUSION

The OHCW remains the first patient contact and must decide how they would like to share information comprehensively to ensure a shared-decision making process, without necessarily misleading the patient to a possible diagnosis. The OHCW should remain cognisant that should the offered diagnosis be incorrect, the patient would have suffered an incorrect diagnosis and the patient could pursue various legal avenues to remedy their perceived trauma. The clinician that would like to consider the sensitive nature of the oral medicine referral process could utilise phrases and wording based on their clinical expertise and patient assessment of readiness to receive the information, such as:

"I have completed my oral examination and I have noticed something on the "area of the [insert location]". This is not the normal representation that would usually be present in this location. As your OHCW, I need to recognise that something looks different from the normal presentation and provide you with the appropriate referral letter. The specialist clinician, I will refer you to, is a specialist dealing with oral medicine and their consultation is essential to achieve a final diagnosis and treatment plan. Because, I am unable to provide you with direction towards the final diagnosis of the "area of the [insert location]" please do not feel that I am being dishonest or do not have your best interest at heart. It is important for me to let you know that a definitive diagnosis in most cases can only be made by a biopsy and subsequent histopathological assessment.

Because I am not a specialist and I am not adequately trained in treating oral medicine conditions / lesions, it could be perceived as out of scope if I were to offer you a diagnosis. Further should my diagnosis be incorrect upon histopathological assessment, you would have endured unnecessary emotional trauma with the diagnosis. I realise you might have some questions towards the seriousness of the "area of the [insert location]". I can confirm that based on the provided history of the "area of the [insert location]" it has a "history of recurrence / non-healing / never pained / tissue shows colour changes / tissue show texture changes / pain / ex" and I would recommend that it is investigated further by a specialist. I realise it might be frustrating that I am unable to give you a final diagnosis at this stage, but be assured we will do everything we can as a team to achieve the best possible treatment outcome, irrespective of what we might find in the biopsy results". It is important to remain calm about the situation and we will systematically manage the scenario as more information becomes available. May I contact the referring specialist and send them your information in the form of a referral letter or alternatively I will provide you now with a referral letter and you can contact the specialist on your own accord?"

DECLARATION

No conflict of interest declared.

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Online CPD in 6 Easy Steps

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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CPD questionnaire

A Comparison of Three Types of Orthodontic Study Models

1. **Please select the INCORRECT statement. The following statements are disadvantages of plaster study models.**
   - A. Plaster study models are easily damaged and broken.
   - B. Plaster study models are inexpensive to produce.
   - C. Plaster study models are time-consuming to measure.
   - D. Plaster study models are difficult to store due to their weight and size.

2. **Select the CORRECT statement. Which of the following statements is an advantage of digital study models?**
   - A. Measuring digital study models can be challenging due to difficulty in locating certain landmarks.
   - B. Digital study models cannot be physically held.
   - C. The electronic storage of digital study models requires maintenance and password protection.
   - D. Digital study models do not require physical storage.

3. **Select the CORRECT statement. Regarding types of Orthodontic study models?**
   - A. 3D printing technology and equipment is inexpensive.
   - B. Managing and maintaining equipment does not require expert help.
   - C. Some printed models shrink during the curing process or during post-curing.
   - D. Some landmarks, such as the cervical margins of teeth, are easy to identify on printed study models.

A Review of Computer Aided Design and Computer Aided Technology (CAD/CAM) in Complete Denture Construction: Part 2

4. **Select the INCORRECT statement. Which one of these statements is incorrect regarding digital workflow**
   - A. Digital scanners cannot record mobile soft tissue detail well
   - B. Digital workflow may omit some crucial chairside steps
   - C. Digital workflow can be used alongside traditional steps in a hybrid approach
   - D. Digital technology cannot be used to modify gingival details
   - E. Digital impressions cannot capture the soft palate well

5. **Which option is CORRECT. With regards to occlusal relationships**
   - A. Inaccurate occlusal relations can lead to excessive tooth wear
   - B. Digital workflows are not accurate when determining occlusal relationships
   - C. It is not possible to alter occlusal relationships after scanning
   - D. All of the above are correct
   - E. Only A) and C) are correct

6. **Select the CORRECT statement. In denture fabrication, 3-D printing allows**
   - A. Less flexibility in design than milling
   - B. Alterations in shade
   - C. Greater strength than milled dentures
   - D. Greater translucency than Milled PMMA dentures
   - E. Less porosity than Milled PMMA with improved hygiene

7. **Which of the following statement is CORRECT. Hybrid workflows**
   - A. Allow for a combination of milling and 3-D printing
   - B. Can result in dentures with improved strength and aesthetics
   - C. Pose problems merging the two modalities, which can make dentures weaker
   - D. All of the above
   - E. Only A) and B) above

8. **Select the CORRECT statement. Regarding the use of PEEK (Polyetheretherketone) in denture fabrication:**
   - A. PEEK is widely used for its excellent biocompatibility and high strength.
   - B. PEEK is a cost-effective material currently utilised in routine denture fabrication.
   - C. Modified PEEK shows promise as an alternative to metal frameworks in patients with allergies.
   - D. PEEK is a fully developed and standardised material in digital denture fabrication.
   - E. Both a) and c) are correct.

Teething problems with the implementation of the HPCSA core competency framework in an undergraduate dentistry curriculum

9. **Choose the CORRECT answer. Which methodology was primarily used in the study to gather educator's experiences with the HPCSA core competency framework?**
   - A. Quantitative surveys with closed-ended questions.
   - B. Experimental study designs with control groups.
   - C. Focus group discussions focusing on quantitative data
   - D. Qualitative methodology with semi-structured interviews

10. **Choose the CORRECT answer. What was the significant barrier to the implementation of the HPCSA core competencies identified by educators?**
    - A. Too many educational frameworks being introduced at once
    - B. Lack of formal training in teaching and assessing the competencies
    - C. Mandatory class sizes that were too large to teach
    - D. Limited of resources available for clinical training

11. **Choose the CORRECT option. Which statement BEST describes the primary aim of the HPCSA core competency framework in South Africa?**
    - A. To standardize teaching methods across all universities
    - B. To adequately prepare graduates to meet the dynamic healthcare needs of patients
    - C. To increase the number of dental procedures performed by graduates
    - D. To promote personal success in the field of dentistry

12. **Select the CORRECT Answer. According to the study, what is essential for the successful implementation of the HPCSA core competency framework?**
    - A. Extensive knowledge of dental procedures
    - B. Limiting the teaching of core competencies to theoretical discussions.
    - C. Increasing student enrolment in dental programmes
    - D. Faculty development initiatives aimed at fostering pedagogical conceptual change

Cephalometric characteristics of South African Black patients presenting at an academic oral health centre

13. Select the CORRECT option. The parameters which showed statistically significant increases with aging in this study were associated with which of the following characteristics?

A. Protrusive mandible
B. Retrusive maxilla
C. Protrusive maxilla
D. None of the above

14. Choose the CORRECT answer. Which one of the following characterises class II malocclusion?

A. A negative ANB angle
B. A negative Wits appraisal
C. Larger SNB angle than SNA angle
D. Larger SNA angle than SNB angle

15. Which of the following dentoskeletal features were noted in males when compared to females?

A. Greater extent of protrusive maxilla in males
B. Greater extent of protrusive mandible in males
C. Pronounced class II malocclusion in males
D. Larger gonial angle in males

16. Which of the following is correct regarding significant age correlations noted in the study?

A. Gonial angle decreased in females
B. SNB angle decreased in males
C. ANB angle increased in negative Wits appraisal groups
D. Gnathic index decreased in females

Cultural Beliefs and Oral Health Practices in Rural KwaZulu-Natal: Bridging Tradition with Modernity through Perspectives of Traditional Health Practitioners

17. Choose the CORRECT answer. Which of the following factors contributes to the delay in seeking oral health care in KwaZulu-Natal (KZN)?

A. Lack of qualified dental professionals
B. High costs of dental treatments
C. Cultural beliefs prevalent among the Zulu nation
D. Limited availability of oral hygiene products

18. Which option is CORRECT. What does the comparison between the number of Traditional Health Practitioners (THPs) and physicians in South Africa (SA) suggest?

A. THPs are less trusted than physicians
B. There are significantly more THPs than physicians in SA
C. Physicians provide a wider range of services than THPs
D. The approximate ratio of THPs to physicians in SA is 4:1

Multidisciplinary Management is crucial for patients with Pierre-Robin syndrome: A Case Report.

19. Select the CORRECT answer. Which one of the following options is a characteristic feature of Pierre-Robin Syndrome?

A. Macroglossia
B. Bilateral cleft palate
C. Mandibular prognathism
D. Glossoptosis
E. Aspiration bronchopneumonia

20. Which answer is CORRECT. Dysregulation of which one of the following genes has recently been identified as an aetiological factor in the development of Pierre-Robin Syndrome?

A. MUM-1
B. SOX-9
C. GLUT-1
D. PLAG-1
E. Podoplanin

Ethics: Oral Medicine: Ethical Implications and Considerations

21. Choose the INCORRECT statement. The OHCW should motivate the patient to visit the specialist for a biopsy by:

A. explaining the histopathology is required for a definitive diagnosis
B. not offering a diagnosis
C. instilling excessive fear
D. motivate with appropriate urgency

22. Which statement is CORRECT. The autonomy of the patient who does not want a biopsy is violated when:

A. You contact the specialist and discuss the patient and lesion.
B. You get permission for a photograph for records.
C. The patient decides with the clinician to receive a referral letter for biopsy.
D. The clinician records comprehensive notes after the consultation.

23. Select the CORRECT answer. The clinician that decides to proceed to biopsy the oral lesion themselves, will:

A. Be evaluated on the same level of standard of care as a specialist, should any law-suits occur.
B. Need to send the biopsy specimen for histopathology.
C. Can ask the oral pathologist to provide the patient with the diagnosis and refer for further treatment.
D. Need to continuously follow-up the area for recurrence / progression of the remaining lesion.

24. Which option is CORRECT. Disclosing the STI diagnosis by the patient to the partner could result in:

A. Concern of stigma associated with diagnosis
B. Threat of violence
C. Accusation of infidelity
D. The clinician overstepping patient confidentiality.

25. Which answer is CORRECT. The ethical term "non-maleficence – do no harm" is satisfied when:

A. The patient that do not seek biopsy has received their referral letter
B. The oral lesion is monitored at each clinical visit
C. A diagnosis of malignancy is offered without histopathology
D. The patient is re-motivated to seek the biopsy

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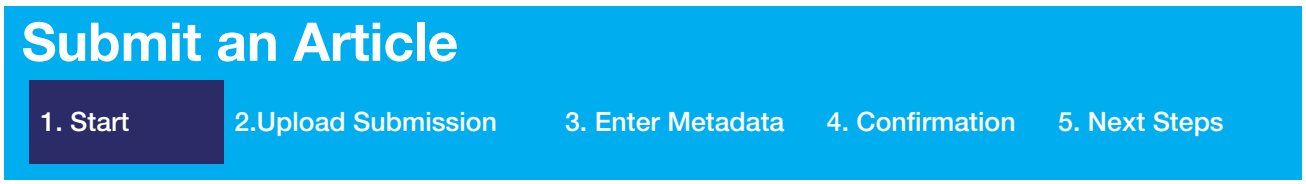

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HEALTH PROFESSIONS COUNCIL OF SOUTH AFRICA – WHO WE ARE AND WHAT WE DO IN OUR REGULATORY MANDATE

The Health Professions Council of South Africa (HPCSA) is a statutory health regulatory body mandated to protect the public and guide the professions by ensuring that healthcare practitioners are fit to practise their profession. Established by Section 2 of the Health Professions Act, 56 of 1974, professionally and ethically the HPCSA operates as a juristic person empowered to perform only those functions defined by legislation. Through this mandate, the Council regulates the scope of practice of health professions, ensures compliance with professional and ethical standards, and provides structured processes for oversight, accountability and disciplinary measures.

Together with the12 Professional Boards under its ambit, the HPCSA is tasked with overseeing the education, training, and registration of health professionals. To protect the public and safeguard the integrity of the professions, Council ensures that practitioners conduct themselves ethically and that complaints are investigated thoroughly, and that disciplinary action is taken when necessary. In fulfilling this broad regulatory responsibility, the Council executes its work through several key divisions, each with a defined role in supporting the overall mandate.

Legal and Regulatory Affairs
The Legal and Regulatory Affairs manages the professional conduct inquiry section which deals with professional conduct inquiries as processed by the committees of preliminary inquiry. The legal advisors appointed within the department act as proforma complainants in the prosecution of complaints referred by the Preliminary Committees of Inquiry (PCI). The Professional Conduct Committee appointed by chairpersons of the boards preside over the prosecution of such complaints. Litigation for and against the Council are also managed by the Department in consultation with the legal advisors.

Road Accident Fund Division
This division was established to render secretariat support to the Road Accident Fund Appeal Tribunal. This function is carried out in terms of regulation 2008 issued by the Minister of Transport which directs the Registrar of the HPCSA to set up tribunals of medical practitioners for the assessment of serious injuries.

The Work of the Inspectorate Office
The Inspectorate Office is central to ensuring compliance with the provisions of the Act, its rules and regulations. It conducts proactive and risk-based inspections, assists the Professional Boards with clinical and professional compliance matters, and monitors adherence to penalties imposed by the Professional Conduct Committee.

A significant focus of this office is the identification and prosecution of unregistered persons masquerading as healthcare professionals. In collaboration with law enforcement agencies, regulatory partners and the public, the Inspectorate exposes and acts against bogus practitioners who pose risks to public health. Strategies employed include proactive inspections, reactive investigations, and the preparation of court dockets for prosecution.

While progress has been made, challenges remain. The widespread presence of unregistered individuals makes detection and tracing difficult, and in some instances registered practitioners have unlawfully engaged unregistered persons as locums. To address this, the Inspectorate continues to emphasise awareness and education campaigns for both practitioners and the public, supported by strengthened collaboration with stakeholders. Members of the public are also encouraged to use the Council's iRegister platform or contact the Call Centre to verify practitioner status.

Investigating Complaints and Maintaining Ethical Standards
A critical part of the HPCSA's regulatory function is handling complaints against practitioners and ensuring adherence to professional and ethical standards. The Complaints Handling and Investigation Division is responsible for receiving, assessing, and investigating allegations of unprofessional conduct.

Complaints undergo a structured process, beginning with verification of practitioner registration and the categorisation of allegations. Where appropriate, matters are resolved through mediation, provided both parties agree to the outcome. Where mediation is unsuccessful, cases proceed to preliminary investigation, during which practitioners are required to respond to allegations within prescribed timeframes.

Matters are then considered by the Preliminary Committee of Inquiry, which determines whether there is evidence of unprofessional conduct. Depending on severity, the Committee may impose a minor penalty or refer the case to a formal inquiry. Where no evidence is found, the matter is closed. This process ensures accountability, protects the public, and preserves trust in the professions.

Ensuring Effective Practitioner Registration
Registration with the HPCSA is both a professional prerequisite and a legal requirement, forming the cornerstone of professional regulation. Practitioners are required to keep their details updated and to maintain good standing through the payment of annual fees. Provisions exist for voluntary erasure from the register and restoration where lapses occur, when practitioners elect not to practise their profession. However, such practitioners will be restored to registers on return, without having to shoulder penalties and/or outstanding fees. There may, however, be conditions to be met for restoration as set by a relevant Professional Board.

The Council manages multiple categories of registration, including student, intern, community service, independent practice, and specialised or temporary categories such as postgraduate, volunteer, and education-related registration. To improve efficiency, the HPCSA has implemented a hybrid registration system through the Enterprise Business System and Oracle Service Cloud. These improvements have reduced turnaround times significantly, with graduate registrations decreasing from three months to 3.5 days, and individual practitioner registrations reduced to an average of 3.5 working days.

Since March 2017, annual registration renewals have been conducted online, further streamlining the process. Future enhancements aim to integrate all applications into the Oracle Service Cloud, which will also enable the collection of employment data to strengthen workforce planning.

Dr Magome Masike

Professional Practice and Ethical Guidance
The Professional Practice Division plays an important role in guiding practitioners on ethical and professional standards. It supports the development of policies, issues directives, and provides advisory support to practitioners and Professional Boards. Its work covers areas such as scope of practice, continuing professional development (CPD), and the curation and review of ethical guidelines.

Recent achievements include attaining a 70% compliance rate in CPD across the professions, reviewing sixteen ethical guidelines, and introducing three new ones. The division has also engaged practitioners through workshops across the country, ensuring that professional and ethical issues remain a shared priority across the sector.

Education and Training Oversight
The Education and Training Division ensures that the education of healthcare professionals meets the highest standards by accrediting training programmes, conducting site visits, and evaluating clinical training facilities. The division also oversees the registration process for foreign-qualified practitioners, ensuring that only suitably trained professionals enter the system. Working closely with the Professional Boards and the ETQA Committee of Council, the division supports the facilitation of Board examinations. During the reporting period, 183 Board examinations were conducted, with 1 806 candidates participating. Of these, 1 316 passed and 490 did not meet the required standard. While notable progress has been achieved, challenges remain, including delays in curriculum reviews and complexities in the administration of Board examinations.

Conclusion
Through its regulatory mandate, the HPCSA continues to play a critical role in safeguarding the public and guiding the health professions in South Africa. Each division, from inspections and registrations to complaints handling, professional practice, and education oversight, contributes to ensuring that practitioners meet the highest professional and ethical standards. While challenges persist, the Council remains committed to strengthening its systems, enhancing stakeholder collaboration, and continuously improving regulatory processes in pursuit of a safer and more accountable health system.

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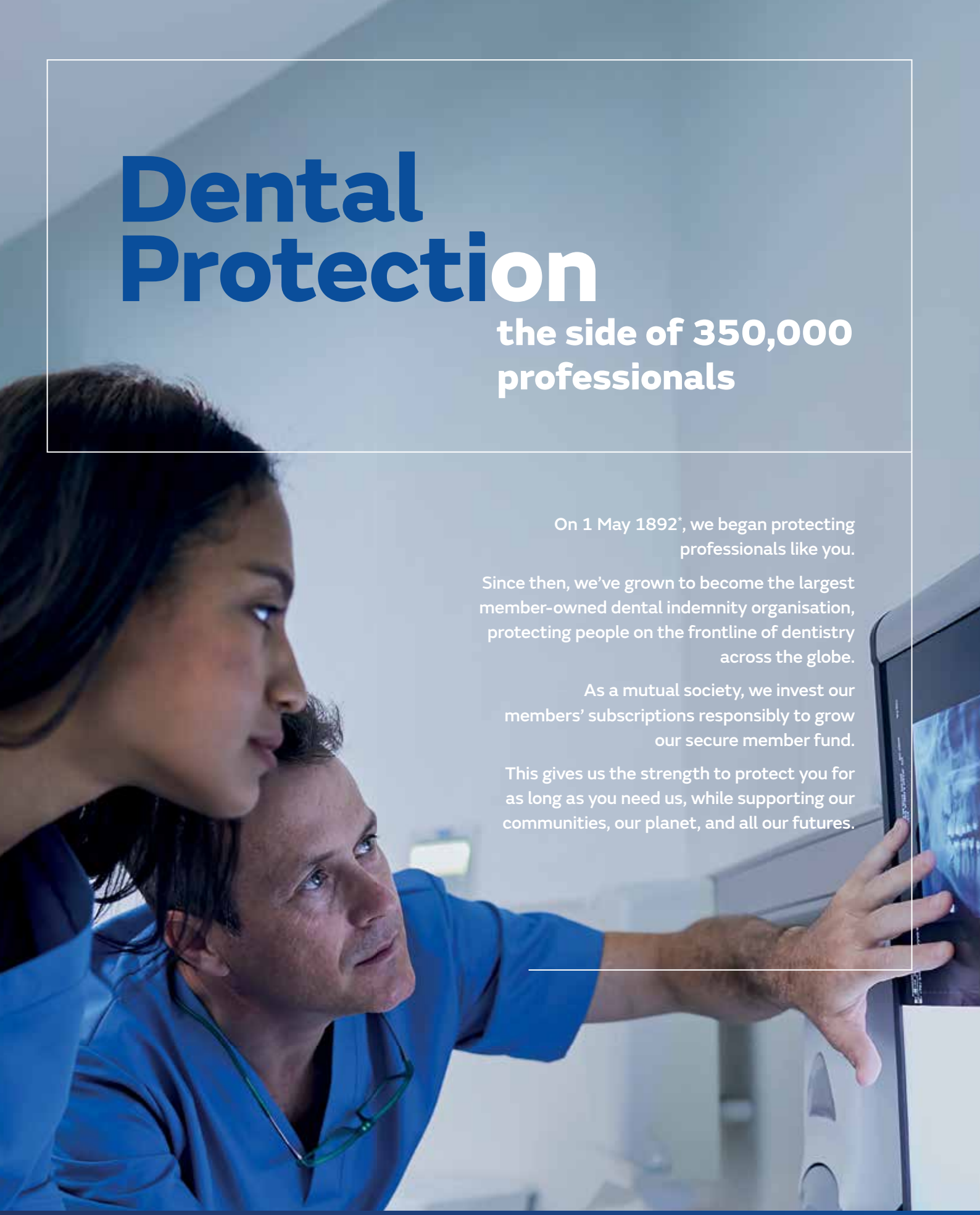

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