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Danger Point Lighthouse

The Danger Point Lighthouse near Gansbaai stood watch from January 1 1895, guarding a treacherous stretch of coast where more than 140 ships were wrecked. Set on a white octagonal masonry tower with a red lantern, it projects three flashes every 40 seconds and covers around 27 nautical miles. It also serves as a memorial to the tragic HMS Birkenhead disaster of 1852, where the “women and children first” protocol was first used.

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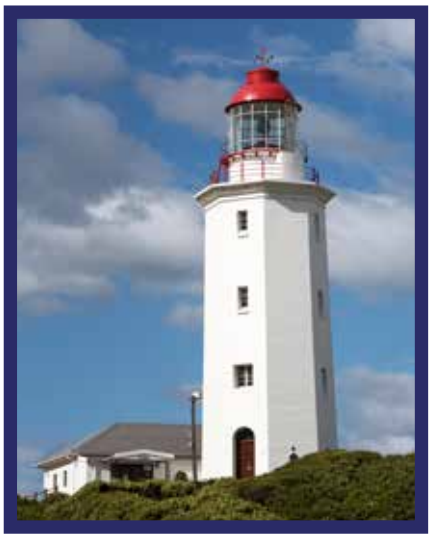

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The quiet crisis of thinking

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

The unspoken fatigue of thinking:

When last did we stop to think deeply about what we teach or even do, and why?

In the rhythm of clinical education, where timetables are full, assessment grids precise, and procedural counts relentlessly tallied, there seems little room for quiet reflection. Students move from simulation to clinic, staff from meeting to meeting and whole institutions from one accreditation cycle to the next. Efficiency has become a virtue, and completion a goal in itself.

Yet beneath this well-oiled activity lies a quieter unease: that we are producing increasingly skilled operators who struggle to think beyond the boundaries of the next patient, the next task, the next grade. The intellectual dimension of dentistry, that is, the ability to reason, question, integrate and imagine, appears to be thinning at the edges. This is not at all because today's students lack intelligence or curiosity, but because our systems reward speed, volume, and procedural certainty more readily than reflection and insight. Time is money after all!

Thinking, and I mean genuine, deliberate thinking, has become almost an act of defiance.

In clinics where productivity is equated with learning, and in classrooms where assessment dominates discourse, the time to think critically has become a scarce resource. And yet, the capacity to think well remains the essence of professional mastery. As educators and dentists, we must ask ourselves an uncomfortable question: in our pursuit of competence, have we neglected to cultivate wisdom?

Travelling from knowledge to knowing: the erosion of intellectual space:

Modern dental curricula have never been richer in information. Advances in biomaterials, digital technologies, and biomedical science have expanded what students must learn, and the pace of change continues to accelerate. But while the knowledge base of dentistry has multiplied, the intellectual space to process that knowledge has contracted. Some who trespass into that space may find themselves chastised by those who oppose or don't understand such development, but still cling to positions of influence.

In the language of educational philosophy, we have become skilled at transferring knowledge, but less confident at cultivating knowing. Knowledge is the accumulation of facts, protocols, and techniques: it tells us what to do. Knowing, by contrast, is interpretive; it requires connecting ideas, questioning assumptions, and applying understanding in contexts of uncertainty. Donald Schön called this the work of the "reflective practitioner": the professional who not only acts, but also thinks in action.

Too often, our systems reward recall over reasoning. Assessments are meticulously aligned with outcomes but not always with understanding. Multiple-choice questions test recognition rather than reflection; OSCE stations measure accuracy of steps rather than depth of judgment.

Even our well-intentioned focus on evidence-based practice can devolve into a form of intellectual outsourcing, quoting evidence without interrogating its applicability.

Granted the loss may be subtle, but it is cumulative. When curricula prize the reproduction of knowledge more than the construction of meaning, both teachers and students begin to value certainty over curiosity. The dental school becomes a place of compliance rather than inquiry. This spills into dental practice. And once that happens, intellectual leadership, the courage to ask better questions, starts to fade.

What is the cost of shallow thinking in clinical education?

The modern dental curriculum rewards doing. Students learn to plan, to scale, to restore, to record, all measured through a system that values countable outcomes, and firmly supported by pseudo-educators. Quotas, case logs, and competency checklists give an impression of precision and fairness. But somewhere between the spreadsheet and the simulation lab, the deeper work of understanding can quietly disappear.

When educational systems treat large numbers of completed procedures as a surrogate for competence, a subtle shift occurs. What was once a reflective, context-sensitive learning process becomes a numbers game, and the narrative of achievement narrows to quantity over quality. While students learn to chase completion rather than comprehension, the craft of thinking critically about what one is doing, and why, fades beneath the weight of numerical validation.

Procedure counts matter, of course; repetition builds confidence and dexterity. But repetition without reflection is mechanical. It risks producing graduates who can perform well-rehearsed tasks yet struggle to reason through novel problems, ethical dilemmas, or patient-specific nuances. The danger is not merely academic, it lives in the clinic, where habits replace judgment.

What is more disquieting is how comfortably some "educators" accept this reductionism. For those who equate busy clinics with successful training, metrics offer the comfort of control. Counting feels objective; reflection feels messy. To engage with complexity requires vulnerability: admitting that learning cannot always be contained in numbers or checklists. Yet, to avoid that discomfort is to abdicate one's duty as an educator. A teacher who stops learning, who resists new pedagogical thinking, slowly ceases to teach. Be aware of those who peddle quota systems in clinical education under the guise of building competency.

True competence is not the sum of completed procedures but the synthesis of experience, reflection, and insight. When we fail to cultivate this synthesis, we risk producing professionals who can perform dentistry, but cannot think dentistry. The difference is profound, and the cost of ignoring it is measured not in missed quotas, but in missed opportunities to create thoughtful, adaptable, and humane practitioners.

Rediscovering intellectual leadership

If the problem is shallow thinking, the antidote is not louder instruction or tighter control, it is leadership of a different kind. Dentistry does not need more managers of timetables, or curators of assessment grids; it needs intellectual leaders who can reconnect the mind to the hand.

Intellectual leadership is not about eloquence, seniority, or authority (or even celebrity). It is the courage to ask difficult questions, the humility to be uncertain, and the discipline to pursue understanding where convenience would prefer compliance. In clinical education, this form of leadership turns ordinary teaching moments into sites of inquiry. It asks students not only what they did but why, how and what else might have been possible.

True educational leadership is evidenced not in the number of students one supervises but in the quality of thought one evokes. The best teachers leave their learners restless: inspired, yes, but also unsettled enough to keep asking questions. They model reflection as a professional habit,

showing that dentistry is as much a cognitive discipline as a technical one.

This kind of leadership also extends beyond the clinic. It shapes curriculum design, assessment philosophy, and institutional culture. Intellectual leaders view curricula not as lists of competencies to be ticked off, but as living frameworks for cultivating judgment. They understand that reflection and dialogue are forms of clinical practice in themselves, essential to the development of professional reasoning and moral agency.

Importantly, intellectual leadership is contagious. When educators think deeply and visibly, students begin to imitate that posture of inquiry. When departments make time for collective reflection, clinical decisions improve. When faculties value ideas as much as throughput, morale and meaning return. Leadership of thought does not require new resources; it requires new priorities.

The challenge, then, is not whether we have capable people, the profession is filled with them, but whether our systems, incentives, and cultures make space for them to lead intellectually. To cultivate thinkers, we must allow thinking to be seen, heard, and rewarded. For every educator who pauses amid the rush of clinical quotas to invite a student to reason aloud, a small act of leadership takes place. That is how disciplines renew themselves: not through policy statements, but through moments of shared reflection that ripple outward into culture.

Reclaiming space for thought

If intellectual leadership is the mind of the profession, then thinking time is its oxygen; and right now, we are running short of breath. The modern dental school moves at the pace of service delivery: clinics must be filled, reports submitted, outcomes documented. The cost of this relentless momentum is not only fatigue, but a gradual suffocation of the very reflection that transforms experience into understanding.

Reclaiming space for thought does not require radical restructuring; it requires permission. Permission to pause, to question, to talk. Permission to let silence do its work. In many clinical departments, the most transformative learning happens not in the operatory but in the few minutes that follow, when teacher and student review what occurred and why. Protecting those conversations is an act of leadership. When educators ring-fence even small moments for debriefing and reflection, they signal that thinking is part of the procedure, not an interruption of it.

There are practical ways to nurture this culture:

- Structured reflection rounds, where students discuss diagnostic decisions, ethical tensions, and clinical reasoning rather than only case statistics.
- Narrative and portfolio assessments that capture growth over time instead of isolated performance.
- Cross-disciplinary seminars linking oral health with public health, ethics, and social determinants, reminding students that dentistry is a social science as much as a biological one.
- Faculty dialogues in which staff analyse teaching challenges together, not to standardise them away, but to learn from their complexity.

Such spaces do not slow education; they deepen it. They remind both teachers and students that professional mastery includes the ability to reason under uncertainty and to locate technical skill within moral and social context. Reflection is not an indulgence, it is the safeguard against arrogance and automation.

The paradox, of course, is that in creating room for thought, we often recover time. Students who understand the why behind a technique learn it faster and retain it longer. Clinicians who reflect in practice make fewer errors and find greater satisfaction in their work. Departments that normalise reflection build trust and collegiality, reducing burnout and cynicism. The return on investment is measured not in hours, but in depth.

To reclaim space for thought is to restore a sense of proportion to professional life. It is a reminder that in dentistry, as in all crafts of the human hand, precision begins in the mind.

Restoring the mind to the hand

Think back to the first time you held a mirror and probe in your hand.

You were nervous, careful, exhilarated. Every movement felt significant. Every patient, every tutor, every mistake: a lesson. Those early days were filled with questions. Why this angle? Why this approach? Why did it work here and not there? You were, without knowing it, both clinician and philosopher: learning not just to do, but to think.

Somewhere along the way, the questions became fewer. The pace quickened, the targets multiplied, and the thinking grew quieter. Dentistry, once defined by reflection and craftsmanship, began to sound more like a production line. In the name of efficiency, we lost something human, that spark of wonder that comes from understanding, not just completing.

But it can be recovered. It starts each time we choose to slow down enough to ask why again. Each time a student is invited to reason aloud rather than merely comply. Each time a colleague challenges a long-held assumption. Intellectual leadership begins in these small acts of courage: moments when we refuse to let thinking be a casualty of busyness.

We owe it to the next generation to model not only excellence of hand, but clarity of mind. A truly competent dentist is not simply one who performs well, but one who perceives deeply, who recognises that behind every procedure lies a decision, an ethic, a life. This is the standard that built our profession, and it is the standard we must now reclaim.

We should return, not nostalgically to the past, but to what the past once promised: a profession grounded in science, lifted by artistry, and guided by thought. Let us measure our success not by how much we do, but by how deeply we understand what we are doing, and why.

We teach our students to steady their hands; we must also teach them to steady their minds.

For in that stillness lies the future of dentistry, and perhaps its soul.

Addressing Dental Burnout: A Growing Concern for the Global and South African Dental Workforce

SADJ SEPTEMBER 2025, Vol. 80 No.8 P406-P407

Mr KC Makhubele – CEO, South African Dental Association

The global healthcare landscape is experiencing a growing prevalence of dental fatigue. The well-being, work performance and care of patients are all being significantly impacted by the significant stress that many dental professionals are enduring as a result of the ever-increasing demands placed on them. Dentists in both public and private sectors are impacted by this phenomenon, which is not restricted to any particular country or region and extends across continents. These challenges are even more severe for South African dental professionals, as they are confronted with distinctive contextual factors that can exacerbate the mental and emotional strain of their work.

The Global Trend: Rising Burnout Among Dental Professionals

Globally, dental burnout is a well-documented concern. A study published in the *British Dental Journal in 2020* revealed that over 50% of dentists report experiencing high levels of stress in their work environment. The American Dental Association (ADA) has identified burnout as a critical issue, highlighting that factors such as heavy workloads, high patient demands and emotional strain from dealing with anxious or difficult patients are significant contributors to mental health challenges within the profession. The increasing complexity of dental treatments and the push toward perfection in patient care further exacerbate this issue, placing substantial mental and physical stress on practitioners (American Dental Association, 2021).

Burnout manifests in many ways, from emotional exhaustion and reduced professional satisfaction to feelings of depersonalization and a lack of empathy for patients. Internationally, the focus has shifted toward addressing mental health issues within the dental workforce. Professional organizations are encouraging proactive measures to reduce burnout, with strategies such as developing better work-life balance, fostering supportive work environments and providing access to mental health resources becoming more common across the profession.

The *National Institute for Health and Care Excellence* (NICE) in the United Kingdom has also emphasized the need for mental health support systems for healthcare workers, including dental professionals, citing research that links burnout with compromised patient care and poor health outcomes (NICE, 2022). Globally, there is a growing recognition that the mental health of dental professionals directly influences not only their well-being but the quality of care they provide to their patients.

The South African Context: A Unique Set of Challenges

Dental fatigue is on the rise in South Africa, as it is in numerous other countries. A significant number of local dentists report elevated levels of stress related to the challenges of balancing clinical duties with administrative responsibilities, as per a study published by the South African Dental Association (SADA). Many South African dentists are obligated to oversee the business aspects of their practice, including staff administration, billing, patient scheduling and other administrative responsibilities, in addition to providing clinical care in private practice. This dual role can result in burnout, as dentists frequently experience the stress of simultaneously overseeing the financial health of their practice and the requirements of their patients (South African Dental Association, 2022).

Additionally, South African dentists encounter stressors that are distinctive to the country's healthcare system. The mental strain is further exacerbated by the complexities of providing care in diverse socioeconomic conditions, varying levels of patient access to care and high patient burdens. In rural areas, dental professionals may be required to work with restricted resources, whereas in urban areas, the stress of dental work is exacerbated by the demands of operating a private practice and the high expectations of patients. This issue is further exacerbated by the insufficient mental health support available to dental professionals in the country, as reported by the South African Medical Journal (2021). A significant number of dentists experience feelings of isolation and are unable to communicate the emotional challenges they encounter in their work.

Impact of Burnout on South African Dental Professionals

Burnout has a significant impact on South African dentists. When mental health is compromised, the quality of care is compromised. Dentists who are experiencing fatigue may find it more difficult to concentrate, which can affect the quality and accuracy of their diagnoses and treatments. Reduced empathy for patients can result from emotional exhaustion, which can lead to a decrease in patient satisfaction and potentially contribute to lower patient retention rates. In addition, burnout can result in increased absenteeism and early retirement, which can further burden the healthcare system in a country that is experiencing a shortage of healthcare professionals.

Addressing Burnout: Practical Solutions for South African Dental Practices

As the global community has recognised, addressing dental burnout requires systemic change and individualized support. For South African dental practices, implementing practical strategies to support mental well-being is crucial for improving both practitioner health and patient care.

1. Promoting Work-Life Balance

One of the primary drivers of burnout is poor work-life balance. In South Africa, private practitioners often work

long hours to meet patient demand, while also managing the administrative demands of their practice. Encouraging dentists to take regular breaks, set realistic schedules and implement vacation time is essential in maintaining long-term well-being. Practice managers can help by reducing unnecessary administrative burdens, automating appointment systems and ensuring that staff is well-trained to handle administrative tasks.

2. Creating a Supportive Work Environment

Another critical approach to mitigating fatigue is to cultivate an environment of mutual support and transparency. Dental practices should promote team-based approaches, in which clinical and administrative personnel collaborate to guarantee the efficient and seamless delivery of patient care. Providing professional development opportunities, establishing regular check-ins with staff and creating a space for staff to discuss challenges can help practitioners feel more connected to their work and less isolated. Additionally, the presence of a robust support system within the practice can alleviate feelings of tension and anxiety.

3. Stress Management Programs and Mental Health Resources

It is imperative that dental professionals in South Africa have access to mental health support programs and stress management resources. The provision of counselling services, mindfulness training and relaxation techniques within the workplace can assist dentists in managing the emotional demands of their profession. On a global scale, numerous dental practices have implemented Employee Assistance Programs (EAPs) to provide confidential mental health support to their employees. The mental health challenges that dentists encounter could be alleviated by implementing comparable programs in South African practices.

4. Professional Counseling and Peer Support

Promoting peer support networks within dental practices can be a beneficial strategy for addressing exhaustion. Peer support enables dentists to exchange experiences, engage in discussions regarding stress management strategies and provide guidance on how to balance the demands of clinical work and administrative responsibilities. Furthermore, practitioners may be able to more effectively address personal and professional obstacles by granting them access to professional counselling services. Dentists should have access to mental health clinicians who specialise in the unique pressures of healthcare workers to assist them in managing the emotional impact of their work.

5. Workload Management and Delegation

Promoting peer support networks within dental practices can be a beneficial strategy for addressing exhaustion. Peer support enables dentists to exchange experiences, engage in discussions regarding stress management strategies and provide guidance on how to balance the demands of clinical work and administrative responsibilities. Furthermore, practitioners may be able to more effectively address personal and professional obstacles by granting them access to professional counselling services. Dentists should have access to mental health clinicians who specialise in the unique pressures of healthcare workers to assist them in managing the emotional impact of their work.

Conclusion: A Call for Action

In South Africa and globally, burnout is a significant concern, as dental professionals encounter distinctive stressors that affect their mental and emotional well-being. It is crucial to address mental health within the dental workforce, as evidenced by international studies. In order to mitigate exhaustion, South African dentists must prioritise stress management, cultivate supportive environments and maintain a healthy work-life balance. Practice managers can significantly impact the lives of their dental professionals by instituting proactive measures, including workload management, mental health resources, peer support and work-life balance. This, in turn, will not only enhance the overall patient experience but also improve the mental health of practitioners, resulting in a more sustainable and prospering dental practice.

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Morphometry of the three prominent facial foramina in a South African sample using Cone Beam Computed tomography scans

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BM Msibi[1], S Van Der Walt[2], AA Adebesin[3]

ABSTRACT

Introduction

The supraorbital notch or foramen, infraorbital and mental foramina transmit sensory nerves commonly anaesthetised in aesthetic and dental procedures. Understanding variations in the location and size of these foramina is essential for safe and effective nerve blocks.

Aims and objectives

This study aimed to determine the mean anatomical location and shape of facial foramina in a South African sample.

Design and methods

Retrospective Cone Beam Computed Tomography (CBCT) scans of 159 South African adults (44 white females, 42 white males, 31 black females, 42 black males) were analysed using the MeVisLab © v.3.0.2 software. The facial foramina were classified by shape (round, oval, notch) while 15 three-dimensional landmarks were used to describe the location of these foramina.

Results

A supraorbital notch was observed in 74% of cases, while the infraorbital and mental foramina were predominantly round. No asymmetry in the location of the foramina was detected. The foramina were positioned further from the midline in males compared to females and in black South Africans compared to white South Africans. Sexual dimorphism in the location of the facial foramina was more pronounced in the white South African sample ($p < 0.01$).

Conclusion

These sex- and population-specific variations should be considered to enhance nerve block effectiveness and reduce the anaesthetic dose during aesthetic and dental procedures.

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Keywords

Aesthetic procedures, infraorbital foramen, mental foramen, population variation, sexual dimorphism, supraorbital foramen.

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Declaration of Interest

The authors declare that they have no competing interests to disclose

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INTRODUCTION

Surgeons rely on palpable skeletal landmarks to identify underlying structures and establish surgical approaches. Precise knowledge of these landmarks and their relationships is essential to minimise the risk of damage to critical neurovascular structures.[1] The supraorbital foramen (SOF) or notch (SON), infraorbital foramen (IOF) and mental foramen (MF) are essential skeletal landmarks which serve as passageways for neurovascular bundles traveling between internal and external cranial regions.[2] Clinicians commonly assume these foramina lie in a single sagittal plane, equidistant from the midline.[3] This assumption underpins surgical guidelines used for nerve blocks, allowing for approximate localization of the infraorbital and mental foramina by palpating the SOF/N.[1] However, research has indicated that the position, shape and size of these foramina exhibit significant variability, which is influenced by ontogeny, sex and population differences.[4-7] To prevent neurovascular damage during anaesthetic administration, these anatomical variations must be carefully considered.[8]

The SOF/N, IOF and MF are located on the anterior aspect of the face and transmit sensory nerves, originating from the divisions of the trigeminal nerve, and vascular structures that bear the same names as the openings.[9-10] The SOF/N is situated on the superomedial aspect of the orbital margin in the frontal bone, and allows the supraorbital nerve, a branch of the ophthalmic division of the trigeminal nerve, to exit and innervate the forehead, scalp, superior eyelid and frontal sinus.[9] The IOF, located in the maxilla just inferomedial to the infraorbital margin, transmits the infraorbital nerve, the terminal branch of the maxillary division of the trigeminal

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nerve.The infraorbital nerve supplies sensory innervation to the inferior eyelid, lateral aspect of the nose, upper lip and maxillary labial gingiva.[11] The MF, found on the anterolateral aspect of the mandibular body, serves as the exit point for the mental nerve, the branch of the inferior alveolar nerve that arose from the mandibular division of the trigeminal nerve. The MF is typically positioned between the roots of the mandibular premolars or apical to the second premolar.[1,11]

Studies conducted to determine the location of the facial foramina have shown contradicting results regarding sexual dimorphism.[1,2,4,10-13] Some research has reported significant differences between males and females,[2,4,12] while others found little to no variation,[1,13] suggesting potential population-specific sex differences. Agthong and co-workers. (2005)[2] reported that the infraorbital foramen was closer to the anterior nasal spine in females compared to males, and the position of the mental foramen varied between sides. Apinhasmit and colleagues (2006)[4] found that males exhibited greater distances from the facial foramina to their surrounding bony landmarks. Sexual dimorphism affected most measurements, except for the specific distances related to the supraorbital and infraorbital foramina, while asymmetry in the location of the mental foramen was reported.[4] Conversely, Lim and colleagues (2016)[13] found minimal sexual dimorphism in a Korean sample, with the only significant difference reported in the distance from the mental foramen to the inferior border of the mandible in males. Similarly, Hester et al. (2021)[1] reported no notable sex differences except for a slightly greater distance from the right infraorbital foramen to the midline in males. These findings highlight the variability in the position of the facial foramina and suggest the need for further research on population-specific sexual dimorphism.

In addition, interpopulation variation was noted in the position of the SOF/N, IOF and MF.[2,13] Research conducted on dry Kenyan skulls revealed that the average distances from the midline to the facial foramina were greater in Kenyans compared to other populations as the SOF/N was located 27.22 mm, the IOF 28.91 mm, and the MF 27.75 mm from the midline.[14] Comparison of these findings to a study conducted on dry Indian skulls revealed greater distances from the midline to the SOF/N and MF in Kenyans, while the IOF was located further from the midline in Indians.[5,14] While previous American surgical guidelines were based on the assumption that White Americans and Hispanics share comparable facial foramina locations, research by Hester et al. (2021)[1] contradicts this assumption. Their study, involving 67 skulls (28 females, 39 males), revealed a significant difference in the infraorbital foramen (IOF) position, with Hispanics exhibiting a greater distance from the midline.

Due to the noted variation in the literature and the lack of comparable data on South Africans, this study was undertaken to determine the size and location of the SOF/N, IOF and MF in contemporary black and white South African Cone Beam Computed Tomography (CBCT) sample.

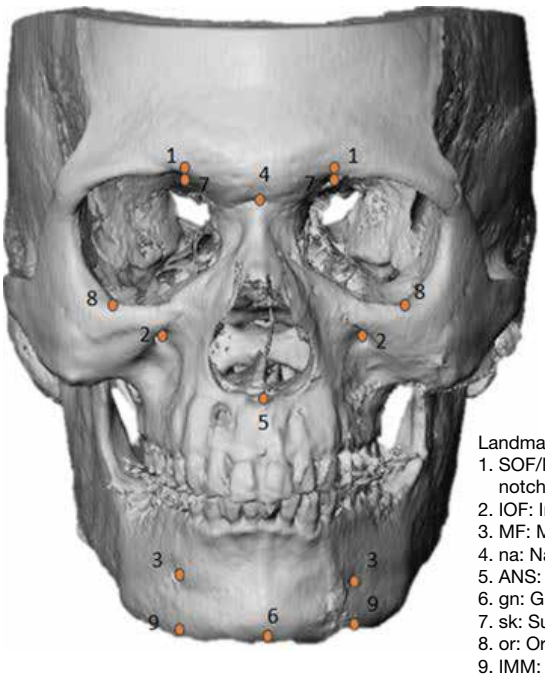
MATERIALS AND METHODS

One hundred and nine CBCT scans of adult South Africans (44 white females, 42 white males, 31 black females, and 42 black males; average age: 33 years) were included in the study. These scans were part of the retrospective collection of the Oral Health Care Centre at the Sefako Makgatho Health Sciences University and a private medical centre in Pretoria, South Africa. A Planmeca ProMax CBCT 3D scanner with the following specifications: 90kV, 8mA, 11.2 mA, voxel size of 0.4 mm^3, and a maximum field of view of 230 (diameter) mm by 260 (height) mm was used in the private hospital, while a Newtom VGi CBCT 3D scanner with the same specifications and maximum field of view was used in the Oral Health Care Centre of the Sefako Makgatho Health Sciences University. Scans with facial pathologies, fractures, or inadequate visualisation of the facial foramina were excluded. Ethical clearance was obtained from the School Research committee, with the following number: SMUREC/M/164/2022: PG.

The CBCT scans were obtained in DICOM (Digital Imaging and Communications in Medicine) format and imported into the MeVisLab © v.3.0.2 software (available from), a free medical image processing and visualisation programme. This software enables the segmentation of radiographic data, facilitating geometric morphometric and anthropological analyses.

Segmentation involves distinguishing between hard and soft tissues, based on their grey values. This is achieved by setting an ISO-value, typically ranging from 450 to 550 for soft tissue and 1450 to 1550 for hard tissue.[15] The segmentation process enables the visualisation of soft and hard tissue surfaces generated from the imported DICOM images. To optimise the visualisation of the three facial foramina under investigation, ISO-values were carefully adjusted. Additionally, the voxel sampling was set to one to ensure high-quality skull rendering. Prior to data acquisition, it was confirmed that the scans had an isometric voxel size of 0.4 mm^3, ensuring precise calculations of linear distances between 3D-placed landmarks.

The shape of the facial foramina was classified based on visual observation. The SON was classified as a notch or a foramen, while the IOF and MF were categorized as round or oval. Nine anatomical landmarks were identified from the literature[1,4,10] and 3D landmarks were placed on the segmented skull surface using the MeVisLab © v.3.0.2 software[2,9] (Fig. 1).



Landmarks:
1. SOF/N: Supraorbital foramen/ notch
2. IOF: Infraorbital foramen
3. MF: Mental foramen
4. na: Nasion
5. ANS: Anterior nasal spine
6. gn: Gnathion
7. sk: Supraconchion
8. or: Orbitale
9. IMM: Inferior mandibular margin

Figure 1: Landmark position on the 3D segmented skull surface

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The position of the facial foramina, from one landmark, - a to the other – b, was determined by calculating the linear distance between the 3D coordinates of the placed landmarks (Table I) using the Pythagorean formula.[16]

Table I: Definitions of the morphometric measurements

Measurements	nr	Definition
SOF/N-Na	1	Distance from the supraorbital notch/ foramen to the nasion
SOF/N-Sk	2	Closest distance from the supraorbital notch/foramen to the supraconchion.
IOF-Or	3	Closest distance from the infraorbital foramen to the orbitale.
IOF-ANS	4	Distance from the infraorbital foramen to the anterior nasal spine.
MF-Gn	5	Distance from the mental foramen to the gnathion.
MF-IMM	6	Vertical distance from the mental foramen to inferior mandibular margin.
SOF/N-IOF	7	Distance from the supraorbital notch/ foramen to the infraorbital foramen.
IOF-MF	8	Distance from the infraorbital foramen to the mental foramen.

Statistical analyses were performed on the calculated linear distances using the PAST statistical programme.[17] The observer error was assessed by performing an Intraclass Correlation Coefficient test (Two-way random effects, absolute agreement, single rater/measurement: ICC (2,1)).

The normality of the data was evaluated using a Shapiro-Wilk test. For each sex-population group, descriptive statistics, including summary statistics, were calculated to quantify the location of the facial foramina. Analysis of variance (ANOVA) was employed for parametric data and the Kruskal-Wallis test was used for non-parametric data, to assess variations between groups. To mitigate the risk of Type I errors arising from multiple comparisons, post hoc tests were performed. Specifically, Tukey's pairwise comparisons were used for parametric data[18-19] and Mann-Whitney tests with sequential Bonferroni correction[20] were applied for non-parametric data. Statistical significance was set at $p \leq 0.05$.

Results

ICC results, interpreted using Koo and Li's guidelines (2016),[21] showed greater measurement repeatability on the left side and higher intra-observer than interobserver reliability. Left-side supraorbital foramen (SOF) positions were more accurately determined relative to the infraorbital foramen (IOF) and nasion (na); left-side IOF relative to the anterior nasal spine (ANS); and left-side mental foramen (MF) relative to gnathion (gn). Excellent repeatability was found for SOF-IOF measurements, high repeatability for SOF-na, MF-gn, and MF-IMM, moderate repeatability for SOF-sk, IOF-ANS, and IOF-MF, and poor repeatability for IOF-or.

In the sample studied, a supraorbital notch (SON) was identified in 62.27% of cases, while the supraorbital foramen (SOF) occurred in 37.73%. Bilateral SONs were the most prevalent (44.03%), followed by unilateral SONs and SOFs (18.24% each), and bilateral SOFs (19.49%). The SON was more commonly observed on the left side, whereas the SOF was more frequently found on the right. The infraorbital foramen (IOF) was consistently present bilaterally in all individuals and was predominantly oval-shaped (72.33%). The mental foramen (MF) was reliably positioned between the mandibular premolars. Oval shapes were more common (61.64%).

The results of the Shapiro-Wilk test indicated that most linear distances calculated from the 3D coordinates followed a normal distribution across all sex-population groups, except for the SOF/N – sk distance. In addition, the following distances were non-parametric in the black male sample: Left SOF/N – na and left MF – gn. In the white female sample, non-parametric distribution was noted for the SOF/N – na on both sides as well as the right IOF – or. Lastly, the right SOF/N – na distance exhibited a non-parametric distribution in the white male sample.

Symmetry in the location of the facial foramina was observed in each sex-population group, although asymmetry was observed in the SOF/N – IOF distance in the combined sample. All three prominent facial foramina were positioned further from the midline in males compared to their female counterparts (Table II), although these positional variations were more significant in the white South African sample (Table III). The IOF was located further from the midline in black males when compared to their female counterparts, which could be due to the wider faces noted in males.

Population affinity had less influence on the position of the facial foramina (Table III). More significant variation was observed in the male sample, compared to the female sample. The SOF/N was located more lateral from the nasion (Na), and the IOF was located more lateral from the anterior nasal spine (ANS) in the black male sample compared to the white male sample, while the SOF/N was found more laterally in white males in relation to the supraconchion (Sk). The mental foramen is located further from the inferior mandibular margin (IMM) in white males compared to black males. The significant positional variations noted between females included the more lateral location of the SOF/N from the Na in black females, while the IOF was located further from the ANS in white females. The distance between the IOF and MF was more in black females compared to white females.

DISCUSSION

The accurate localisation of the supraorbital foramen/ notch, infraorbital foramen, and mental foramen is critical for the effective delivery of local anaesthesia in both surgical and dental procedures. This is particularly important in a diverse population such as South Africa, where anatomical variations are commonly observed across sex and ancestry [(16)]. Knowledge of these variations aids in the successful administration of infraorbital and mental nerve blocks, which are routinely used in dental procedures including restorations, extractions, crown preparations, and soft tissue surgeries in the anterior maxilla and mandible [(4)]. CBCT imaging offers a reliable method for assessing these landmarks, contributing to safer and more predictable clinical outcomes.[16]

In this South African sample, a bilateral SON was the most prevalent, followed by a unilateral foramen on one side and a notch on the opposite side. A bilateral SOF was least commonly observed. The findings of this study are consistent

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Table II. Basic descriptive statistics of the position of the three prominent facial foramina and asymmetry of the combined groups

Measurements	Side	Black females n=31	Black males n=42	White females n=44	White males n=42	Asymmetry (p)
SOF/N-na	R	**29.00** ± *4.82* (21.54-37.49)	**30.09** ± *4.25* (21.99- 40.79)	**26.01** ± *3.59* (18.85- 38.14)	**27.73** ± *4.07* (20.87- 38.65)	0.63
	L	**30.11** ± *4.35* (22.62-40.84)	**30.53** ± *4.75* (21.28- 42.74)	**25.53** ± *4.25* (18.21- 38.99)	**27.92** ± *3.76* (20.69- 38.80)	
SOF/N-sk	R	**3.01** ± *0.77* (2.12- 6.39)	**3.19** ± *1.44* (2.01- 11.34)	**3.13** ± *0.90* (2.09- 5.90)	**3.73** ± *0.94* (2.22- 6.96)	0.11
	L	**3.21** ± *2.23* (2.21-14.19)	**3.44** ± *0.64* (2.39- 4.94)	**3.29** ± *1.00* (2.09- 5.72)	**4.04** ± *1.76* (2.41-13.10)	
IOF-or	R	**13.92** ± *4.28* (6.82-22.63)	**14.62** ± *2.75* (6.65-19.42)	**12.96** ± *3.82* (7.03-19.25)	**14.74** ± *1.99* (11.66-19.21)	0.69
	L	**13.79** ± *3.68* (5.78-20.17)	**13.96** ± *2.56* (7.79- 20.31)	**12.79** ± *3.62* (5.34-19.90)	**15.17** ± *1.61* (12.18-18.21)	
IOF-ANS	R	**34.64** ± *3.23* (29.06-42.15)	**36.59** ± *2.63* (31.45- 42.73)	**32.67** ± *1.89* (28.40-36.87)	**35.29** ± *2.37* (30.45-39.27)	0.96
	L	**34.28** ± *2.53* (28.82-39.06)	**36.81** ± *2.58* (31.80- 43.59)	**32.65** ± *2.05* (28.08-37.56)	**35.30** ± *2.45* (29.40-39.85)	
MF-gn	R	**29.91** ± *3.01* (24.45-36.48)	**30.68** ±*3.10* (22.94-40.99)	**29.24** ± *1.98* (25.90-33.58)	**30.59** ± *2.18* (27.38-35.24)	0.08
	L	**30.02** ± *2.38* (25.71-36.45)	**31.76** ± *3.29* (26.68-42.22)	**29.66** ± *2.05* (26.12-35.71)	**30.95** ± *2.46* (24.56-35.87)	
MF-IMM	R	**11.37** ± *1.72* (8.20-16.27)	**11.51** ± *1.44* (8.86- 16.05)	**10.73** ± *1.48* (7.95-14.10)	**12.65** ± *1.14* (9.86-15.09)	0.78
	L	**11.41** ± *1.53* (8.58-15.06)	**11.54** ±*1.47* (8.11-14.99)	**10.52** ± *1.43* (7.41-14.20)	**12.60** ± *1.70* (9.10-17.11)	
SOF/N -IOF	R	**44.75** ± *2.99* (40.12- 53.27)	**46.60** ± *3.05* (40.31-53.86)	**44.55** ± *2.94* (38.90-51.05)	**46.41** ± *2.81* (41.07-52.60)	0.04*
	L	**45.73** ± *3.17* (40.70- 53.12)	**47.28** ± *3.04* (40.65-53.72)	**45.24** ± *2.88* (39.20-50.51)	**47.01** ± *2.46* (42.99-51.55)	
IOF-MF	R	**63.53** ± *5.26* (54.71- 77.52)	**66.17** ± *6.20* (51.09-83.37)	**59.86** ± *3.46* (50.24-65.64)	**65.47** ± *4 .83* (56.07-75.37)	0.66
	L	**63.44** ± *4.86* (55.65- 76.06)	**66.02** ± *5.75* (53.14- 83.92)	**59.61** ± *3.57* (51.12-66.90)	**64.91** ± *4.88* (55.97-75.30)	

Statistically significant values were indicated as follows: p<0.01** & p < 0.05*

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Table III. Variation in the position of the prominent facial foramina between sexes within populations and between populations within sexes.

Measurement	Side	Sexual dimorphism within populations		Population variation within sex groups	
		Black South Africans n=73	White South Africans n=86	SA females n=75	SA males n=84
SOF-na	R	0.68	0.03*	0.01**	0.00**
	L	0.94	0.00**	0.00**	0.03*
SOF-sk	R	0.85	0.00**	0.94	0.00**
	L	0.96	0.00**	0.57	0.00**
IOF-or	R	0.80	0.03*	0.37	0.99
	L	0.99	0.00**	0.33	0.14
IOF-ANS	R	0.01**	0.00**	0.01**	0.05*
	L	0.00**	0.00**	0.02*	0.02*
MF-gn	R	0.71	0.05*	0.69	0.99
	L	0.02*	0.10	0.94	0.50
MF-IMM	R	0.97	0.00**	0.23	0.00**
	L	0.99	0.00**	0.06	0.01**
SOF-IOF	R	0.04*	0.02*	0.99	0.99
	L	0.24	0.01**	0.89	0.97
IOF-MF	R	0.12	0.00**	0.01**	0.91
	L	0.11	0.00**	0.00**	0.72

Statistically significant values were indicated as follow: $p \leq 0.01$** & $p \leq 0.05$*

with the results published by Webster and colleagues (1986) [22] based on 108 dry Indian skulls. The SOF/N was located more laterally to the nasion in the black South African sample compared to the white South African sample, regardless of sex. This was expected, as it had been noted that black South Africans have wider facial breadths, especially the upper facial width, compared to white South Africans.[23] The effect of sex on the position of the facial foramina was more profound in white South Africans. The SOF/N were often located more laterally in males compared to their female counterparts, which is in line with the results by Chrcanovic et al. (2011)[10] where the mean distances from the SOF/N to the midline of the female crania were smaller relative to the male crania. This could be due to the prominent brow ridges noted in males, which are more pronounced in white males compared to black males.[24] These findings support the recommendation that sex and population affinity should be considered when locating the supraorbital foramen.

The infraorbital foramen (IOF) was bilaterally present in all South African specimens examined. Consistent with previous research,[9,25] the IOF was predominantly oval-shaped rather than circular. In South African males, the IOF was significantly further from the anterior nasal spine compared to their female counterparts, as reported by Chrcanovic et al. (2011)[10] on Brazilian skulls. This variation likely correlates with the greater facial width typically seen in males, resulting in a more laterally situated IOF.[26-27] White South Africans displayed notable sexual dimorphism, where all assessed IOF-related linear distances were consistently greater in males than in females. This can be attributed to the wider orbits, bizygomatic breadths, and mandibles observed in white males compared to white females.[27-28] The IOF was also located further from the ANS on the right side of the cranium than on the left side and was statistically significant in black and white South Africans. These findings agree with those reported in a previous study by Agthong and co-workers (2005).[2] However, contrary to these findings, Nanayakkara and colleagues (2016)[12] reported symmetry in the distance from the IOF to the ANS in a Thai sample.

In various population groups, the position of the infraorbital foramen (IOF) relative to the inferior orbital margin (IOM) has been reported to range between 6 and 10 mm.[12] In this South African sample, the IOF was situated slightly further from the IOM compared to findings by Chung et al. (1995)[9] and Cutright et al. (2003).[29] Notably, sexual dimorphism in IOF positioning relative to the orbitale was evident only in the white South African sample. This disparity may be attributed to historical differences in access to nutrition and healthcare, which likely contributed to more pronounced physical development and, consequently, greater visibility of sexual dimorphism.[30]

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The mental foramen was present in the entire South African sample, and as Berge and Bergman (2001)[31] reported, the mental foramen was mostly oval-shaped. The mental foramen was located significantly further from the inferior mandibular margin in white males when compared to white females and black males respectively. This indicates that the mandibular height of white males is greater, which also appears longer in proportion to its width due to a narrower jaw and less robust mandibular features.[23] No variation was noted between black males and females, nor between black females and white females.

Sexual dimorphism in the location of the MF in relation to the IOF and inferior mandibular margin was significant in the white South African sample only and greater in males. The etiology of such variation may likely be attributed to differential growth trajectories and functional adaptations [(32)]. For example, white populations often exhibit more vertical maxillary and mandibular growth, leading to an elongated lower face. Black populations typically show more forward prognathic growth, contributing to shorter but wider facial proportions.[28]

Population affinity influenced the position of the mental foramen (MF) in relation to the inferior mandibular margin, with this effect being statistically significant only in males. White South African males exhibited greater values compared to their black South African counterparts. However, the overall distance to the inferior rim of the mandible was consistent with findings from other studies, ranging approximately between 11 and 15 mm.[33] Notably, all scans in the present study were from dentate individuals, leaving open the question of whether edentulous would affect the distance between the MF and the inferior mandibular margin. Additionally, the average distance between the MF and gnathion (gn) was greater in this sample compared to findings reported for Korean[9] and white American populations[29] due to South Africans having a higher ramus height and a broader mandibular corpus, resulting in the appearance of more prominent jawlines compared to Koreans and White Americans.[34]

The Limitation of this study include an unequal sample size despite incorporating private facility scans. A larger and more representative cohort could yield more informative results, in particular using the same modality and comparing with studies in other African countries, such as Angola, Kenya, Nigeria, and Tunisia, would be beneficial. Future research should also assess the facial width and breadth to express the facial foramen location as a ratio for greater utility.

Conclusion

The study revealed that a supraorbital notch (SON) was observed more frequently than a supraorbital foramen (SOF), while the infraorbital foramen (IOF) and mental foramen (MF) were predominantly oval. Notably, the facial foramina in black South Africans were generally located farther from selected bony landmarks compared to white South Africans. Additionally, pronounced sexual dimorphism was observed in the white South African sample, with males exhibiting larger dimensions than their female counterparts. However, no asymmetry was detected in the positions of the three prominent facial foramina across any sex or population groups.

These findings contribute to the growing body of knowledge on the morphometrics of the SOF/N, IOF and MF, particularly within South African populations. The ability to accurately identify the locations of these foramina is critical for minimising the risk of injury to neurovascular structures during surgical procedures. The observed differences related to sex and population emphasise the importance of tailored approaches when performing surgical interventions or administering regional nerve blocks in the maxillofacial region, to mitigate potential complications.

Take home message: The anatomical locations of the supraorbital foramen/notch (SOF/N), infraorbital foramen (IOF), and mental foramen (MF) show significant variation among sexes and populations, emphasising the need for tailored approaches in aesthetic surgical procedures. In black South Africans, the foramina are generally positioned further from midline landmarks due to broader facial dimensions, with black males exhibiting more lateral placement of the SOF and IOF relative to the nasion and anterior nasal spine (ANS). In contrast, white South Africans presented with more pronounced sexual dimorphism, as the facial foramina were located significantly further from the midline in males compared to females. The MF was located higher relative to the inferior mandibular margin (IMM) compared to females. These variations necessitate targeting the SOF, IOF, and MF more laterally in males, particularly black males, and higher for mental nerve blocks in white males. The accurate localisation of these foramina is critical to improving nerve block efficacy and reducing complications in maxillofacial procedures.

REFERENCES

1. Hester KM, Rahimi OB, Fry CL, Nation HL. The relative locations of the supraorbital, infraorbital, and mental foramina: A cadaveric study. Journal of Anatomy. 2021 Oct;239(4):782-7.
2. Agthong S, Huanmanop T, Chentanez V. Anatomical variations of the supraorbital, infraorbital, and mental foramina related to gender and side. Journal of oral and maxillofacial surgery. 2005 Jun 1;63(6):800-4.
3. Rd M. Miller's anaesthesia. Philadelphia: Elsevier Churchill Livingstone. 2005:1763-98.
4. Wandee Apinhasmit DD, Supin Chompoopong MS, Methathrathip D, Sansuk R, Phetphunphiphat W. Supraorbital notch/foramen, infraorbital foramen and mental foramen in Thais: anthropometric measurements and surgical relevance. J Med Assoc Thai. 2006;89(5):675-82.
5. Gupta T. Localization of important facial foramina encountered in maxillo-facial surgery. Clinical anatomy. 2008 Oct;21(7):633-40.
6. Zhang KR, Blandford AD, Hwang CJ, Perry JD. Anatomic variations of the infraorbital foramen in Caucasian versus African American skulls. Ophthalmic Plastic & Reconstructive Surgery. 2019 Jan 1;35(1):25-8.
7. Moodley S, Ishwarkumar S, Pillay P. Localisation of the supraorbital, infraorbital and mental foramina: a review. Translational research in anatomy. 2023 Sep 1; 32:100257.
8. Aziz SR, Marchena JM, Puran A. Anatomic characteristics of the infraorbital foramen: a cadaver study. Journal of oral and maxillofacial surgery. 2000 Sep 1;58(9):992-6.
9. Chung MS, Kim HJ, Kang HS, Chung IH. Locational relationship of the supraorbital notch or foramen and infraorbital and mental foramina in Koreans. Cells Tissues Organs. 1995 Jul 17;154(2):162-6.
10. Chrcanovic BR, Abreu MH, Custódio AL. A morphometric analysis of supraorbital and infraorbital foramina relative to surgical landmarks. Surgical and radiologic anatomy. 2011 May;33: 329-35.
11. Moore KL, Dalley AF. Clinically oriented anatomy. Wolters kluwer india Pvt Ltd; 2018 Jul 12.
12. Nanayakkara D, Peiris R, Mannapperuma N, Vadysinghe A. Morphometric analysis of the infraorbital foramen: the clinical relevance. Anatomy research international. 2016;2016(1):7917343.
13. Lim JS, Min KH, Lee JH, Lee HK, Hong SH. Anthropometric analysis of facial foramina in Korean population: a three-dimensional computed tomographic study. Archives of craniofacial surgery. 2016 Mar 21;17(1):9.
14. Ongeti K, Hassanali J, Ogeng'o J, Saidi H. Biometric features of facial foramina in adult Kenyan skulls. Eur J Anat. 2008 Sep 1;12(1):89-95.
15. Spoor CF, Zonneveld FW, Macho GA. Linear measurements of cortical bone and dental enamel by computed tomography: applications and problems. American journal of physical anthropology. 1993 Aug;91(4):469-84.
16. Van der Walt S, Oettlé AC. Dimensions and position of the eye for facial approximations in a South African cone beam computed tomography sample. Journal of Forensic Sciences. 2025 Mar 1:70(2):446-59.
17. Hammer Ø, Harper DA. Past: paleontological statistics software package for educaton and data anlysis. Palaeontologia electronica. 2001;4(1):1.
18. Copenhaver MD, Holland B. Computation of the distribution of the maximum studentized range statistic with application to multiple significance testing of simple effects. Journal of Statistical Computation and Simulation. 1988 Aug 1;30(1):1-5.
19. Benjamini Y, Braun H. John W. Tukey's contributions to multiple comparisons. Annals of Statistics. 2002 Dec 1:1576-94.
20. Abdi H. Holm's sequential Bonferroni procedure. Encyclopedia of research design. 2010;1(8):1-8.
21. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. Journal of chiropractic medicine. 2016 Jun 1;15(2):155-63.

www.sada.co.za / SADJ Vol. 80 No.8
https://doi.org/10.17159/sadj.v80i07.22127

22. Webster RC, Gaunt JM, Hamdan US, Fuleihan NS, Giandello PR, Smith RC. Supraorbital and supratrochlear notches and foramina: anatomical variations and surgical relevance. The Laryngoscope. 1986 Mar;96(3):311-5.
23. L'Abbé EN, Kenyhercz M, Stull KE, Keough N, Nawrocki S. Application of Fordisc 3.0 to explore differences among crania of North American and South African blacks and whites. Journal of forensic sciences. 2013 Nov;58(6):1579-83.
24. Rosas A, Bastir M. Thin-plate spline analysis of allometry and sexual dimorphism in the human craniofacial complex. American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists. 2002 Mar;117(3):236-45.
25. Gour KK, Nair S, Trivedi GN, Gupta SD. Anthropometric measurements of infraorbital foramen in dried human skulls. Int J Biol Med Res. 2012;3(3):2003-6.
26. Albert AM, Ricanek Jr K, Patterson E. A review of the literature on the aging adult skull and face: Implications for forensic science research and applications. Forensic science international. 2007 Oct 2;172(1):1-9.
27. van der Walt S. Creating guidelines for the approximation of the eye and periorbital regions of South Africans using cone beam computed tomography scans (Doctoral dissertation, University of Pretoria).
28. Mendelson B, Wong CH. Changes in the facial skeleton with aging: implications and clinical applications in facial rejuvenation. Aesthetic plastic surgery. 2012 Aug; 36:753-60.
29. Cutright B, Quillopa N, Schubert W. An anthropometric analysis of the key foramina for maxillofacial surgery. Journal of oral and maxillofacial surgery. 2003 Mar 1;61(3):354-7.
30. Krüger GC, L'Abbé EN, Stull KE, Kenyhercz MW. Sexual dimorphism in cranial morphology among modern South Africans. International journal of legal medicine. 2015 Jul;129: 869-75.
31. Berge JK, Bergman RA. Variations in size and in symmetry of foramina of the human skull. Clinical Anatomy: The Official Journal of the American Association of Clinical Anatomists and the British Association of Clinical Anatomists. 2001 Nov;14(6):406-13.
32. Franklin ME, Flessner CA, Woods DW, Keuthen NJ, Piacentini JC, Moore P, Stein DJ, Cohen SB, Wilson MA, Board TL. The child and adolescent trichotillomania impact project: descriptive psychopathology, comorbidity, functional impairment, and treatment utilization. Journal of Developmental & Behavioral Pediatrics. 2008 Dec 1;29(6):493-500.
33. Alrahabi M, Zafar M. Anatomical Variations of Mental Foramen: A Retrospective Cross-Sectional Study. International Journal of Morphology. 2018 Sep 1;36(3).
34. Iscan MY, Steyn M. Craniometric determination of population affinity in South Africans. International Journal of legal medicine. 1999 Jan;112: 91-7.

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Oral Health-Related Quality of Life (OHRQoL) of Oral Squamous Cell Carcinoma (OSCC) patients

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ABSTRACT

Introduction

Oral squamous cell carcinoma (OSCC) is a prevalent form of oral cancer, associated with high morbidity and mortality rates. Treatment often involves surgery, chemotherapy and radiotherapy, which can impact patients' quality of life (QoL) and oral health-related quality of life (OHRQoL).

Aim and Objectives

This study aimed to evaluate the OHRQoL of OSCC post-treatment, to inform comprehensive treatment plans that prioritize patients care and QoL improvement.

Study Design

A cross-sectional study was conducted in a tertiary hospital in Cape Town, South Africa.

Methods

50 OSCC patients attending follow-up visits at least three months post-treatment were included. Data collection involved extracting oral cancer history and treatment data from hospital records, collecting demographic information, and administering the Oral Health Impact Profile (OHIP-14) questionnaire.

Results

The mean age of participants was 58.56 years, with a majority being male. The most common primary site of OSCC was the tongue, and the predominant cancer stage was IV. Most participants received a combination of radiation and surgery. The physical pain dimension was the primary contributor to deterioration of OHRQoL.

Conclusions

The study highlights the need for improved strategies in diagnosis and management of OSCC patients, emphasizing early detection and treatment plan. The findings showcase the importance of addressing physical and functional aspects of treatment and rehabilitation to enhance the overall well-being of OSCC patients.

Key words

Oral Cancer, Oral Squamous Cell Carcinoma (OSCC), Oral Malignancy, Head and Neck Cancer, Quality of Life (QoL), Oral Health-Related Quality of Life (OHRQoL).

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1. INTRODUCTION

Oral health extends beyond the mere absence of disease or impaired function, given that it includes a complex, multifaceted concept that involves various aetiological factors and dimensions.[1] It hugely affects one's daily life and has a significant impact on well-being. It is influenced by several factors. These include, daily activities such as diet, personal habits as well as tooth brushing.[1]

Among oral diseases, Oral cancer is most important in terms of high mortality and sever morbidity. It's ranked the 6th most prevalent cancer with Oral Squamous Cell Carcinoma (OSCC) being among the 10 most prevalent human malignancies.[2] Oral cancer is recognised as one of the most prevalent cancers in the region of the head and neck with a projected incidence of 263,000 new case each year.[3] The five-year prevalence rate of oral cancer stands 5.15 per 100,00 over 5 year period in South Africa,[4] as it accounts for 5% and 0.6% of all cancers in males and females respectively.[5] The global 5-years survival rate is 50%.[6] The highest reported frequency of oral cancer is often observed in the lower lip, mouth floor, and lastly the lateral borders of the tongue.[7]

Oral cancer is regarded as disease that is age-related with individuals who are 40-years and older contributing to 98% of all patients diagnosed,[5] most of them are men in the majority of countries. Until the present day the aetiology of oral cancer is unknown, but its risk factors are well recognized, including; smoking, alcohol, areca nut, infections (e.g., HPV and candida), mucosal disease (e.g., lichen planus), genetics and exposure to direct sunlight. The most prevalent form of oral cancer is OSCC, and in South Africa it is regarded as the fifth most prevalent cancer among men and tenth most common among women.[5]

Early diagnosis is a crucial step in the treatment of cancer, depending on factors such as the site, stage, grade and metastasis, in addition to the patient's general health.[3] Cancer care is a multidisciplinary process, and its treatment modalities may include surgery, chemotherapy, radiotherapy, or a combination of these approaches.[8]

Treatment of oral cancer is associated with physical and psychological challenges leading to a poor quality of life (QoL) and subsequently also a lower oral health-related quality of life (OHRQoL) of patients.[3,6,8,9] The World Health Organization (WHO) define health as the following: "the complete state of physical, mental and social well-being and not just the absence of disease".[10] QoL is further described as "individual's perceptions of their position in life in the context of culture and value systems in which they live, and in relation to their goals, expectations, standards and concern".[11] Given the broad nature of the QoL concept, researchers have introduced specific terms

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such as health-related quality of life (HRQoL) and OHRQoL.[3] OHRQoL is defined by the United States Surgeon General as "a tridimensional construct that reflects (among other things) people's comfort when eating, sleeping and engaging in social interaction, their self-esteem, and their satisfaction concerning their oral health".[12] In 2003 the WHO reported OHRQoL upon the list of priorities of global oral health programmes.[13]

Studies had found that oral cancer prevalence remains increasing on yearly,[14] primarily attributed to advancements in its treatment,[15] resulting in extended patients lifespans. Despite it being a positive outcome, it means that individuals will have to contend with adverse effects of the disease and its treatment, potentially impacting their QoL. The oral cavity pays a significant role in verbal and non-verbal communication, personal appearance and intake of nutrition.[16] Any deformity affecting these functions directly contributes to the status of QoL and OHRQoL; two measures that have become important tools in measuring treatment outcomes and receiving more attention in the medical field for evaluation of oral health programs[17] the influence on the quality of life of affected patients is still unclear. Objective: To evaluate the impact of OM on the oral-health-related quality of life (OHRQoL. OHRQoL is a specific measure that has been constructed specifically for the oral cavity.18 Various research studies have been done to compare OHRQoL of cancer patients to the general population, but the majority of the results were inconclusive.[18]

Some of the issues of oral cancer that affect patients' QoL is pain, a dry mouth (xerostomia), altered taste, eating challenges and mucositis.[6] The latter are more common during acute period of radiotherapy and chemotherapy.[6] Another issue that was frequently reported was dysphagia for patients undergoing radiotherapy with swallowing ranked 6 out of 45 concerns that patients wished to discuss further with their physicians, in addition to loss of functional, which both affect the eating process and subsequently their nutrition leading to poor QoL.[6]

Psychological impact of oral cancer and OSCC can be described as the traumatic experience that patients go through during diagnosis that leads to a tremendous amount of anxiety,[19] and depression that patients feel during or post treatment as it being the most mentioned mental health disorder among OSCC patients.[6] It was reported by one study that patients experienced more pain and suffering at the follow-up visits than at diagnosis time.[6] It was further reported that patients wished to consult a psychologist prior to their treatment also reported better QoL scores.[6] One important factor that affects patients' treatment is the negative effect of mental illness of patients that lead them to lose interest in continuing the prescribed treatment plan leading to longer hospital stays and less self-care, which in turn influence morbidity and mortality. A study done by Hassel *et al*., found that OHRQoL predicted psychological illness including anxiety and depression on OSCC patients.[2] Another important factor that affects patients' self-esteem and mental health is surgical procedures on the face to excise cancerous tissues. Fortunately the impact of such an issue could be minimize by reconstructive surgeries and facial prosthesis.

The measurement of OHRQoL serves as a valuable tool in treatment planning allowing for the establishment of appropriate goals as well as clinical outcomes related to the patient's individual condition. This approach aims to describe the negative impact that cancer treatment can have on the QoL of affected individuals.[20] From a public health standpoint, OHRQoL holds implications for addressing oral health disparities and access to care.[20] Therefore, it is a very good instrument in delivering optimum communication to decision makers and policy-makers through assisting in negotiations regarding healthcare access.[21] Bennadi and Reddy emphasized its utility in planning welfare policies by identifying population needs and priorities.[12]

Sischo and Broder highlighted that assessing OHRQoL can help identify a patient's strengths and weaknesses, informing the development of service programs. This information is particularly useful for planning and testing service programs, such as including psychological adjunct services in community-based projects if psychological deficits are identified in elderly patients.[20] Beyond these applications, OHRQoL plays a crucial role in screening for suspicious health challenges associated OSCC. By prioritizing and addressing these may enhances clinical decision-making between physicians and patients. Subsequently it will improve monitoring of patient responses to cancer treatment.[12]

Multi-item questionnaires are the most appropriate and accurate measuring method of OHRQoL[12] given that they can be generic or specific to certain condition or certain population groups (10,22). The specificity of the questionnaire helps to investigate relevant symptoms and in addressing more related issues.[20] Before using a questionnaire; validity, acceptability and reliability should be proven.[12] Most of these questionnaires are reported in the form of scores showing the severity of diseases or outcomes.[12] One of the widely utilized questionnaires for assessing OHRQoL is Oral Health Impact Profile (OHIP). Initially developed in 1994 by Slade and Spenser, the original version comprised 49 questions, while a later condensed version consists of 14 questions. OHIP assesses seven dimensions: physical pain, functional limitation, physical disability, psychological discomfort, psychological disability, social disability and handicap[23] assess the psychometric properties and performance of this new instrument, and then use it to investigate the impacts of selected oral disorders on oral health-related quality of life (OHRQoL. Participants rate the frequency of impact on a 5-point Likert scale, through response options being "never = 0, hardly ever = 1, occasionally = 2, fairly often = 3, and very often = 4". The total score for OHIP-14 can range from 0 to 56, with higher scores suggesting a poorer OHRQoL.[17,24]

In conclusion, OSCC affects various aspects of patients' lives by having a major impact on oral functions such as speech, swallowing and chewing. It also alters patients' appearances in advanced stages and post-surgical treatment, resulting in psychological and social challenges. The aggressive treatment of OSCC, involving radiotherapy, surgical intervention and chemotherapy may lead to severe facial disfigurement, further exacerbating its impact on QoL and OHRQoL.

This study aimed to evaluate the OHRQoL of post-treatment OSCC patients, with the goal of assisting healthcare professionals and managers in developing comprehensive treatment plans that equally prioritize patient care and post-treatment QoL improvement.

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2. METHODS

A cross-sectional study was done at a tertiary hospital in Cape Town, South Africa. The study population consisted of patients diagnosed with OSCC attending follow-up visits from April 28, 2021, to June 30, 2021 at a Radiation Oncology unit. Convenience sampling was employed, and the first 50 patients meeting the inclusion criteria and providing consent were included in the study.

Inclusion criteria included patients aged 18 years and above diagnosed with OSCC, attending follow-up visits scheduled at least three months after treatment. Patients diagnosed with oral pharyngeal carcinoma were excluded from the study.

Data collection involved the use of three parts delivered through one instrument. Firstly, a researcher-administered data collection sheet was utilized to extract oral cancer history and treatment data from patients' hospital records. The second part was a researcher-administered questionnaire designed to collect demographic information from participants. The third part involved completing the OHIP-14 form, a validated instrument for determining OHRQoL. While the English version was primarily used, translated versions in Afrikaans and IsiXhosa were utilized as needed.

Data captured from completed questionnaires were categorized and then transferred to an Excel 2010 spreadsheet for basic descriptive analysis. The database was then imported to STATA/IC 16 for more advanced statistical analyses. Correlations were determined by the independent t-test between two categorical variables, while the One-way ANOVA assessed correlations among more than two categorical variables, the Bonferroni correction served as a post hoc test. The Chi-square test examined associations with a significance level set at 0.05. Linear regression was applied to ascertain relationships between variables, with a significance cutoff at 0.01.

Ethical approval for the research study was obtained from the Biomedical Research Ethics Committee of the UWC (BM19/9/17). Participation was voluntary and anonymous and signed informed consent was obtained from each patient. Anonymity was secured by not using the participants' names on the questionnaires and were recorded with reference codes. The questionnaire completion process took place in a private room at the Department of Radiation Oncology. Permission was also obtained from the Head of Department. Signed informed consent had been obtained from all participants after they were fully informed of the aim, objectives and methodology of the study. Participants were able to ask questions and were informed that they could withdraw from the study at any stage.

3. RESULTS

The study comprised a predominantly male participant group (60%), with a mean age for the overall sample at 58.56 years (SD = 10.55) (Table I). The mean age among men and women were 57.7 and 59.8 years, respectively. The majority of participants identified as pensioners (46%), and 60% had completed high school or attained higher education levels. Regarding marital status, 48% of the sample was married, 26% were single or divorced, or widowed, and the remaining participants chose not to disclose this information.

Table I: Demographic Profile and OHIP_14 Score

Variables	Categories	n (%)	Mean OHIP-14 score (SD) per category	*p*-value
Age	< 55	16 (32)	25.06 (17.38)	0.34
	55-64	18 (36)	18.06 (16.20)	
	>= 65	16 (32)	26.25 (19.22)	
Sex	Female	20 (40)	19.65 (16.72)	0.29
	Male	30 (60)	25.1 (18.33)	
Marital Status	Single, divorced or widowed	13 (26)	17.54 (19.50)	0.45
	Married	24 (48)	25.04 (17.01)	
	Non disclosed	13 (26)	24.38 (17.04)	
Education	High School or Higher	30 (60)	21.77 (17.42)	0.58
	Primary School or Less	20 (60)	24.65 (18.22)	
Employment Status	Full-time	3 (6)	28.67 (12.06)	0.77
	Retired	23 (46)	24.96 (18.36)	
	Student	2 (4)	21.00 (0)	
	Unemployed	23 (46)	20.28 (18.02)	
Income	< R2500	30 (60)	22.63 (17.16)	0.89
	>= R2500	20 (40)	23.35 (18.73)	
Total OHIP Mean (SD)			22.92 (17.62)	

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Variables	Categories	n (%)	Mean OHIP score (SD) per category	*p*-value
Main Complain	Loose teeth and pain	1 (2)	41.00 (0)	0.17
	Mass or Swelling	7 (14)	19.00 (14.74)	
	Painful Lesion	11 (22)	14.27 (11.46)	
	Painless Lesion	28 (56)	28.4 (17.58)	
	Sore Throat	1 (2)	4.00 (0)	
	Ulcer	5 (10)	20.20 (26.33)	
Location	Buccal mucosa	5 (10)	16.2 (15.82)	0.64
	Buccal mucosa and Lower jaw	1 (2)	21.00 (0)	
	FOM	14 (28)	26.79 (16.56)	
	Lip	5 (10)	30.2 (16.56)	
	Lower jaw	3 (6)	25.67 (20.03)	
	Soft palate	6 (12)	12.33 (19.65)	
	Tongue	15 (30)	21.87 (14.61)	
	Tongue and FOM	1 (2)	39.00 (0)	
Tumour Grade	Well-Differentiated	39 (78)	23.54 (17.53)	0.65
	Moderate-Differentiated	11 (22)	20.72 (18.62)	
Cancer Staging	I	9 (18)	9.78 (11.50)	0.02*
	II	5 (10)	12.4 (13.96)	
	III	16 (32)	23.69 (16.21)	
	IV (A)	15 (30)	33.27 (17.12)	
	IV (B)	4 (8)	19.25 (20.19)	
	IV (C)	1 (2)	41.00 (0)	
Treatment	Radiation alone	3 (6)	27.00 (23.39)	0.09
	Surgery alone	6 (12)	15.17 (21.76)	
	Radiation + Surgery	28 (56)	19.07 (14.70)	
	Radiation + Chemotherapy	1 (2)	25.00 (0)	
	Radiation + Surgery + Chemotherapy	12 (24)	34.58 (17.71)	
Follow-up Visit	3 Months	10 (20)	27 (19.97)	0.27
	6 Months	8 (16)	21 (17.54)	
	9 Months	10 (20)	20.6 (13.19)	
	12 Months	4 (8)	26.75 (17.91)	
	18 Months	3 (6)	43.33 (13.01)	
	24 Months	6 (12)	11.33 (14.67)	
	>24 Months	9 (18)	21.89 (19.85)	
Total OHIP Mean (SD)			22.92 (17.62)	

Table II: Oral Cancer History and OHIP-14 Score.

The reported primary site of OSCC was most frequently the tongue (30%), followed by the floor of the mouth (28%) (Table II). Other sites, including buccal mucosa, soft palate, mandible, lips, or combinations, were reported to a lesser extent. In terms of tumor grade, 78% had a well-differentiated grade, while the remainder had a moderate-differentiated grade. The predominant cancer stage was stage IV (40%), followed by stage III (32%), stage I (18%), and stage II (10%) (Table II). The majority of participants received a combination of radiation and surgical (56%) intervention, with other combinations involving radiation and chemotherapy, and radiation, surgery, and chemotherapy. Just less than half (40%) of participants attended their 3rd and 9th month follow-up visits (Table II).

The One-way ANOVA test was utilized to assess whether the OHIP-14 score differed across different categories for each variable. Post hoc tests using the Bonferroni correction were also conducted. The mean OHIP-14 score for participants was 22.9 (SD = 17.62). Descriptive statistics, including mean and standard deviation, for OHIP-14 scores in relation to demographic and oral cancer variables, are presented in Tables I and II. The level of statistical significance was established at $p < 0.05$.

The OHIP-14 questionnaire comprises seven dimensions, with each two questions in order corresponding to one dimension. Each dimension score was added together for two questions forming it. Provided that the study sample size was 50, each

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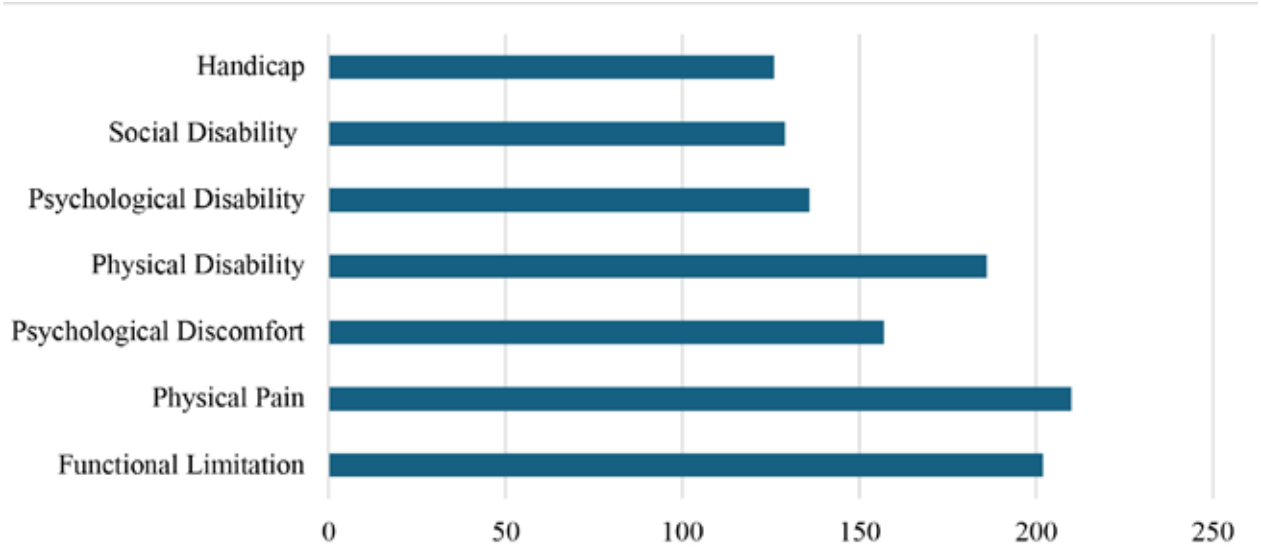

Figure 1: Distribution of Dimension Scores Achieved by Size.

one of the seven dimensions, could attain a possible value of 400 points for the entire sample. The physical pain dimension emerged as the primary contributor to the deterioration of OHRQoL in the study population, obtaining the highest score (210/400), followed by the physical disability (186/400), psychological discomfort (157/400) psychological disability (136/400), functional limitation dimension (202/400), and social disability (129/400). The lowest score was attained in the handicap dimension (126/400) (Figure 1).

4. DISCUSSION

The global concept of QoL involves various overlapping domains and has primarily been developed in medical research to gauge individuals' perceptions of overall well-being. There is a limited number of studies in the literature that specifically assess both QoL and OHRQoL for post-treatment oral cancer patients. This research gap underscores the need for more comprehensive investigations into the overall impact of oral cancer on patients' lives beyond clinical outcomes, emphasizing the importance of addressing patients' well-being as well as oral health-related quality of life.

The treatment of oral cancer is a challenging process that introduces various obstacles, ultimately deteriorating patients' overall QoL. Reflecting on these challenges enables physicians to better understand patients' perceptions and priorities, facilitating improved clinical judgment and treatment selection. To capture the intricacies of the oral cavity's impact, the construct of OHRQoL was specifically designed. Various tools measure OHRQoL, such as the University of Washington QoL scale, the European Organization for Research and Treatment of Cancer QoL Core Questionnaire 30 and the Oral Impact of Daily Performances, and OHIP (Oral Health Impact Profile). OHIP, which is most frequently used in oral cancer patients, provides a superior demonstration of changes in their QoL. Originally comprising 49 questions, however a more practical 14-question version was developed, proven to be valid, reliable, and sensitive to variations with consistent cross-cultural applicability.[3]

While some studies indicate a moderate impact of oral cancer on OHRQoL, this remains an area of research deserving more attention, particularly considering the vulnerability of individuals facing oral cancer. A study in the USA confirmed this matter as they reported that among Head and Neck cancer (HNC) patients including oral cancer, suicide incident is more than three times higher than in general population.[25]

Although many studies indicate that the QoL tends to return to its initial state following HNC treatment, so *et al.* propose that specific dimensions of treatment-related morbidity may persist up to 12 months post-treatment. This suggests the importance of preparing patients for the potential continuation of adverse symptoms and treatment side effects beyond the immediate post-treatment period.

In this research study we investigated OHRQoL of OSCC patients after they received various treatment modalities during separate follow-up visits The average age of our study cohort was 58.56, consistent with the prevalent occurrence of cancer in the geriatric demographic,[5] particularly in the 6th decade.[1] Most participants were male, with a male-to-female ratio of 1.5:1, mirroring the global distribution (1,5). It's noteworthy that Karbach *et al*. found no association between age and sex in OSCC cases ($p > 0.05$).[27]

Prior studies have highlighted the significance of socioeconomic status (SES) as a risk factor for oral cancer (1), emphasizing its role in predicting disease mortality and morbidity within this patient cohort. Consequently, SES is recognized as a crucial determinant influencing OHRQoL. In our investigation, 46% of the study participants were unemployed, and 60% reported a monthly household income below 2500 ZAR, collectively indicating a lower socioeconomic status among the majority. This aligns with the findings of Indrapriyadhrashini *et al.* and Khandekar *et al.*, who observed that low SES may serve as a risk factor for suboptimal oral hygiene, thereby increasing the susceptibility to oral cancer (3,28). Moreover, individuals with lower education and income levels are more prone to engaging in behaviours such as alcohol consumption, smoking, and tobacco chewing, all recognized risk factors for oral cancer. In developing countries, low SES and income are associated with challenges in accessing healthcare facilities, contributing

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to delayed diagnosis of oral cancer and necessitating more aggressive treatments with poorer prognoses. Although the inverse relationship between education level and oral cancer is reported in the literature,[3] Despite the reported inverse relationship between education level and oral cancer, our study noted that 60% of participants had attended high school or pursued further education, diverging from this expected correlation.

The manifestation of OSCC varies based on factors such as cancer stage, location, and the type of affected tissue within the oral cavity. Articulating these experiences can be challenging for patients, leading to diverse descriptions. In our study, 56% of the participants characterized their OSCC as a painless lesion during the examination, while 22% perceived it as a painful lesion. Interestingly, some individuals could distinctly express their experiences, using terms such as ulcer, mass, or swelling to describe the nature of their condition.

The location of oral cancer appears to be influenced by various factors, including individual oral habits, diet and factors that cause an irritation. Indrapriyadharshini *et al*. conducted a study in India found that the most commonly reported site of OSCC was the buccal mucosa, primarily influenced by the prevalent tobacco-using habit in that region.[3] However, Singhania et al. have established a connection between the location of oral cancer and tobacco consumption, which may explain the variance in our findings. In our study, the most frequently recorded locations were the tongue (30%) and the floor of the mouth (FOM) (28%), contrasting with the reported prevalence in the mentioned Indian study.[29] Our study findings, on the other hand, align with existing literature regarding common oral cancer sites, as supported by the gathering of carcinogens in the FOM area.[8] A study done by Khandelwal *et al*., reported the tongue, retromolar region, and floor of the mouth with the highest probability of sites for oral cancer, reinforcing the consistency of our results with established patterns in the literature[30]

A primary reason for the late-stage diagnosis of oral cancer is the delay in seeking medical attention, as highlighted in previous research.[28] Despite the ease of clinical examination for oral cancer, many patients postpone their visits to healthcare facilities due to a lack of awareness or ignorance[30] Our study findings substantiate this trend, revealing that 40% of the study population were diagnosed at stage IV, and 32% at stage III, both indicative of advanced stages of oral cancer. This parallels the overall pattern seen in developing nations, where 80% of HNC patients, including those with oral cancer, tend to present at advanced stages like III and IV.[30] Indrapriyadharshini *et al.,* reported identical findings corroborating that, late reporting to health facilities is a frequent factor that led to late-stage diagnosis.[3]

In the present study, overall, 56% of patients received surgery and radiation as the primary form of treatment, while 24% received a treatment regimen comprising surgery, radiation, and chemotherapy, creating a total proportion of 80% in the study population. These findings are consistent with those presented by Stuani *et al*., in which 90% of their patients also belonged to these two treatment categories.

It's important to note that our study specifically focused on OSCC patients, whereas Stuani *et al.* included various types of HNC in their study population. The concentration of participants in these two treatment combinations in our study could be attributed to the fact that a significant proportion of our participants were diagnosed at late stages of oral cancer, necessitating aggressive and comprehensive therapeutic interventions.[25]

No demographic profile variable yielded statistically significant results concerning perceived OHRQoL. This outcome can be attributed to the predominant concentration of our study population within the geriatric group. In our study, the highest OHIP-14 scores, indicative of poorer OHRQoL, were observed among patients with OSCC affecting both the tongue and FOM. The serious damage of these anatomical structures significantly impacted speech, eating and function contributing to a diminished OHRQoL. While the literature lacks consensus on whether the location of oral cancer affects QoL.[18] our findings highlight the considerable impact of specific cancer locations on OHRQoL. Participants in late cancer stages, particularly stage IV, reported the worst OHRQoL. This association is linked to the comprehensive treatment provided and the extensive damage caused by the cancer itself. Regarding OHIP-14 scores in relation to the treatment modality received, participants who underwent only surgery exhibited better scores compared to those who received combined treatments. Surgery, causing minimal damage to surrounding oral structures and function, tends to result in fewer complications after treatment,[18] nevertheless participants who underwent all three treatment modalities reported the poorest OHRQoL, emphasizing the compounded side effects and complications associated with each treatment modality.[18] Contrary to the findings of Khandelwal *et al.,* participants in their 18th-month follow-up visit recorded the worst OHRQoL. This contradicts the notion that long-term survivors generally experience good QoL.[30] Despite the lack of statistical significance, functional limitation, physical pain and physical disability dimensions had a negative impact caused by oral cancer, aligning with Barrios et al., this also aligns with what has been reported before among HNC patients. [25]

This study's results should be interpreted considering several limitations. The cross-sectional study design employed precludes the establishment of causal inferences. Additionally, the limited participant selection from a single institution, coupled with the small sample size, introduces potential selection biases. Therefore, it is recommended to conduct studies on a larger scale and in diverse settings to enhance generalizability. Despite these limitations, this study offers valuable baseline health data on the OHRQoL of OSCC patients in a developing country.

Another limitation relates to the use of generic OHRQoL questionnaires. Although useful for comparing findings across different populations, these questionnaires may not entirely account for the impact solely attributed to oral cancer, leaving room for potential influence from other oral conditions. One potential means of overcoming this limitation is by employing oral cancer specific QoL measure.

Another limitation of the current study was the variation in treatment modalities and follow-up durations; the heterogeneity brings in several cause-and-effect relationships for a single outcome. The convenience sampling method employed in this study raised the potential for introducing selection bias, along with translation bias from the translation of questionnaires. To mitigate these biases, future research

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may utilize alternative sampling techniques and use piloted translated questionnaires to increase the validity and reliability of the research outcomes.

5. CONCLUSION

Implications of this research are the need for improved patient management and OSCC diagnosis strategies in Tygerberg Hospital. The late diagnosis recorded signifies a need to boost oral cancer screening programs, interventions to enhance awareness among patients, and improvements to expand access to health facilities. Early detection is crucial in improving patient outcomes as well as addressing the issues of late-stage cancer.

In addition, this study provides an summary of the demographic profile of people diagnosed with OSCC at Tygerberg Hospital, indicating that, the most common and susceptible population is elderly males. These findings can be used for planning more targeted interventions and support services accordingly.

Later stages of OSCC patients had worse OHRQoL compared to early stages, stressing the effects of disease progression on the QoL of patients. Additionally, those who underwent comprehensive treatment intervientions, involving surgery, radio therapy and chemotherapy, exhibited lower OHRQoL compared to those who underwent fewer modalities. This insight into the variations in OHRQoL based on treatment approaches can inform more targeted and patient-centered care strategies.

The study highlights specific dimensions of the OHIP-14 where patients experienced the greatest impact—physical pain, functional limitation, and physical disability. This emphasizes the importance of focusing on the physical- and functional characteristics of treatment options and rehabilitative processes to enhance the overall well-being of OSCC patients.

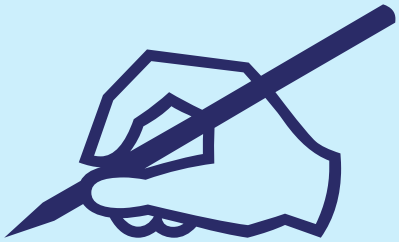
In conclusion, this study not only contributes valuable baseline information on the demographic profile and treatment history of oral cancer among patients at Tygerberg Hospital, but also emphasizes the pressing need for proactive measures in screening, awareness promotion, and healthcare accessibility to address the challenges associated with late-stage diagnoses and enhance patient outcomes.

6. REFERENCES

1. Abram MH. *The Incidence of Oral and Oropharyngeal Cancer in South Africa for the five year period 1997-2001* (Doctoral dissertation, University of Pretoria).
2. Hassel AJ, Danner D, Freier K, Hofele C, Becker-Bikowski K, Engel M. Oral health-related quality of life and depression/anxiety in long-term recurrence-free patients after treatment for advanced oral squamous cell cancer. Journal of Cranio-Maxillofacial Surgery. 2012 Jun 1;40(4):e99-102.
3. Indrapriyadharshini K, Madankumar PD, Karthikeyan GR. Oral health-related quality of life in patients treated for oral malignancy at Kanchipuram district, India: A cross-sectional study. Indian journal of cancer. 2017 Jan 1;54(1):11.4. Hille J, Johnson NW. The burden of oral cancer in sub-Saharan Africa. Transl Res Oral Oncol. 2017;2:2057178X1772109.
5. Botha PJ, Schoonees A, Pontes CC. Mapping oral cancer research in South Africa. South African Dental Journal. 2018 Jul;73(6):384-94.
6. Moore KA, Ford PJ, Farah CS. Support needs and quality of life in oral cancer: a systematic review. International journal of dental hygiene. 2014 Feb;12(1):36-47.
7. Cawson RA, Odell EW, Porter S. Oral pathology and oral medicine. Edinburgh: Churchill Livingstone. 2002:216-7.
8. Scully C. Oral and Maxillofacial Medicine—E-Book: The Basis of Diagnosis and Treatment, ; Churchill Livingstone Elsevier: Edinburgh, UK, 2013.
9. Hassel AJ, Danner D, Freier K, Hofele C, Becker-Bikowski K, Engel M. Oral health-related quality of life and depression/anxiety in long-term recurrence-free patients after treatment for advanced oral squamous cell cancer. Journal of Cranio-Maxillofacial Surgery. 2012 Jun 1;40(4):e99-102.
10. WHO (World Health Organization). Constitution of the World Health Organization. Basic Documents. 45th edition Supplement. 2006.
11. Kuyken W. The World Health Organisation quality of life assessment (WHOQOL): position paper from the World Health Organisation. Soc Sci Med. 1995;41:1409-.
12. Klassen A, Wickert N, Tsangaris E, Klaassen R, Anthony S. Health-related quality of life. InCancer in Adolescents and Young Adults 2017 (pp. 735-747). Springer, Cham.
13. Al Shamrany M. Oral health-related quality of life: a broader perspective. EMHJ-Eastern Mediterranean Health Journal, 12 (6), 894-901, 2006. 2006.
14. Siegel R, Ma J, Zou Z, Jemal A. Cancer statistics, 2014. CA: a cancer journal for clinicians. 2014 Jan;64(1):9-29.
15. Jemal A, Bray F, Center MM, Ferlay J, Ward E, Forman D. Global cancer statistics. CA: a cancer journal for clinicians. 2011 Mar;61(2):69-90.
16. Bhalla A, Anup N, Bhalla AP, Singh SB, Gupta P, Bhalla S. Oral health related quality of life (OHRQOL) amongst head and neck cancer patients undergoing chemotherapy and radiotherapy at Sawi Mansingh Hospital Jaipur, India. Scholars Academic Journal of Biosciences. 2015;3(1A):3-12.
17. Barkokebas A, Silva IH, de Andrade SC, Carvalho AA, Gueiros LA, Paiva SM, Leao JC. Impact of oral mucositis on oral-health-related quality of life of patients diagnosed with cancer. Journal of oral pathology & medicine. 2015 Oct;44(9):746-51.
18. Barrios R, Bravo M, Gil-Montoya JA, Martínez-Lara I, García-Medina B, Tsakos G. Oral and general health-related quality of life in patients treated for oral cancer compared to control group. Health and quality of life outcomes. 2015 Dec;13(1):1-8.
19. Valdez JA, Brennan MT. Impact of oral cancer on quality of life. Dental Clinics. 2018 Jan 1;62(1):143-54.
20. Sischo L, Broder H. Oral health-related quality of life: what, why, how, and future implications. Journal of dental research. 2011 Nov;90(11):1264-70.
21. Al Shamrany M. Oral health-related quality of life: a broader perspective. EMHJ-Eastern Mediterranean Health Journal, 12 (6), 894-901, 2006. 2006.
22. Barrios R, Tsakos G, García-Medina B, Martínez-Lara I, Bravo M. Oral health-related quality of life and malnutrition in patients treated for oral cancer. Supportive Care in Cancer. 2014 Nov;22(11):2927-33.
23. Khalifa N, Allen PF, Abu-bakr NH, Abdel-Rahman ME. Psychometric properties and performance of the Oral Health Impact Profile (OHIP-14s-ar) among Sudanese adults. Journal of Oral Science. 2013;55(2):123-32.
24. Agrawal SK, Dahal S, Shrestha A, Bhagat TK. Assessment of oral health impact profile (OHIP– 14) among villagers of Jyamirgadi VDC, Nepal: a cross-sectional study. Eur J Biomed Pharm Sci. 2017;4(8):400-3.
25. Stuani VT, Santos PS, Damante CA, Zangrando MS, Greghi SL, Rezende ML, Sant'Ana AC. Oral health impact profile of head and neck cancer patients after or before oncologic treatment: an observational analytic case-control study. Supportive Care in Cancer. 2018 Jul;26(7):2185-9.
26. So WK, Chan RJ, Chan DN, Hughes BG, Chair SY, Choi KC, Chan CW. Quality-of-life among head and neck cancer survivors at one year after treatment–a systematic review. European journal of cancer. 2012 Oct 1;48(15):2391-408.
27. Karbach J, Al-Nawas B, Moergel M, Daubländer M. Oral health-related quality of life of patients with oral lichen planus, oral leukoplakia, or oral squamous cell carcinoma. Journal of Oral and Maxillofacial Surgery. 2014 Aug 1;72(8):1517-22.
28. Khandekar SP, Bagdey PS, Tiwari RR. Oral cancer and some epidemiological factors: A hospital based study. Indian J Community Med. 2006 Jul 1;31(3):157-9.
29. Singhania V, Jayade BV, Anehosur V, Gopalkrishnan K, Kumar N. Carcinoma of buccal mucosa: A site specific clinical audit. Indian journal of cancer. 2015 Oct 1;52(4):605.
30. Khandelwal A, Neeli A, Gadiyar A, Khandelwal A. Assessment of quality of life of patients 1–5 years after treatment for oral cancer. Indian Journal of Dental Research. 2017 Sep 1;28(5):538.

CPD questionnaire on page 454

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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A Review of Chemical Approaches Inherent to Endodontic Disinfection Protocols: Part 2

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ABSTRACT

Objectives

Part two of this chemical endodontic disinfection protocol review discusses adjunctive practices such as irrigant activation techniques and intracanal medicaments with a look into the future of endodontics.

Materials and methods

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

Results

As discussed in part one of this review, sodium hypochlorite in combination with EDTA is still the gold standard for endodontic irrigation. However, anatomical variations and conventional instrumentation limit the effectiveness of these solutions. To overcome these limitations, activation techniques such as ultrasonic irrigation, photo-activated disinfection, and photon-induced photoacoustic streaming have been used. Intracanal medicaments are used to support endodontic disinfection as temporary dressings between appointments, but their usefulness is controversial.

Conclusions

Irrigant activation has shown the potential to improve disinfection. Intracanal medicaments have been losing favour in recent years, and their benefit should be evaluated in each case. Nanoparticles have been suggested to improve the delivery of irrigant solutions. Nanoparticles are relatively new in endodontics, and further research is needed on their optimisation, limitations, and toxicity.

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INTRODUCTION

Caries is a common disease and, when left untreated, causes pulpal pathologies requiring endodontic treatment. Endodontic treatment is a fairly common and routine dental procedure whereby 10% of all teeth will require such treatment.[1] A review by Tibúrcio-Machado *et al.* found that half the adult population worldwide would have at least one tooth displaying signs and symptoms of disease requiring endodontic treatment.[2] For predictable and successful outcomes, the clinician must comprehensively understand endodontic principles.

The main goal of endodontic treatment is debridement and disinfection of the root canal system. In 1992, Chong and Pitt Ford emphasised the importance of controlled asepsis in infected root canals and the primary role of canal debridement and adequate canal preparation in successful outcomes.[3] Ordinola-Zapata *et al.,* also support this concept that what is removed from the root canal is of greater significance with regard to success than what is used to seal the root canal system.[4] Therefore, it is vital for the clinician to have not only an understanding of tooth morphology and pathosis of pulp infection but also an understanding of the materials and techniques available to debride and disinfect the root canal.

Endodontic treatment is a complex multi-step procedure that aims to disinfect the root canal system to allow for the resolution of inflammation, infection and apical periodontitis. Complete disinfection is achieved with a combination of mechanical debridement, chemical irrigation and application of intracanal medicaments.[5] Mechanical debridement is carried out with manual and motorised filing instruments. This removes infected tissue while opening and shaping the root canals to allow for the delivery of antimicrobial and sealing materials. Studies have shown that mechanical instrumentation alone is insufficient to remove microbes from infected root canals, and while microbial loads decrease during instrumentation, positive cultures are still found afterwards.[6] Combining mechanical instrumentation with chemical irrigation has effectively decreased subsequent microbial loads.[6, 7] This two-part review will focus on chemical disinfection protocols, including irrigation solutions, activation methods, and intracanal medicaments. Part one discussed the different irrigant solutions while part two will discuss irrigant activation techniques and intracanal medicaments.

Microorganisms and their endotoxins are responsible for the initiation of root canal infections and persistent endodontic-induced apical periodontitis.[8, 9] A core microbiome of just twenty to thirty species of microorganisms is responsible

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for root canal infections.[10] The root canal system is a closed system limiting bacterial interactions, nutrient availability and produces low oxygen potentials restricting the number of bacterial species in endodontic infections. These conditions allow for mostly facultative and anaerobic microorganisms to dominate the microflora in infected root canals.[11] To further complicate disinfection, the variegated anatomy of the root canal system adds further complexity to endodontic treatment. Complex and intricate anatomical variations such as isthmuses and ramifications often make mechanical irrigation impossible in these spaces. Chemical irrigating solutions are able to flow into these spaces, augmenting mechanical debridement for more thorough disinfection.[7]

However, an irrigant is only beneficial when it comes into direct contact with all parts of the root canal, particularly the most apical parts.[12] Variations in root canal anatomy, such as isthmuses, ramifications, accessory canals and wide oval canals, can hinder fluid flow dynamics into the apical part of the canal, decreasing irrigant efficacy. Straight-forward delivery systems may not be effective enough, so to improve the effectiveness of irrigants, enhancements are made to their delivery and activation protocols. These enhancements include negative apical pressure irrigation, irrigant activation with ultrasonic or sonic instruments, and laser-assisted irrigant activation.[13]

Positive-pressure irrigation systems

Positive pressure irrigation (Figure 2a and 2c) is the most commonly used irrigation technique.[14] This technique uses a syringe and a narrow-gauge side vented needle where the needle is inserted as far as possible into the root canal system. The irrigant is injected as close as possible to the root apex. The irrigant then flows back up towards the pulp chamber and is evacuated with suction. In 1983, Chow demonstrated that the irrigant solution does not penetrate further than the tip of the needle in a closed canal system.[15] As a result, debris and microbes can be left behind in the apical air pocket beyond the needle tip – the dead zone (Figure 2a). Some believe that this air pocket can be popped with an endodontic instrument. This theory is controversial as it defies the laws of physics and mechanical files will only pass through the air pocket. An alternative suggestion to overcome this air pocket is to use a gutta percha cone to manually agitate the irrigation solution, forcing the solution closer to the apex safely (Figure 2b)[16]. It can be difficult to control the pressure applied during positive pressure irrigation, and since the root canal system is a closed system, if too much pressure is exerted, there is a risk of accidental extrusion where the irrigant is pushed under pressure into the periapical tissues and can cause adverse effects such as inflammation, swelling, intense pain and at worse tissue necrosis.[17]

Negative-pressure irrigation systems

Negative pressure irrigation systems (Figure 2d) minimise the risk of accidental irrigant extrusion.[18, 19] This method uses a needle or master delivery tip (MTD), a macro cannula and a micro cannula. The needle is placed in the pulp chamber to deliver the irrigant, and the macro cannula and micro cannula are placed in the root canal to safely pull the irrigant into the canal, towards the apex and then draw it back up the cannula, preventing any risk of extrusion.[20] An added advantage of negative pressure systems is that it stabilises irrigant flow rate to keep a constant "flow" of irrigant in the canal to flush out debris. Examples of these systems are Endo Vac and RinsEndo. Konstantinidi *et al.* reviewed the effectiveness of negative pressure irrigation against conventional syringe irrigation. The study analysed the following outcomes: antimicrobial effects and removal of pulp tissue remnants, hard tissue debris or both pulp and hard tissue. There was no significant difference between the two methods in disinfecting and debriding the main root canal. Negative pressure irrigation demonstrated an

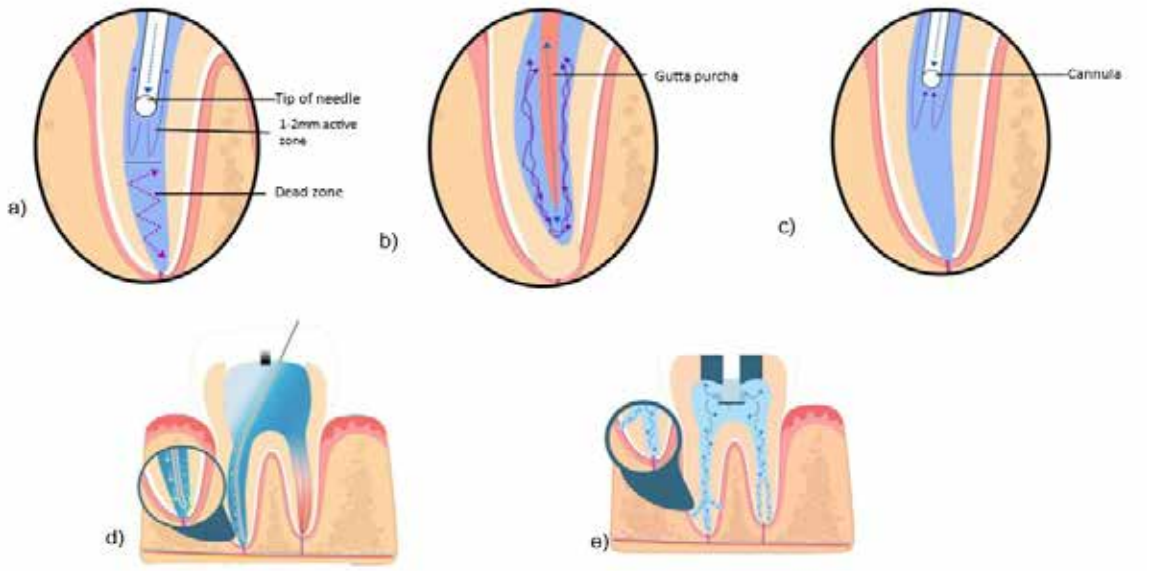

Figure 1: a) Positive pressure irrigation systems. The irrigant does not penetrate further than 1-2mm beyond the tip of the needle (154). **b)** Diagrammatic representation of a gutta percha cone manually pumping the irrigant deeper into the canal (154). **c)** Diagrammatic representation of irrigant beyond the cannula and being "pulled" back up into the cannula to prevent extrusion (154). **d)** Negative pressure system (EndoVAc) with MTD to introduce the irrigant into the root canal and the microcannula demonstrating the "pulling" of the irrigant out of the canal and into the cannula allowing the cannula tip to safely penetrate deeper into the root canal. **e)** The GentleWave system delivering the irrigant in a sealed environment, and activation of the irrigant enhances fluid dynamics.

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advantage when analysing isthmuses and uninstrumented oval extensions. These "unreachable" areas were debrided significantly better with negative pressure irrigation than syringe irrigation.[18]

Ultrasonic and Sonic irrigant activation

Ultrasound is a vibration of the same nature as sound but at a frequency higher than the highest frequency perceptible to the human ear (approximately 20,000 Hz).[12] These vibrations are mechanical energy that produces powerful shearing forces. Ultrasonic and sonic irrigation involves applying this energy to a liquid to generate cavitation and acoustic streaming effects. Bacterial biofilms, common in root canal infections, are more resistant to antimicrobial chemicals, and their disruption comes with its own set of challenges. Koo *et al.* theorised that applying ultrasonic-induced shear forces in combination with antimicrobial chemicals would be more effective in biofilm obliteration.[21] It is thought that as ultrasound-induced acoustic streaming causes deagglomeration of bacteria disrupting the biofilm, it gives rise to planktonic bacteria, which are more susceptible to the antibacterial effects of the irrigant used.[22] Ultrasonic-induced cavitation may also temporarily weaken the cell membrane, making bacteria more permeable to NaOCl and other irrigants.[22] In endodontics, this energy is applied with ultrasonic endodontic files and is the most common method to enhance root canal irrigation.[14]

Cavitation is the formation of gas bubbles within a liquid. During each ultrasound cycle of refraction and compression, these bubbles expand during refraction and collapse during compression repeatedly, thus growing with each subsequent cycle (Figure 3a). During these cycles, gas cannot be transported through the bubble-liquid interface, limiting amounts of gas within the bubble. Eventually, without new gas entering the bubble, the expanding bubble violently implodes (Figure 3a). On implosion, high-amplitude shock waves and high-velocity micro jets are released, exerting high shear forces on the surrounding biofilm, disrupting it and lifting it off the surface.[23]

Acoustic streaming is fluid flow caused by momentum transfer from the acoustic wave to the propagation liquid (Figure 3b).[24] When acoustic streaming occurs on a small scale, it is referred to as microstreaming. Microstreaming is fluid flow around the expanding and collapsing gas bubbles. The drag forces generated by these microstreams can detach the biofilm within its vicinity and carry it away from the surface.[23, 25]

In the root canal environment, such forces can disrupt bacterial biofilms, rupture bacterial cell walls, and remove debris and the smear layer from the root surface. An additional benefit is shockwave generation, which can also increase the breakdown of agents such as H2O2, enhancing the disinfection and debridement actions of the irrigation solutions.[26] Ultrasound activation improves access cavity preparation, cleaning, shaping and sealing of canals, eliminates obstructions, intracanal medicament removal and endodontic surgery.[27]

There are many different endodontic ultrasound devices available on the market. To simplify matters, there are two ultrasound irrigation methods: active and passive. Active ultrasound irrigation involves the simultaneous use of an irrigant with an active cutting tip, and passive ultrasound irrigation (PUI) is irrigation without simultaneous instrumentation using a non-cutting tip.[28] PUI is considered to be safer than active ultrasound irrigation as there is less risk of creating aberrant dentine defects.[29] PUI uses ultrasonic power with a non-cutting smooth oscillating wire or file, typically with a polymer tip, to transmit energy to the irrigant. Studies have shown that PUI is significantly more effective than standard needle irrigation. [27, 30, 31]

There are two theories regarding the best time to use ultrasound irrigation. The first is that PUI must be used as part of the initial protocol as this improves the flow action of the irrigant, enabling the irrigant to flow towards the apical part of the canal using fine files. However, the more popular opinion is that ultrasound should be used after mechanical canal preparation. Effective ultrasound irrigation depends on the vibratory potential of the instrument, and wider canals allow for unrestricted vibratory movement. Therefore, ultrasound irrigation is more suited to prepared canals. There is also a risk of defect formation when instruments touch a narrow canal wall during cavitation and, so a wider canal with narrower files is recommended to limit this risk.[12] Other important physical parameters to consider during irrigation are the depth of needle insertion, the volume of irrigant delivered and the contact time of the irrigant.[18] Căpută *et al.* tested the effectiveness of ultrasound irrigation on the healing of apical periodontitis, removal of pulp, hard tissue debris and smear layer.[32] Their study found that ultrasound irrigation was superior to conventional methods in removing these substances. However, ultrasound irrigation provided no significant advantage in healing apical periodontitis.[32] Mozo *et al.* reviewed methods to increase the activation of irrigating solutions and found that NaOCl combined with ultrasound or a wave vibration system had the most excellent antibacterial effect.[12] Another study by de Gregorio *et al.*, determined that ultrasonic and sonic NaOCl activation was more effective than using NaOCl alone as it allows for improved irrigant penetration.[33] Elnaghy *et al.*, also found that supplementing irrigation activation with ultrasonic and sonic protocols improved irrigation efficiency.[34]

There are a variety of irrigant activator systems available on the market today. A few of these systems are GentleWave System (GWS; Sonendo, Inc, Laguna Hills, CA), EDDY (VDW), MM1500 Sonic Air (Micro-Mega) and EndoActivator System (Dentsply Tulsa Dental Specialties, Tulsa, OK). Although each system varies in its armamentarium, the mechanisms by which they work are similar. Gentlewave (Figure 2e) uses a specialised handpiece to deliver NaOCl into the root canal under pressure and is activated by acoustic waves, while suction removes the outflowing fluid through the handpiece simultaneously.[35] A silicon ring surrounding the extremity of the handpiece creates a tight seal with the artificially created flat tooth surface. This establishes a vented and closed-loop fluid flow within the root canal[36] and is meant to improve irrigation dynamics in minimally mechanically prepared canals.[35]

Sonic-powered irrigation involves using a noncutting plastic tip mounted on an airscaler or specialised air-driven handpiece operating at a lower frequency than ultrasonic to produce sonic agitation of the irrigant. Kaloustian *et al*, compared the effectiveness of EDDY and MM1500 Sonic Air in reducing root filling remnants and found no statistical difference between the two systems with both systems improving the removal of residual filling material from distal

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canals of mandibular molars.[37] Conflictingly, a review by Boutsioukis and Arias-Moliz determined that sonic agitation occurs at too low a frequency and too large an oscillation amplitude to create effective acoustic streaming or transient cavitation. This review found that systems which used a higher frequency with a subsequent decrease in oscillation amplitude were more effective, and the authors questioned the rationale of using sonic agitation.[38]

A comparative study by Azim *et al*. tested four different irrigation protocols: Standard needle irrigation, EndoActivator (specially designed sonic handpiece used with non-cutting polymer tips to agitate root canal irrigants), XP Endo finishing file (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) is a highly flexible mechanical endodontic file that is used to mechanically activate the irrigant solution in the root canal and Photo-induced photoacoustic streaming (PIPS). This study found that while all the tested protocols were able to significantly reduce the bacterial biofilm, the XP Endo finishing file was the most effective in eliminating bacteria from the canal. PIPS, however, was the most effective at the apical third of the canal. The poorest-performing protocol was standard needle irrigation.[13] Donnermeyer *et al.*, compared the efficacy of sonic activation using EDDY, PUI and mechanical activation with XP Endo finishing file in removing CaOH from artificial grooves in straight canals. Their results were slightly different than Azim *et al.*, in that the EDDY and PUI systems were significantly more effective in the removal of calcium hydroxide than the XPendo Finisher regarding the apical region, while the poorest performing system in this study was also standard needle irrigation.[39]

In conclusion, irrigant activation in some form appears to be more effective at root canal disinfection and medicament removal than standard needle irrigation.

Laser-assisted endodontic disinfection

The popularity of lasers in medical treatments is increasing. The field of dentistry is no exception, and lasers have been used to enhance endodontic disinfection. Lasers activate photosensitisers that associate with bacteria[40] or activate irrigant solutions by the transfer of pulsed laser energy.[35] Photo-activated disinfection (PAD) is laser-induced photochemical disinfection whereby non-toxic photosensitisers are applied to the affected tissues and then activated by light at precise wavelengths (Figure 3c and d) 26). Photosensitisers are molecules that can use light absorption energy to activate chemical reactions in cells.[41] Photosensitisers are specially chosen to have a specific affinity to bacterial membranes without affecting the viability of host cells.[42] When a photosensitiser molecule absorbs light, it is excited to a higher level. The molecule will then lose energy, which is transferred to the environment, and this energy transfer may lead to cytotoxic oxidative reactions, which occur in the vicinity of a microbe or the intracellular space.[41, 43] PAD is bactericidal and has been effective against both gram-positive and negative bacteria, viruses and, to a lesser degree, fungi.[44, 45]

PAD is a promising aid to endodontic disinfection protocols. Studies have shown that traditional root canal debridement may not remove all microbes, and PAD can improve endodontic disinfection.[7, 26, 44] Furthermore, chemical irrigants can be toxic and are known to cause structural changes to dentine, which can decrease the tooth's structural and flexural strength.[44] PAD has less affinity for cells of the body and is a potentially viable alternative to these conventional protocols with fewer adverse effects.[7, 44, 45] Common photosensitisers used in endodontics are methylene blue or toluidine blue with a wavelength of 665nm.[46, 47] Tolonium chloride has also been used with 635nm wavelengths.[48]

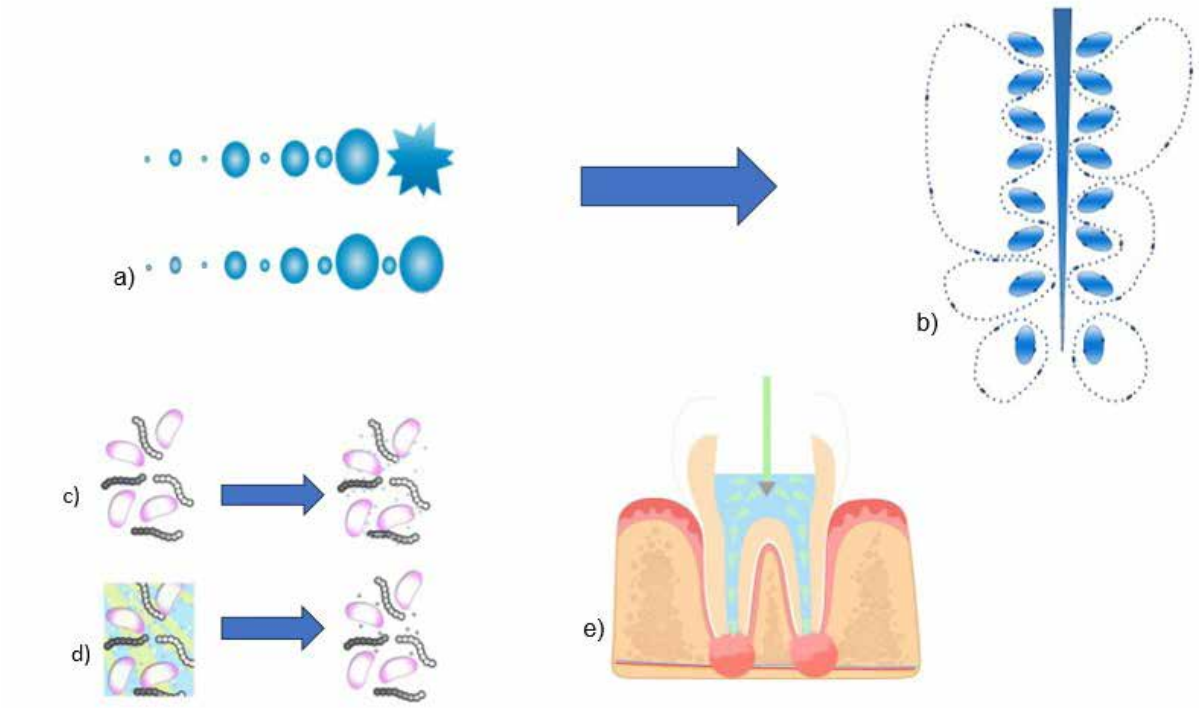

Figure 2: a) Schematic representation of inertial cavitation and non-inertial cavitation during ultrasound activation (163). **b)** Schematic representation of acoustic streaming when ultrasound is applied to fluid (166). c and d) diagrammatic representation of PAD at work. **c)** Bacteria are selectively tagged by PAD solution (photosensitisers). **d)** Exposure to red light activates the solution eliminating the bacteria (187). **e)** Photon-induced photoacoustic streaming. Low-power Er:Yag lasers generate photoacoustic shockwaves (195).

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However, anatomical complexities can hinder the effectiveness of PAD as its effects are limited to areas where light can penetrate. Isthmuses, ramifications, and curves prevent effective light distribution. Some studies have shown that the effectiveness of PAD is limited and not comparable to NaOCl.[47] To improve its effectiveness, there needs to be deeper light penetration and distribution into the apical portions of the root canal. Sabino and co-workers have experimented on methods to improve light penetration by using diffuser fibres attached to the laser and found that this improved light penetration and significantly improved the effectiveness of PAD.[44] These diffusers or optic fibres ensure uniform light distribution not only through the canal but also in a 360° direction, allowing for improved irradiation near the root apex and along the length of the root which improves disinfection outcomes.[49, 50] Radial tips have also been suggested to improve light distribution.[44] As with any irrigation method, it is important to remember that the instrument's tip needs to be as close as possible to the root apex to be effective in the apical third of the canal, otherwise known as the tip-to-target distance.

Other important considerations with PAD are the power level, duration of exposure, light absorption in the tissues, light wavelength, and photosensitiser absorbance.[43, 51-54] At this stage, PAD demonstrates potential and is a promising adjunct to endodontic disinfection protocols, bearing in mind the anatomical limitations and it cannot be used as a solitary disinfection protocol.

Photon-induced photoacoustic streaming (PIPS) involves using a erbium/yttrium-aluminium garnet (Er:YAG) laser light in a liquid solution to produce photoacoustic shockwaves (Figure 3e). These shockwaves create three-dimensional fluid flow through the isthmuses, anastomoses and lateral canals, allowing for a deeper cleaning of the entire root canal system.[55] The laser system is equipped with a fiberoptic delivery tip and subablative parameters, enhancing bubble dynamics and improving irrigant flow within the root canal.[35] Current evidence on the effectiveness of PIPS in root canal irrigation is contradictory.

Guneser *et al.* compared various techniques for removing precipitate formed after irrigation with NaOCl and CHX. They compared conventional syringe irrigation, CanalBrush, EndoActivator system, PIPS, and manual instrumentation techniques during which 5 mL of distilled water was used for 1 minute. All experimental groups contained residual precipitate and the authors concluded that none of these techniques were able to completely remove the orange-brown precipitate from the root canal surface.[56] Arslan *et al.* compared the efficiency of the PIPS technique with conventional, sonic and ultrasonic irrigation on the removal of apically placed dentinal debris from an artificial groove created in a root canal. The authors found that PIPS was significantly more effective than both sonic and ultrasonic irrigation in removing this debris.[57]

In a randomised clinical trial by Mandras and co-workers, the ability of PIPS technique to reduce root canal bacterial count in vivo was evaluated and compared to conventional irrigation. While there was a reduction in bacterial load with both techniques, PIPS demonstrated greater antibacterial efficacy. However, this difference between the two groups was not statistically significant. Within the limits of this study, the authors concluded that the PIPS technique could be considered a viable protocol for endodontic disinfection, especially in the case of simplified operational protocols and reduced instrumentation times.[55] Li *et al.* compared CaOH removal between PIPS, EndoActivator and needle irrigation. Their study showed that PIPS was more effective at removing CaOH from the central canal and isthmus in maxillary premolars than either of the two techniques.[58] Al Shahrani *et al.* compared the effectiveness of the PIPS technique combined with NaOCl, the PIPS technique with saline and NaOCl alone. They observed that the PIPS technique combined with NaOCl showed the most efficient bacterial biofilm eradication. They concluded that laser-activated irrigation utilising PIPS may enhance the disinfection of the root canal system.[59]

Studies have shown that even when placing the PIPS optic tip only in the pulp chamber, it can drive the irrigation solution to the end of the canal without harming the apical tissues and still be effective at removing debris through the length of the canal up to the apex.[60-62] In comparison with other techniques, where it has been observed that instrumentation and irrigation needle tips need to be as close to the root apex as possible to be effective along the length of the root canal, PIPS may offer a unique advantage. An added advantage of laser-assisted disinfection is the biostimulatory effects which can enhance healing and reduce inflammation.[63, 64] Despite the contradictory literature on the effectiveness of PIPS technique, it appears that there may be value in this technique as an adjunct for endodontic disinfection. Further research in this field is required.

INTRACANAL MEDICAMENTS

Endodontic treatment can be completed during single or multiple visits. Both techniques carry benefits; single-visit treatment decrease the number of appointments and allows for good patient acceptance and practice management considerations.[65] Multiple visits offer the advantage of time between root canal preparation and obturation allowing for drainage of apical periodontal infections, resolution of inflammation with its associated symptoms and shorter appointments minimising operator and patient fatigue. A common thread in considering single or multiple visit treatment is the risk of post-operative flare-ups. Dhyani *et al.* define flare-ups as "severe uncontrollable amount of inter-appointment and postoperative pain that is not relieved by medication, requiring an unscheduled visit to the dental surgery for active treatment".[66] There is no clear evidence in support of one technique over the other, as there seem to be as many studies in support of single-visit endodontic treatment as there are in support of multiple-visits.[65, 67-74] Factors that contribute to the decision-making tree of single vs multiple appointments range from operator skill, longer working times, trauma to the periapical tissues which can cause a more severe acute inflammatory response and postoperative pain to psychosocial factors such as high levels of distress before appointments and a patient's desire to control the anticipated unpleasantness associated with treatment.[69, 74-76] Each clinical case must be evaluated on its own merit to determine the most predictable and effective protocol for complete endodontic disinfection. A consensus is that the more severe the pre-operative symptoms are, the less likely a single visit is indicated.

With technological advancements such as magnification, heat-treated nickel-titanium instruments and new irrigation protocols, single visit treatment outcomes have improved. [4]

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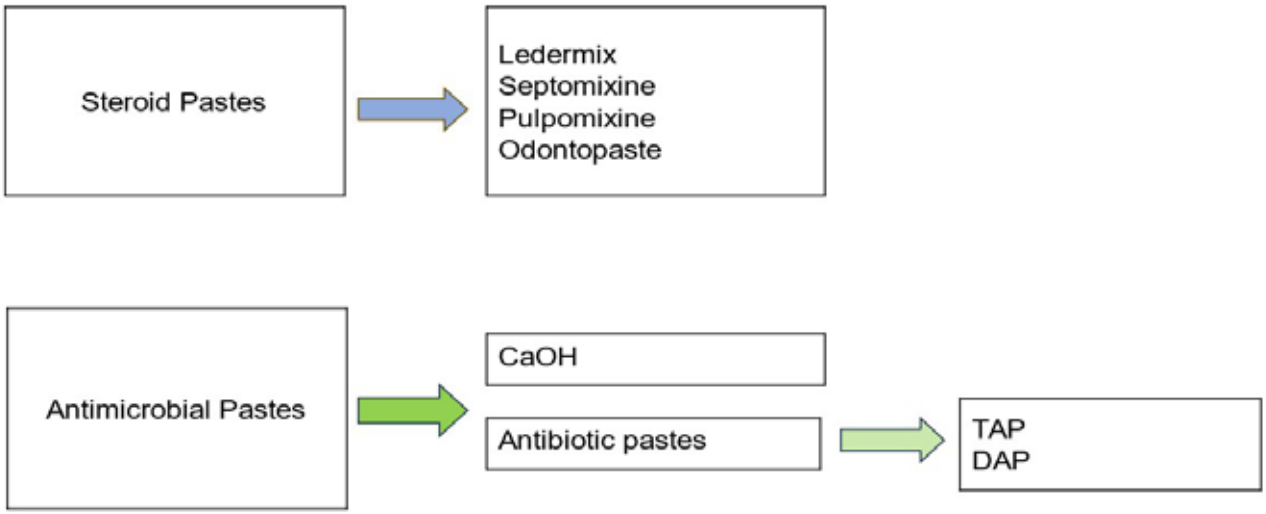

Figure 3: Classification of intracanal medicaments.

However, not all clinical scenarios can be treated with a single visit. In cases with persistent infection, difficulty to target micro-organisms in canals with complex anatomy, presence of large apical cysts or in patients with reduced immune competence, multiple visits, using intracanal medicaments between appointments, improves prognosis. Intracanal medicaments allow time for improved disinfection as the medicaments have time to diffuse and eradicate remaining microbes after canal preparation and provide time to confirm symptom improvement before final sealing of canals.[3, 77]

In cases where multiple visits are indicated, intracanal medicaments with high residual inhibitory effects can achieve successful outcomes and prevent reinfection.[78] However, the effects of intracanal medicaments are unpredictable in areas of debris and cannot be a substitute for thorough debridement of the canal.[79] Instead, intracanal medicaments should augment complete disinfection protocols.

According to Chong and Pitt Ford, intracanal medicaments should:[3]

1. Eliminate any remaining microbial populations after mechanical instrumentation.
2. Reduce inflammation of periapical tissues and pulp remnants.
3. Render canal contents inert and neutralise tissue debris.
4. Act as a barrier against leakage from the temporary filling.
5. Aid in drying persistently wet canals.

Intracanal medicaments can be classified according to their mechanism of action into steroid based pastes and antimicrobial pastes (see Figure 3).

Steroid pastes

Steroids are known to reduce inflammation and pain, and steroid preparations are used as an adjunct in endodontic disinfection. Gurney stated that local delivery of corticosteroids into the root canal and periapical tissues may provide symptomatic relief from post-treatment pain (80). Smith *et al.* observed that corticosteroids effectively decreased inflammation secondary to instrumentation.[81] However, corticosteroids are known to suppress the body's immune response, which may result in a bacteraemia.[82] Therefore, it is recommended to add an antibiotic to the corticosteroid preparation to protect against this potential bacteraemia and its associated symptoms.[83] Use of a corticosteroid/antibiotic paste has shown a rapid reduction in pain levels, with Schneider stating that once these pastes are applied, the majority of patients feel pain relief within an hour of leaving the dental office, and there was no occurrence of postoperative pain and swelling.[82] Common corticosteroid/antibiotic pastes available today are Ledermix paste, Septomixine Forte, Pulpomixine and Odondopaste.

Ledermix paste contains 1% triamcinolone and 3,2% demeclocycline in a polyethylene glycol paste.[84] Its active ingredients exert potent anti-inflammatory and antimicrobial effects. Triamcinolone is a steroid decreasing pulpal and periapical inflammation and aids in pain relief. Demeclocycline, a tetracycline derivative, has broad-spectrum antibacterial effects against gram-positive and gram-negative bacteria. It has been observed that patients whose teeth were dressed with Ledermix experienced less pain than those who had CaOH dressings or no dressings at all.[85] Ledermix paste can prevent external inflammatory root resorption, has no damaging effects on the periodontal membrane and is effective in treating progressive root resorption in traumatically injured teeth.[86, 87]

Septomixine and Pulpomixine pastes contain the antibiotic neomycin and framycetin, respectively, and dexamethasone as its steroid component. These agents are not as potent against common endodontic pathogens, and dexamethasone is less effective than other steroid agents used in alternative endodontic pastes.[88] Odontopaste is a zinc oxide-based paste with 5% clindamycin hydrochloride and 1% triamcinolone acetonide. Clindamycin is effective against many endodontic pathogens, is bacteriostatic, and prevents bacterial repopulation within the root canal.[89] The steroid triamcinolone acetonide is more potent than dexamethasone and temporarily reduces inflammation and postoperative pain.[90]

Antimicrobial pastes

The risks with systemic use of antibiotics are well known, with drug-resistant infections on the increase. Another limitation of systemic antibiotics within the context of root canal infections, is the anatomically complex and closed root canal system where limited amounts of antibiotic reach the infected pulp tissue.[91] Hence, an intracanal antibiotic paste provides a

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local delivery system, lowering the risk of antibiotic-resistant infections and increasing antibiotic effectiveness.

Calcium hydroxide

Calcium hydroxide (CaOH) is a broad-spectrum antimicrobial commonly used as a disinfectant dressing for vital inflamed pulp between visits. CaOH has an alkaline pH, is biocompatible with bactericidal effects, and has good tissue dissolution capability.[4, 92] CaOH works by decreasing the nutrient supply to any lingering microbes and so prevents root canal reinfection, neutralises endotoxin and also neutralises the lactic acid produced by osteoclasts and prevents dentine demineralisation while stimulating hard tissue repair and regeneration.[7, 78, 93, 94] Its mechanism of action is mediated by the release of hydroxyl ions which create free radicals that damage the cytoplasmic membrane, causes protein denaturation and damages bacterial DNA. In addition, bacteria are unable to survive in a high pH environment.[7]

CaOH has been shown to decrease microbial loads after mechanical instrumentation. In a study by Shuping *et al.*, where mechanical debridement was followed with 1% NaOCl irrigation and CaOH as an intracanal dressing, 61% of cases were bacteria-free after instrumentation and irrigation. After applying CaOH, 92% of cases did not have a positive culture. The results revealed that the apical size of the preparation and the use of the intracanal medication contributed to the reduction in the microbial load.[95] Sjögren *et al.* evaluated the effects of CaOH as a short-term intracanal dressing and found that CaOH was effective at eliminating bacteria that may be left behind after instrumentation and that predictable results can be achieved by dressing the canal for seven days.[96] CaOH is not without its limitations. CaOH has shown limited effectiveness against *E. faecalis*, which is the predominant pathogen in secondary infections and therefore, CaOH is more effective in primary endodontic infections than in secondary infections and alternative medicaments are recommended.[26]

There have been some additions to CaOH to improve its antibacterial and anti-inflammatory effects. In previous years, it was advised to combine CaOH with steroid pastes such as Ledermix. As the two pastes provide different effects, the combination was thought to provide improved antibacterial and anti-inflammatory properties.[97, 98] However, recent studies have shown that CaOH, being alkaline, degrades the steroid component of the second paste, and there was no benefit in combining the two pastes. It was recommended that its use be reviewed.[93] To improve the physical properties and radio-opacity of CaOH, iodoform has been added to CaOH. Iodoform maintains the paste's consistency and pH, making it easier to work with.[99] Iodoform also demonstrates antibacterial effects with restorative properties, and any excess material is resorbable.[100] Known materials in this category are Vitapex and Metapex.[94] The downside of such materials is their ability to prevent an adequate seal, and meticulous care must be taken to remove all excess material from the canal.[101]

Recently, Afkahami and co-workers tested a novel approach of adding silver nanoparticles (AgNPs) to CaOH. AgNPs are small, inert and biocompatible particles.[102] AgNPs create a cavity in the bacterial cell wall, decreasing bacterial adhesion and preventing biofilm formation.[103] These nanoparticles also prevent bacterial invasion into dentine.[104] In addition, AgNPs have demonstrated excellent antimicrobial activity with a low risk of microbial resistance.[35] Akhahami and co-workers showed that the addition of silver nanoparticles to CaOH has a two-fold effect: it enhances the antibacterial effects of CaOH at low concentrations and increases the residual antibacterial effects of CaOH as an intracanal medicament.[78] Studies by Fernandez *et al.* and *Yousefshahi et al*.support the idea that AgNPs increase the antibacterial properties of CaOH and are effective as intracanal medicaments.[105, 106]

Antibiotic pastes

Antibiotic pastes are typically used in teeth with incomplete root formation where regenerative and revascularisation of immature teeth allow apical closure of open apices and thickening of dentine walls.[107, 108] The microbial biofilm's complexity and diversity necessitates using an antibiotic combination rather than a single antibiotic to increase its efficacy. Triple antibiotic paste (TAP) is most commonly a combination of metronidazole, ciprofloxacin and minocycline, usually in 1:1:1 ratio and mixed with sterile water.[78] Studies have shown that these pastes can eliminate the microorganisms infecting the root canal and prevent recolonisation.[109-111] Ordinola-Zapata *et al.*, compared the antimicrobial activity of TAP, 2% CHX gel and CaOH paste on intraorally infected dentine biofilm models and found that TAP was the most effective at killing live microorganisms. However, the minocycline component causes dentine staining, so an alternative antibiotic paste was suggested. An alternative TAP combination of metronidazole, ciprofloxacin and clindamycin can be used,[91] or removal of minocycline from the original TAP without replacement making it a double antibiotic paste [78]

Nanoparticles

Nanotechnology is becoming increasingly popular in the medical field and uses nanoparticles as its delivery system. Nanoparticles are small particles with diameters between the range of 1 and 100 nm with increased chemical activity due to their large surface area.[112] Nanoparticles can be derived from various sources: metals such as silver and gold, polymers such as chitosan poly (lactic-co-glycolic acid), or even metallic oxides such as calcium oxide, zinc oxide, magnesium oxides and titanium oxide.[113, 114] As discussed earlier, CaOH has been impregnated with silver nanoparticles and has shown excellent antimicrobial activity with a low risk of microbial resistance.[35] Nanoparticles, with their higher reactivity and larger surface area, can improve the delivery, reach and effectiveness of irrigant solutions. The potential uses of nanoparticles can be broad, from combining with antibiotics to improve their efficacy while preventing antimicrobial resistance, being loaded with photosensitisers to improve photoactivated disinfection, or even combined with restorative dental materials providing a substantive antimicrobial effect. Nanoparticles are relatively new in endodontics, and further research is needed on their optimisation, limitations, and toxicity.

A dentist's perspective and the future of endodontic disinfection

Endodontic treatment is a routine dental procedure. It is essential for the clinician to understand tooth morphology, pathosis of pulp infection, and the materials and techniques best suited to debride and disinfect the root canal. Despite the lack of a single ideal irrigant, NaOCl combined with ethylenediaminetetraacetic acid as a chelator remains the most popular protocol for disinfection as it is effective and economical. The limitations of conventional irrigation are well

documented, so agitating techniques have been employed to overcome these limitations. Techniques such as ultrasonic activation have been useful in improving disinfection and overcoming limitations around anatomical variations and apical access of irrigants. The introduction of technologies such as laser into the disinfection armamentarium has also shown promising results. To effectively gain maximum output from these technologies, the clinician must understand the mechanisms at work and appreciate the relevant limitations of such technologies. The choice of irrigant and medicaments depends on clinical time, cost, and effectiveness. Effective and predictable combination solutions, such as continuous chelator irrigants have the potential to simplify irrigation while reducing chair time.

The use of intracanal medicaments is still controversial. It is now understood that with the continuous advancements in technologies and if the clinical situation is favourable to single-visit endodontic treatment, then the success rate of single-visit treatments has improved. However, there are still scenarios where multiple visits would be favoured. In cases where the risk of post-operative flare-ups is higher and when shorter appointments better serve operator or patient factors such as in-chair comfort and fatigue, multiple visits are still advised. Furthermore, psychological factors such as the degree of patient anxiety, fear of dentists, and previous traumatic experiences may impact the patient's pain perception and post-operative responses. In these scenarios, it may be beneficial from a psychological perspective to undergo multiple visits to ease the patient into treatment slowly and decrease the likelihood of post-op flare-ups. Therefore, each case should be evaluated on its own merit to determine if a single or multi-visit approach should be used.

Medical treatment is moving away from the generic and generalised approach towards individuality, targeting specific cells or pathogens for a more significant localised effect to minimise unwanted systemic and generalised adverse reactions. Custom antimicrobial functional peptides are a potential source for individualising endodontic disinfection and can be designed to target precise microbial pathogens. Specific endodontic challenges are three-fold: the complexity of the endodontic micro-flora, protease production by pathogens which could degrade these peptides and the high cost of custom peptide manufacturing.[115] Nevertheless, bespoke medical intervention is an exciting new field that can target specific endodontic pathogens, and further research is needed.

The future for endodontics includes dental pulp regeneration with revitalising and revascularising diseased pulp. The principles of regeneration hold for dental tissues: an extracellular matrix to provide scaffold support for cellular interactions, stem cells, and secretome complexes to mediate and influence cellular interactions. The first step in successful tissue regeneration is to eliminate infection to provide a clean and biologically healthy environment to facilitate tissue regeneration. This is where endodontic disinfection protocols are critical. The standard disinfection protocols aim to eliminate microbial infection and diseased tissue, destroying all cellular components within the root canal. Therefore, there is a need to create a biologically supportive disinfection protocol that will not only eliminate infection but retain or even stimulate positive cellular responses. Elnawam *et al.* proposed a novel concept, "minimally invasive regenerative endodontic procedures", by amalgamating the sciences of minimal invasive endodontics with regenerative endodontic procedures (116). This concept will not only regenerate lost tooth structures but conserve those that remain while maintaining the dentinogenic capacity of pulpal stem cells.[116] In the quest to regenerate dental pulp, a new biologically friendly disinfection protocol needs to be developed. This protocol must provide a balance between antimicrobial disinfection and preservation of stem cells to allow for cellular interactions. To this end, some alternative irrigants and medicaments such as ozonated oils, morinda citrifolia juice, Photo-activated disinfection, nitric oxide releasing nanomatrix, nanoparticles or dual effect scaffolds have been suggested.[116, 117] Regenerative endodontics is an exciting and developing field, and further research is needed.

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Data availability statement

No datasets were generated or analysed during the current study.

Competing Interests

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

REFERENCES

1. Pak JG, Fayazi S, White SN. Prevalence of periapical radiolucency and root canal treatment: a systematic review of cross-sectional studies. Journal of endodontics. 2012;38(9):1170-6.
2. Tibúrcio-Machado C, Michelon C, Zanatta F, Gomes MS, Marin JA, Bier CA. The global prevalence of apical periodontitis: a systematic review and meta-analysis. International endodontic journal. 2021;54(5):712-35.
3. Chong B, Ford TP. The role of intracanal medication in root canal treatment. International endodontic journal. 1992;25(2):97-106.
4. Ordinola-Zapata R, Noblett WC, Perez-Ron A, Ye Z, Vera J. Present status and future directions of intracanal medicaments. International Endodontic Journal. 2022;55:613-36.
5. Mohammadi Z, Jafarzadeh H, Shalavi S, Kinoshita J-I. Unusual Root Canal Irrigation Solutions. The journal of contemporary dental practice. 2017;18(5):415-20.
6. BYSTRÖM A, SUNDQVIST G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. European Journal of Oral Sciences. 1981;89(4):321-8.
7. Kennedy J, Hussey D. The antimicrobial effects of root canal irrigation and medication. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2007;103(4):560-9.
8. Murray PE, Farber RM, Namerow KN, Kuttler S, Garcia-Godoy F. Evaluation of Morinda citrifolia as an endodontic irrigant. Journal of endodontics. 2008;34(1):66-70.
9. Sundqvist G. Ecology of the root canal flora. Journal of endodontics. 1992;18(9):427-30.
10. Siqueira Jr JF, Rôças IN. Present status and future directions: Microbiology of endodontic infections. International Endodontic Journal. 2022;55:512-30.
11. Seltzer S, Farber PA. Microbiologic factors in endodontology. Oral surgery, oral medicine, oral pathology. 1994;78(5):634-45.
12. Mozo S, Llena C, Forner L. Review of ultrasonic irrigation in endodontics: increasing action of irrigating solutions. Medicina oral, patologia oral y cirugia bucal. 2012;17(3):e512.
13. Azim AA, Aksel H, Zhuang T, Mashtare T, Babu JP, Huang GT-J. Efficacy of 4 irrigation protocols in killing bacteria colonized in dentinal tubules examined by a novel confocal laser scanning microscope analysis. Journal of endodontics. 2016;42(6):928-34.
14. Dutner J, Mines P, Anderson A. Irrigation trends among American Association of Endodontists members: a web-based survey. Journal of endodontics. 2012;38(1):37-40.
15. Chow T. Mechanical effectiveness of root canal irrigation. Journal of endodontics. 1983;9(11):475-9.
16. Darcey J, Jawad S, Taylor C, Roudsari RV, Hunter M. Modern endodontic principles part 4: irrigation. Dental update. 2016;43(1):20-33.
17. Hülsmann M, Schäfer E. Problems in Endodontics. Acta Stomatol Croat. 2010;44(2):79-136.
18. Konstantinidi E, Psimma Z, Chávez de Paz L, Boutsioukis C. Apical negative pressure irrigation versus syringe irrigation: a systematic review of cleaning and disinfection of the root canal system. International endodontic journal. 2017;50(11):1034-54.
19. Nielsen BA, Baumgartner JC. Comparison of the EndoVac system to needle irrigation of root canals. Journal of endodontics. 2007;33(5):611-5.
20. Boutsioukis C, Psimma Z, Van der Sluis L. Factors affecting irrigant extrusion during root canal irrigation: a systematic review. International endodontic journal. 2013;46(7):599-618.
21. Koo H, Allan RN, Howlin RP, Stoodley P, Hall-Stoodley L. Targeting microbial biofilms: current and prospective therapeutic strategies. Nature Reviews Microbiology. 2017;15(12):740-55.
22. Carver K, Nusstein J, Reader A, Beck M. In vivo antibacterial efficacy of ultrasound after hand and rotary instrumentation in human mandibular molars. Journal of endodontics. 2007;33(9):1038-43.

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https://doi.org/10.17159/sadj.v80i07.22002

23. Vyas N, Manmi K, Wang Q, Jadhav AJ, Barigou M, Sammons RL, et al. Which parameters affect biofilm removal with acoustic cavitation? A review. Ultrasound in medicine & biology. 2019;45(5):1044-55.
24. Nowak T, Cairós C, Batyrshin E, Mettin R, editors. Acoustic Streaming and Bubble Translation at a Cavitating Ultrasonic Horn. AIP Conference Proceedings; 2015.
25. Wu J. Acoustic streaming and its applications. Fluids. 2018;3(4):108.
26. Jaju S, Jaju PP. Newer root canal irrigants in horizon: a review. International journal of dentistry.2011.
27. Plotino G, Pameijer CH, Grande NM, Somma F. Ultrasonics in endodontics: a review of the literature. Journal of endodontics. 2007;33(2):81-95.
28. Weller RN, Brady JM, Bernier WE. Efficacy of ultrasonic cleaning. Journal of endodontics. 1980;6(9):740-3.
29. Hülsmann M, Hahn W. Complications during root canal irrigation–literature review and case reports. International endodontic journal. 2000;33(3):186-93.
30. Al-Jadaa A, Paqué F, Attin T, Zehnder M. Acoustic hypochlorite activation in simulated curved canals. Journal of endodontics. 2009;35(10):1408-11.
31. Briseño M B, Wirth R, Hamm G, Standhartfnger W. Efficacy of different irrigation methods and concentrations of root canal irrigation solutions on bacteria in the root canal. Dental Traumatology. 1992;8(1):6-11.
32. Căpută PE, Retsas A, Kuijk L, de Paz LEC, Boutsioukis C. Ultrasonic irrigant activation during root canal treatment: a systematic review. Journal of endodontics. 2019;45(1):31-44. e13.
33. Cesar de Gregorio D, Estevez R, Cisneros R, Heilborn C, Cohenca N. Effect of EDTA, Sonic, and Ultrasonic Activation on the Penetration of Sodium Hypochlorite into Simulated Lateral Canals: An In Vitro Study. 2009.
34. Elnaghy AM, Mandorah A, Elsaka SE. Effectiveness of XP-endo Finisher, EndoActivator, and File agitation on debris and smear layer removal in curved root canals: a comparative study. Odontology. 2017;105(2):178-83.
35. Kishen A, Peters OA, Zehnder M, Diogenes AR, Nair MK. Advances in endodontics: Potential applications in clinical practice. Journal of conservative dentistry: JCD. 2016;19(3):199.
36. Haapasalo M, Wang Z, Shen Y, Curtis A, Patel P, Khakpour M. Tissue dissolution by a novel multisonic ultracleaning system and sodium hypochlorite. Journal of endodontics. 2014;40(8):1178-81.
37. Kaloustian M, Nehme W, El Hachem C, Zogheib C, Ghosn N, Mallet J, et al. Evaluation of two shaping systems and two sonic irrigation devices in removing root canal filling material from distal roots of mandibular molars assessed by micro CT. International Endodontic Journal. 2019;52(11):1635-44.
38. Boutsioukis C, Arias-Moliz MT. Present status and future directions–irrigants and irrigation methods. International Endodontic Journal. 2022;55:588-612.
39. Donnermeyer D, Wyrsch H, Bürklein S, Schäfer E. Removal of calcium hydroxide from artificial grooves in straight root canals: sonic activation using EDDY versus passive ultrasonic irrigation and XPendo Finisher. Journal of endodontics. 2019;45(3):322-6.
40. George S, Kishen A. Advanced noninvasive light-activated disinfection: assessment of cytotoxicity on fibroblast versus antimicrobial activity against Enterococcus faecalis. Journal of endodontics. 2007;33(5):599-602.
41. Garcez AS, Núñez SC, Lage-Marques JL, Jorge AOC, Ribeiro MS. Efficiency of NaOCl and laser-assisted photosensitization on the reduction of Enterococcus faecalis in vitro. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2006;102(4):e93-e8.
42. Lee MT, Bird PS, Walsh LJ. Photo-activated disinfection of the root canal: a new role for lasers in endodontics. Australian Endodontic Journal. 2004;30(3):93-8.
43. Wainwright M, Crossley KB. Photosensitising agents—circumventing resistance and breaking down biofilms: a review. International biodeterioration & biodegradation. 2004;53(2):119-26.
44. Sabino C, Garcez A, Núñez S, Ribeiro M, Hamblin M. Real-time evaluation of two light delivery systems for photodynamic disinfection of Candida albicans biofilm in curved root canals. Lasers in medical science. 2015;30(6):1657-65.
45. Plotino G, Cortese T, Grande NM, Leonardi DP, Di Giorgio G, Testarelli L, et al. New technologies to improve root canal disinfection. Brazilian dental journal. 2016;27:3-8.
46. Soukos NS, Chen PS-Y, Morris JT, Ruggiero K, Abernethy AD, Som S, et al. Photodynamic therapy for endodontic disinfection. Journal of endodontics. 2006;32(10):979-84.
47. Souza LC, Brito PR, de Oliveira JCM, Alves FR, Moreira EJ, Sampaio-Filho HR, et al. Photodynamic therapy with two different photosensitizers as a supplement to instrumentation/irrigation procedures in promoting intracanal reduction of Enterococcus faecalis. Journal of endodontics. 2010;36(2):292-6.
48. Williams J, Pearson G, Colles M, Wilson M. The effect of variable energy input from a novel light source on the photoactivated bactericidal action of toluidine blue O on Streptococcus mutans. Caries research. 2003;37(3):190-3.
49. Garcez AS, Fregnani ER, Rodriguez HM, Nunez SC, Sabino CP, Suzuki H, et al. The use of optical fiber in endodontic photodynamic therapy. Is it really relevant? Lasers in medical science. 2013;28(1):79-85.
50. Fimple JL, Fontana CR, Foschi F, Ruggiero K, Song X, Pagonis TC, et al. Photodynamic treatment of endodontic polymicrobial infection in vitro. Journal of endodontics. 2008;34(6):728-34.
51. Tewfik HM, Pashley DH, Horner JA, Sharawy MM. Structural and functional changes in root dentin following exposure to KTP/532 laser. Journal of endodontics. 1993;19(10):492-7.
52. Moshonov J, Sion A, Kasirer J, Rotstein I, Stabholz A. Efficacy of argon laser irradiation in removing intracanal debris. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 1995;79(2):221-5.
53. Dederich DN, Zakariasen KL, Tulip J. Scanning electron microscopic analysis of canal wall dentin following neodymium-yttrium-aluminum-garnet laser irradiation. Journal of Endodontics. 1984;10(9):428-31.
54. Onal B, Ertl T, Siebert Gt, Müller G. Preliminary report on the application of pulsed CO2 laser radiation on root canals with AgCl fibers: a scanning and transmission electron microscopic study. Journal of endodontics. 1993;19(6):272-6.
55. Mandras N, Pasqualini D, Roana J, Tullio V, Banche G, Gianello E, et al. Influence of Photon-Induced Photoacoustic Streaming (PIPS) on root canal disinfection and post-operative pain: A randomized clinical trial. Journal of Clinical Medicine. 2020;9(12):3915.
56. Guneser MB, Dincer AN, Arslan D. Comparison of conventional syringe, canalbrush, endoactivator, photon-induced photoacoustic streaming, and manual instrumentation in removing orange-brown precipitate: an in vitro study. Photomedicine and Laser Surgery. 2017;35(6):311-6.
57. Arslan H, Capar I, Saygili G, Gok T, Akcay M. Effect of photon-initiated photoacoustic streaming on removal of apically placed dentinal debris. International endodontic journal. 2014;47(11):1072-7.
58. Li D, Jiang S, Yin X, Chang JWW, Ke J, Zhang C. Efficacy of needle, ultrasonic, and endoactivator irrigation and photon-induced photoacoustic streaming in removing calcium hydroxide from the main canal and isthmus: an in vitro micro-computed tomography and scanning electron microscopy study. Photomedicine and laser surgery. 2015;33(6):330-7.
59. Al Shahrani M, DiVito E, Hughes CV, Nathanson D, Huang GT-J. Enhanced removal of Enterococcus faecalis biofilms in the root canal using sodium hypochlorite plus photon-induced photoacoustic streaming: an in vitro study. Photomedicine and laser surgery. 2014;32(5):260-6.
60. Peeters HH, Mooduto L. Radiographic examination of apical extrusion of root canal irrigants during cavitation induced by Er, Cr: YSGG laser irradiation: an in vivo study. Clinical oral investigations. 2013;17(9):2105-12.
61. Peeters HH, Suardita K. Efficacy of smear layer removal at the root tip by using ethylenediaminetetraacetic acid and erbium, chromium: yttrium, scandium, gallium garnet laser. Journal of endodontics. 2011;37(11):1585-9.
62. DiVito E, Lloyd A. ER: YAG laser for 3-dimensional debridement of canal systems: use of photon-induced photoacoustic streaming. Dentistry today. 2012;31(11):122, 4-7.
63. Walsh L. The current status of low level laser therapy in dentistry, Part 1. Soft tissue applications. Australian dental journal. 1997;42(4):247-54.
64. Walsh L. The current status of low level laser therapy in detistry. Part 2. Hard tissue applications. Australian dental journal. 1997;42(5):302-6.
65. Sathorn C, Parashos P, Messer H. Effectiveness of single-versus multiple-visit endodontic treatment of teeth with apical periodontitis: a systematic review and meta-analysis. International Endodontic Journal. 2005;38(6):347-55.
66. Dhyani VK, Chhabra S, Sharma VK, Dhyani A. A randomized controlled trial to evaluate the incidence of postoperative pain and flare-ups in single and multiple visits root canal treatment. Medical Journal Armed Forces India. 2022;78:S35-S41.
67. Schwendicke F, Göstemeyer G. Single-visit or multiple-visit root canal treatment: systematic review, meta-analysis and trial sequential analysis. BMJ open. 2017;7(2):e013115.
68. Sathorn C, Parashos P, Messer H. The prevalence of postoperative pain and flare-up in single-and multiple-visit endodontic treatment: a systematic review. International endodontic journal. 2008;41(2):91-9.
69. Mergoni G, Ganim M, Lodi G, Figini L, Gagliani M, Manfredi M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochrane Database of Systematic Reviews. 2022(12).
70. Imura N, Zuolo M. Factors associated with endodontic flare-ups: a prospective study. International endodontic journal. 1995;28(5):261-5.
71. de Oliveira Alves V. Endodontic flare-ups: a prospective study. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2010;110(5):e68-e72.
72. Albashaireh Z, Alnegrish A. Postobturation pain after single-and multiple-visit endodontic therapy. A prospective study. Journal of dentistry. 1998;26(3):227-32.
73. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth: a Cochrane systematic review. Journal of Endodontics. 2008;34(9):1041-7.
74. Law A, Logan H, Walton R. Abstract# 23—Identification of a psychosocial model as a predictor of flare-ups. Journal of Endodontics. 1992;18(4):192-3.
75. Ikram O, Neal T, Mounce R. Endodontics: single versus multiple visit. Clinical Dentistry. 2021;1(6):57-63.
76. Ashkenaz PJ. One-visit endodontics. Dental Clinics of North America. 1984;28(4):853-63.
77. Vera J, Siqueira Jr JF, Ricucci D, Loghin S, Fernández N, Flores B, et al. One-versus two-visit endodontic treatment of teeth with apical periodontitis: a histobacteriologic study. Journal of endodontics. 2012;38(8):1040-52.
78. Afkhami F, Rostami G, Batebi S, Bahador A. Residual antibacterial effects of a mixture of silver nanoparticles/calcium hydroxide and other root canal medicaments against Enterococcus faecalis. Journal of Dental Sciences. 2022;17(3):1260-5.
79. Haapasalo M, Qian W, Portenier I, Waltimo T. Effects of dentin on the antimicrobial properties of endodontic medicaments. Journal of endodontics. 2007;33(8):917-25.
80. Gurney B. Clinical pharmacology in endodontics and intracanal medicaments. Dental Clinics of North America. 1974;18(2):257-68.
81. Smith R, Patterson SS, El-Kafrawy AH. Histologic study of the effects of hydrocortisone on the apical periodontium of dogs. Journal of Endodontics. 1976;2(12):376-80.
82. Schneider D. Triamcinolone acetonide-demethylchlortetracycline HCl treatment in endodontic practice. Journal of Oral Medicine. 1968;23(2):51-5.
83. Schroeder A. Corticosteroids in endodontics. Journal of oral Therapeutics and Pharmacology. 1965;2(3):171-9.
84. Athanassiadis B, Abbott P, Walsh LJ. The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. Australian dental journal. 2007;52:S64-S82.
85. Ehrmann E, Messer H, Adams G. The relationship of intracanal medicaments to postoperative pain in endodontics. International endodontic journal. 2003;36(12):868-75.
86. Pierce A, Heithersay G, Lindskog S. Evidence for direct inhibition of dentinoclasts by a corticosteroid/antibiotic endodontic paste. Dental Traumatology. 1988;4(1):44-5.
87. Mohammadi Z, Abbott P. On the local applications of antibiotics and antibiotic-based agents in endodontics and dental traumatology. International endodontic journal. 2009;42(7):555-67.
88. Sivakumar N. Steroids in root canal treatment. Int J Pharm Pharm Sci. 2014;6(3):17-9.
89. Lin S, Levin L, Peled M, Weiss EI, Fuss Z. Reduction of viable bacteria in dentinal tubules treated with clindamycin or tetracycline. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2003;96(6):751-6.
90. Bansal R, Jain A. Overview on the current antibiotic containing agents used in endodontics. North American journal of medical sciences. 2014;6(8):351.
91. Makandar SD, Noorani TY. Triple antibiotic paste—Challenging intracanal medicament: A systematic review. Journal of International Oral Health. 2020;12(3):189.
92. Carrotte P. Endodontics: Part 9 Calcium hydroxide, root resorption, endo-perio lesions. British dental journal. 2004;197(12):735-43.
93. Athanassiadis M, Jacobsen N, Parashos P. The effect of calcium hydroxide on the steroid component of Ledermix® and Odontopaste®. International endodontic journal. 2011;44(12):1162-9.
94. Kwon W, Kim I-H, Kang C-M, Kim B, Shin Y, Song JS. Comparative study of pulpal responses to ProRoot MTA, Vitapex, and Metapex in canine teeth. Journal of Dental Sciences. 2021;16(4):1274-80.
95. Shuping GB, Ørstavik D, Sigurdsson A, Trope M. Reduction of Intracanal Bacteria Using Nickel-Titanium Rotary Instrumentation and Various Medications. 2000.
96. SJÖGREN U, FIGDOR D, SPÅNGBERG L, SUNDQVIST G. The antimicrobial effect of calcium hydroxide as a short-term intracanal dressing. International Endodontic Journal. 1991;24:119-25.

https://doi.org/10.17159/sadj.v80i07.22002

97. Abbott PV, Hume WR, Heithersay GS. Effects of combining Ledermix® and calcium hydroxide pastes on the diffusion of corticosteroid and tetracycline through human tooth roots in vitro. Dental Traumatology. 1989;5(4):188-92.
98. Taylor MA, Hume WR, Heithersay GS. Some effects of Ledermix® paste and Pulpdent® paste on mouse fibroblasts and on bacteria in vitro. Dental Traumatology. 1989;5(6):266-73.
99. Fava L, Saunders W. Calcium hydroxide pastes: classification and clinical indications. International endodontic journal. 1999;32(4):257-82.
100. Estrela C, Estrela CRdA, Hollanda ACB, Decurcio DdA, Pécora JD. Influence of iodoform on antimicrobial potential of calcium hydroxide. Journal of applied oral science. 2006;14:33-7.
101. Carrotte P. Endodontics: Part 7 Preparing the root canal. British dental journal. 2004;197(10):603-13.
102. Joshi AS, Singh P, Mijakovic I. Interactions of gold and silver nanoparticles with bacterial biofilms: Molecular interactions behind inhibition and resistance. International Journal of Molecular Sciences. 2020;21(20):7658.
103. Javidi M, Afkhami F, Zarei M, Ghazvini K, Rajabi O. Efficacy of a combined nanoparticulate/calcium hydroxide root canal medication on elimination of E nterococcus faecalis. Australian Endodontic Journal. 2014;40(2):61-5.
104. Sofi W, Gowri M, Shruthilaya M, Rayala S, Venkatraman G. Silver nanoparticles as an antibacterial agent for endodontic infections. BMC Infectious Diseases. 2012;12(1):1-.
105. Fernandez CC, Sokolonski AR, Fonseca MS, Stanisic D, Araújo DB, Azevedo V, et al. Applications of silver nanoparticles in dentistry: advances and technological innovation. International journal of molecular sciences. 2021;22(5):2485.
106. Yousefshahi H, Aminsobhani M, Shokri M, Shahbazi R. Anti-bacterial properties of calcium hydroxide in combination with silver, copper, zinc oxide or magnesium oxide. European journal of translational myology. 2018;28(3).
107. Valverde ME, Baca P, Ceballos L, Fuentes MV, Ruiz-Linares M, Ferrer-Luque CM. Antibacterial efficacy of several intracanal medicaments for endodontic therapy. Dental materials journal. 2017:2016-102.
108. Patil U, Yeli M, Tapashetti S, Naik B, Tilakchand M. Effect of varying durations of intracanal medicament application used in regenerative endodontic treatment on the push-out bond strength of a novel cement: NeoMTA Plus. Journal of conservative dentistry: JCD. 2019;22(1):48.
109. Ordinola-Zapata R, Bramante C, Minotti P, Cavenago B, Garcia R, Bernardineli N, et al. Antimicrobial activity of triantibiotic paste, 2% chlorhexidine gel, and calcium hydroxide on an intraoral-infected dentin biofilm model. Journal of Endodontics. 2012;39(1):115-8.
110. Hoshino E, Kurihara-Ando N, Sato I, Uematsu H, Sato M, Kota K, et al. In-vitro antibacterial susceptibility of bacteria taken from infected root dentine to a mixture of ciprofloxacin, metronidazole and minocycline. International endodontic journal. 1996;29(2):125-30.
111. Ordinola-Zapata R, Bramante CM, Minotti PG, Cavenago BC, Garcia RB, Bernardineli N, et al. Antimicrobial activity of triantibiotic paste, 2% chlorhexidine gel, and calcium hydroxide on an intraoral-infected dentin biofilm model. Journal of Endodontics. 2013;39(1):115-8.
112. Shrestha A, Kishen A. Antibacterial nanoparticles in endodontics: a review. Journal of endodontics. 2016;42(10):1417-26.
113. Samiei M, Farjami A, Dizaj SM, Lotfipour F. Nanoparticles for antimicrobial purposes in Endodontics: A systematic review of in vitro studies. Materials Science and Engineering: C. 2016;58:1269-78.
114. Kishen A, Shrestha A. Nanoparticles for endodontic disinfection. Nanotechnology in endodontics: current and potential clinical applications. 2015:97-119.
115. Wright PP, Walsh LJ. Optimizing antimicrobial agents in endodontics. Antimicrobial Agents Croatia: InTech. 2017:87-107.
116. Elnawam H, Abdelmougod M, Mobarak A, Hussein M, Aboualmakarem H, Girgis M, et al. Regenerative endodontics and minimally invasive dentistry: intertwining paths crossing over into clinical translation. Frontiers in Bioengineering and Biotechnology. 2022;10.
117. Padmakumar I, Hinduja D, Mujeeb A, Kachenahalli Narasimhaiah R, Kumar Saraswathi A, Mirza MB, et al. Evaluation of Effects of Various Irrigating Solutions on Chemical Structure of Root Canal Dentin Using FTIR, SEM, and EDS: An In Vitro Study. Journal of Functional Biomaterials. 2022;13(4):197.

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Maturation Staging of the Midpalatal Suture using Cone Beam Computed Tomography

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ABSTRACT

Introduction
Rapid maxillary expansion (RME) in a young adult is unpredictable because of individual variability in the fusion of the midpalatal suture (MPS) that may be independent of chronologic age.

Aims and objectives
To determine if the maturation stage of the midpalatal suture can be predicted by using a classification based on its morphology as observed on cone-beam computed tomography (CBCT) images.

Design
A single-centre, retrospective study.

Methods
216 CBCT images were analysed; 125 female and 91 males, aged 7 to 78 years. The CBCT images were exported to the OnDemand3D[R] software program. The most central axial cross-sectional slices were used to evaluate the suture morphology according to five maturational stages; namely stages A-E.

Results
There was a statistically significant association between ossification of the MPS and increasing chronological age. The proportion of those aged <12y was higher in stage A/B while the proportion of those aged >=30y was higher in stage E. However, large variations in the degree of closure of the MPS among subjects of the same age group were observed.

Conclusions
In a patient where age might be a deterrent against the use of conventional RME, CBCT may assist in determining prospectively which patients could benefit from conventional RME.

Keywords
Midpalatal suture, cone beam computed tomography, maxillary expansion, maxillary constriction, transverse dimension, suture synostosis, suture maturation, suture morphology, skeletal maturity indicator.

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Conflict of Interest
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BACKGROUND
Rapid maxillary expansion (RME) or rapid palatal expansion (RPE) is a commonly used procedure in orthodontics to correct a transverse deficiency of the maxilla and to increase the maxillary arch perimeter in patients who present with mild crowding (crowding of < 5mm) of the dental arches.[1] RME has also been advocated in the spontaneous correction of Angle Class II malocclusions[2] and to facilitate protraction facemask treatment for the early correction of skeletal Class III malocclusions.[3]

The concept of maxillary expansion was first introduced by Angell in 1860.[4] RME remained controversial for nearly a century until Haas published the results of a study on the rapid expansion of the maxillary dental arch by opening the mid-palatal suture.[5] This validated the use of RME in routine orthodontic practice.[6]

The incidence of maxillary transverse constriction in adolescents is 7.9% and in adults it is 10% .[7] The successful use of RME has largely been limited to growing patients and entails the splitting of the midpalatal suture with an appliance that applies high forces of 15–50 newtons to the maxillary and circummaxillary sutures.[8] In patients with residual or surplus skeletal growth this treatment results in a combination of dental and orthopaedic expansion. On the contrary, when it is used for the skeletally mature patient, more dento-alveolar tipping as opposed to skeletal expansion with a more unstable outcome occurs. Excessive dental tipping is not desirable as it may lead to periodontal complications like loss of attachment, fenestrations, dehiscences and root resorption.[1]

An understanding of the growth, development and ossification of the MPS and circummaxillary sutures is essential in predicting the response to RME in a young child, adolescent or young adult. Growth of the nasomaxillary complex follows a cephalo-caudal pattern; hence skeletal maturation involves

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progressive closure of the midpalatal and circummaxillary sutures. This leads to increased impedance to RME and eventual failure to separate the hemimaxillae.[9]
During the infantile period, the suture is a broad gap between the maxillary bones and is filled with connective tissue which appears radiolucent on radiographs as it is not mineralised. As maturation and ossification progresses into the juvenile stage, bony spicules begin to form from the margins of the suture, along with "islands" in the middle of the sutural gap. This results in a mixture of non-mineralised connective tissue and calcified bone. During the adolescent period, these bony spicules begin to interdigitate leading to calcification and fusion of the suture.[10]

Patency of the MPS has been reported in patients aged 27, 54 and 71[11,12,24] years respectively. These findings indicate that there is individual variability in the fusion of the midpalatal suture that may be independent of chronologic age. Furthermore, sutural ossification occurs from posterior to anterior and the timing of ossification varies between the genders.[11,12]

To circumvent the complications associated with conventional RME in skeletally mature patients, miniscrew-assisted rapid palatal expansion (MARPE) may be used to increase orthopaedic changes in the midface especially in post-pubertal patients, and to negate the negative consequences that may occur with conventional RME.[13] MARPE is essentially another method of RME that is bone supported as opposed to conventional RME appliances.

The surgical approach is another medium used to expand the maxilla. This method is generally employed in young adults and older patients when the midpalatal suture has already fused or when the maxillary transverse constriction is greater than 5mm. This method entails an intraoperative widening of the maxilla through a multipiece LeFort I osteotomy or a surgically assisted rapid palatal expansion (SARPE).[14,15] The midsagittal osteotomy line is favoured for SARPE; the rationale being the considerable ossification that has to be weakened in this region.[12] Proffit *et al*. have reported that surgical expansion of the maxilla is the least stable of all orthognathic procedures.[9] Furthermore, SARPE is associated with a large range of adverse surgical complications and morbidity.[14]

The clinical decision between RME or SARPE to treat maxillary deficiency has traditionally been based on the chronological age of the patient. However, the individual variability in the ossification and fusion of the midpalatal suture has led to a lack of consensus in the literature regarding the age at which transverse maxillary deficiency should be treated surgically[14,16] as successful nonsurgical RME has been reported in young adults as well.[17,18]

In addition to chronological age, other indicators of midpalatal suture maturation (MPSM) that have been proposed include sutural morphology as assessed on occlusal radiographs,[19] skeletal maturity indicators (SMI) as appraised on a hand-wrist radiograph (HWR),[20] cervical vertebral maturation (CVM) indicators evaluated on lateral cephalograms [21] as well as the five-stage classification of MPSM by Angelieri and colleagues.[22]

SMI and CVM were developed to predict the timing of facial growth, and not to directly quantify facial skeletal maturity.[23]

Revelo and Fishman[20] demonstrated that there is an association between SMI and midpalatal suture maturation, however, only fifty percent of the total MPS was ossified by the end of puberty.

The occlusal radiograph which is often used for assessing the palatal suture has proven to be unreliable. The limitations encountered includes inadequate visualization of the posterior aspect of the intermaxillary suture because of the superimposition of the vomer and the external structure of the nose on the midpalatal suture. This can lead to misinterpretation of the fusion stage of the midpalatal suture. Furthermore, it is surmised that the midpalatal suture is a straight-running oronasal suture and that the radiographic path projects through this suture. However, the midpalatal suture may not always run in a straight path. If the midpalatal suture is not visible on an occlusal radiograph, it may be because the suture runs in an oblique direction relative to the x-ray path. Therefore a "radiologically closed" midpalatal suture is not analogous to a histologically closed suture.[24]

To circumvent the limitations associated with conventional radiographs, Angelieri *et al*.[22] described a 5-stage classification system for the midpalatal suture with the use of CBCT images. The authors used the histological classification to define MPSM on CBCT images. These researchers were able to show that the midpalatal suture was not fused in 12% of adult patients.[22] Clinically, it is this subgroup of patients who are difficult to identify. The results of the latter study also validated earlier studies that showed no fusion of the mid-palatal suture in subjects of ages 27 years, 32 years, 54 years and even 71 years.[11,12,25]

Considering the variation observed in MPSM in the literature, the aim of this study was to determine whether the maturation stage of the MPS can be predicted in a South African sample by using a classification based on its morphology as observed on CBCT images.

Research on age-specific characteristics of sutural morphology is an important factor to consider for orthodontic treatment planning in patients with constricted maxillary widths. Should maxillary expansion be needed, the use of conventional RME appliances may not produce the desired skeletal effects after synostosis of the MPS since the resultant effects of RME would largely be dental and unstable. Therefore, a reliable and reproducible tool is needed to determine a more valid diagnostic method for these patients so that an appropriate approach to treatment can be implemented. This will prevent undesired dento-alveolar movement and the associated iatrogenic periodontal problems that may ensue.

AIMS AND OBJECTIVES

The aim of this study was to evaluate MPSM in young children (<12 years), older children (12-<15 years and 15-<18 years), young adults (18-<30 years) and older adults (>=30 years) as observed on CBCT images.

The objectives of this study were to:

1. Classify the maturational stage of the midpalatal suture in young children (<12 years), children (12-<15 years and 15-<18 years), young adults (18-<30 years) and older adults (>=30 years) on CBCT images.

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2. Determine the inter and intra-rater reliability (reclassification reliability).
3. Determine the relationship between the maturational stage of the midpalatal suture and chronological age.
4. Determine the relationship between the maturational stage of the midpalatal suture and gender.

MATERIALS AND METHODS

This was a cross-sectional retrospective study based on CBCT images obtained from the archives of the dental faculty, spanning the period March 2011 to December 2018. Permission to conduct the study was obtained from the Biomedical Research Ethics Committee (BM18/2/2).

For the purposes of this study 250 CBCT scans were required. The sample size estimation was based on the key research question to be answered, in this case the determination of the relationship between chronological age, gender and the classification of the MPS which consists of five stages according to Angelieri *et al.*[22]

This required the use of multinomial logistic regression with the estimation of five parameters (one for gender, and four for age category). The rule of thumb given by Peduzzi *et al*.[26] states that the smallest outcome category (stage) should have at least the number of cases = 10* the number of parameters to be estimated, i.e. 10*5 parameters = 50. Thus, a minimum sample size of 50*5 stages = 250 was required. To ensure adequate representation of all age groups and both genders in the sample, the total sample was divided equally into each age group-gender combination; i.e. 25 scans per group as follows: young children from below the age of 12, young children aged 12 to 15 years, teenagers from age 15 to age 18, younger adults from 18 to 30 years of age and older adults (> 30 years of age). The stratification of the sample population was based on previous studies of MPSM.[6,10-12] After excluding patients with prior expansion appliances, orthognathic surgery and craniofacial syndromes including cleft lip and palate, the final sample size was 216 CBCT scans. Every CBCT volume was assigned a random numerical identifier.

A Newtom® (VGI®, Verona, Italy) CBCT scanner was used to obtain full field-of-view scans (15 x 15 cm). The images were saved in DICOM and transferred to the OnDemand3D® software package (Cybermed Inc, South Korea).

Images for sutural evaluation were obtained in a standardized way. Slice thickness was set at 0.3mm for evaluation and 1mm for identification. The image analysis software cursor was positioned as follows (Figure 1):

1. The head was oriented in the natural head position in all three planes of space. In the sagittal view, the patient's head was adjusted so that the anteroposterior long axis of the palate was horizontal. The vertical and horizontal cursors were positioned in the centre of the palate in the coronal and axial views.
2. Sagittal plane - the horizontal axis of the cursor passed through the centre of the supero-inferior dimension of the hard palate, with the line corresponding to ANS and PNS or a parallel to ANS and PNS.
3. Coronal plane - the cursor was positioned over the midpalatal suture and nasal spine.
4. Axial plane - the vertical axis passed through the anterior and posterior nasal spine.

Figure 1: Standardization of the multiplanar images to orientate the reconstruction as mentioned above

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The most central axial cross-sectional slices were used for sutural assessment. The slice thickness was set at 1mm to get a 1:1 ratio (Figures 2-4).

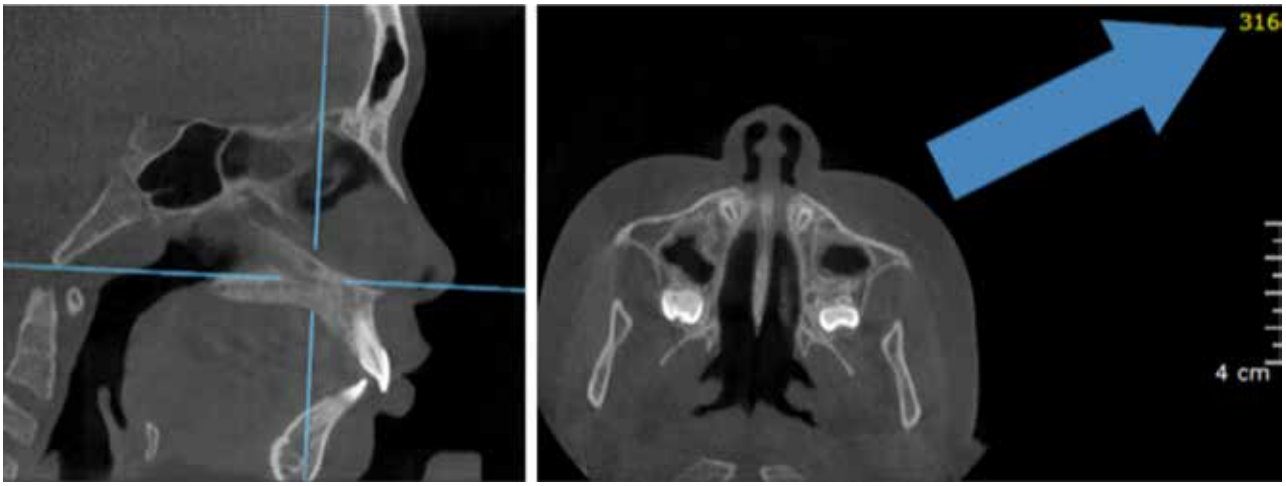

Figure 2: Step one. The horizontal axis of the cursor was positioned on the superior aspect of the palate and the corresponding slice number was noted (slice number 316).

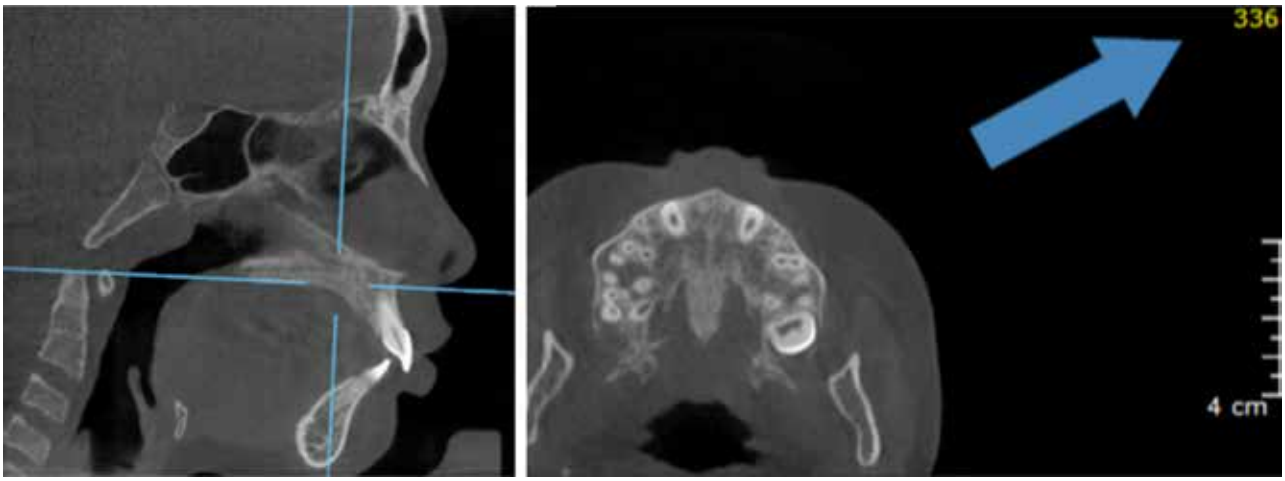

Figure 3: Step two. The horizontal axis of the cursor was positioned on the inferior aspect of the palate and the corresponding slice number was noted (slice number 336).

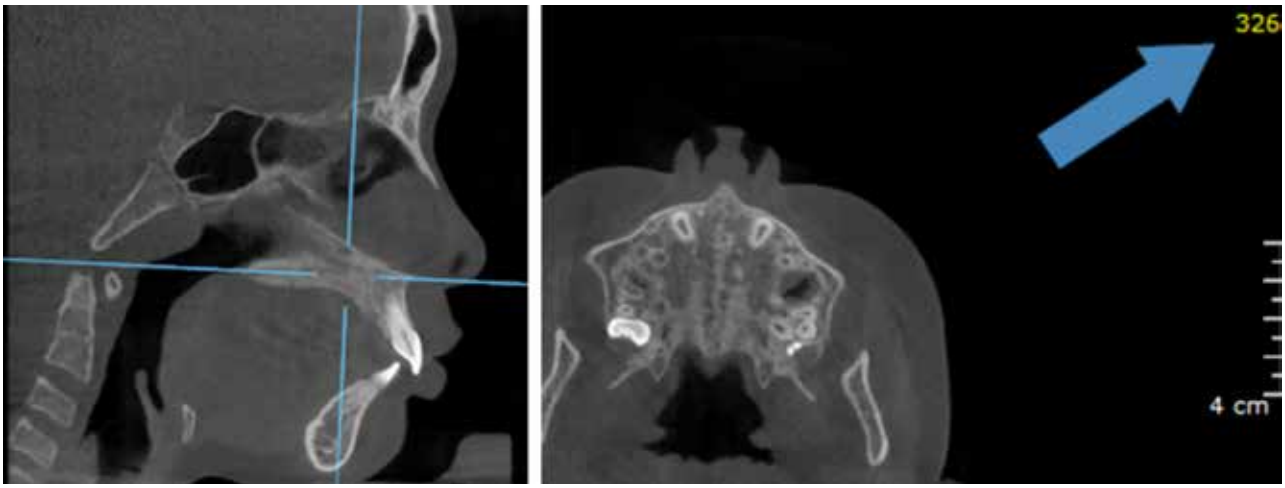

Figure 4: Step three. The superior and inferior slice numbers were subtracted from each other and the middle most slice was selected (slice number 326).

For subjects who exhibited a curved palate, two sagittal slices were used. In the first sagittal slice the horizontal axis of the cursor passed through the suture in the most posterior region, and in the second slice, the cursor passed through the most anterior region. The posterior and anterior region of the midpalatal suture were then identified separately but both were used to evaluate the maturation stage.

Prior to staging of suture maturation, the two examiners, one an expert in radiology and one a registrar in orthodontics, were calibrated. The maturational stages of the MPS were classified according to the morphologic parameters established by Angelieri and colleagues (Figure 5).[22]

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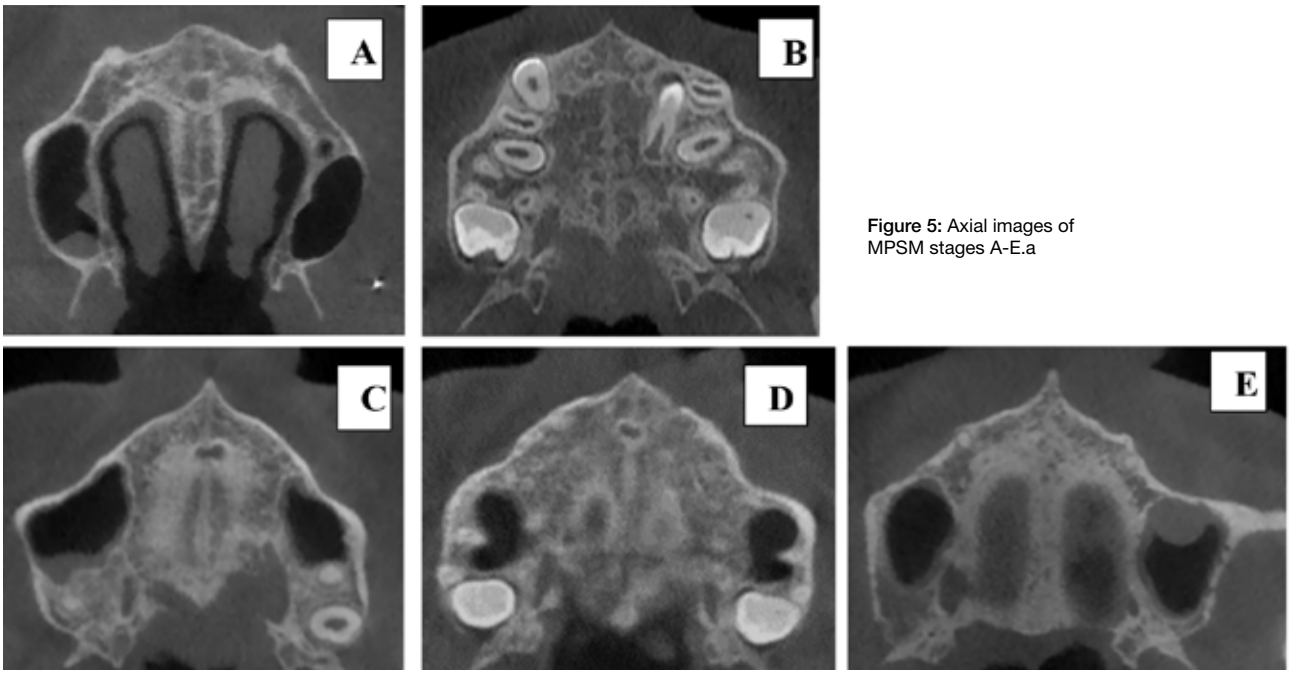

Figure 5: Axial images of MPSM stages A-E.a

1. Stage A: The MPS is characterized by one relatively straight high-density midpalatal suture line with little or no interdigitation.
2. Stage B is observed as one scalloped, high-density line at the midline, or by a scalloped high-density line in some areas and, in other areas, as 2 parallel, scalloped, high-density lines close to each other and separated by small low-density spaces.
3. Stage C is visualized as two parallel, scalloped, high-density lines that are close to each other, separated in some areas by small low-density spaces. The suture can be arranged in either a straight or an irregular pattern.
4. Stage D is visualized as two scalloped, high-density lines at the midline on the maxillary portion of the palate, the MPS cannot be identified in palatine bone.
5. Stage E, sutural fusion has occurred in the maxilla. The MPS cannot be identified.

After the calibration process, staging of suture maturation on the CBCT images was performed by both examiners. Each examiner arrived at a diagnosis separately. The diagnoses were then compared to assess the level of concordance. If there was disagreement regarding the suture stage, this was followed by a robust discussion until consensus was reached. The consensus diagnosis formed the "ground truth" for this thesis. To assess the reliability of classifying the maturational stages of the midpalatal suture (stages A-E), staging and reclassification of the midpalatal suture was repeated by both examiners who randomly assessed and reclassified every tenth CBCT scan after a two-week period. A total of twenty-two images were reclassified.

STATISTICAL ANALYSIS

Categorical variables (age group, gender and stage) were summarised by frequency and percentage tabulation. Continuous variables (age and gender) were summarised by the mean, standard deviation, median and interquartile range. The association between age group and gender, gender and stage and age group and stage, was determined by the chi-squared test. The relationship between age, gender and stage was determined by ordinal logistic regression with maturation stage as the dependent variable and age group and gender as the independent variables.

Interrater and reclassification reliability (intra-rater) were quantified by Cohen's weighted kappa and the Stuart-Maxwell test for bias.[27] The magnitude of the kappa was interpreted according to the classification by Landis and Koch.[28] Data analysis was carried out in SAS. The 5% significance level was used for all statistical tests.

RESULTS

The intra- rater reliability was 0.94 (95% confidence interval/CI 0.91-0.97) and the inter-rater reliability (reclassification) was equal to 0.92 (95% CI 0.83-1.00). There was no significant intraobserver bias (p>0.99). Thus, the staging categorisation was reliable.

Based on the research design, 250 CBCT scans were required. This sample size would have ensured an equal representation of all age groups and both genders in the sample. However, we were only able to obtain 216 CBCT studies. Overall, the mean age at the time the CBCT images were taken was 24.9 years with a standard deviation (SD) of 16.5 years and an age range of 7.1-77.5 years (Table 1).

Table 1: Mean age at time CBCT scan taken (yrs).

N	Mean	SD	Minimum	Maximum
216	24.9	16.4	7.1	77.5

From the available images, females were overrepresented in the sample and accounted for 57.9% of the final CBCT images. The <12year and the 15-<18year groups were under-represented, while the oldest age group (>=30) was over-represented (Table 2). Furthermore, males were under-represented in the 18-<30year age group (p=0.033).

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Table 2: Demographics of the sample group by age and gender.

Gender	Age at time CBCT scan taken (y)					
	<12	12-<15	15-<18	18-<30	>=30	N
F	13	28	13	36	35	125
M	17	22	16	12	24	91
Total	30	50	29	48	59	216
% Male	57	44	55	25	41	42
% Female	43	56	45	75	59	57.9
Total %	13.8	23.1	13.4	22.2	27.3	100

MPSM stages B to E were approximately equally represented in the sample, while the prevalence of stage A was very low (Table 3).

Table 3: Distribution of the maturational stages of the midpalatal suture (F=female, M= Male).

Stage	Age at time CBCT image was taken													
	<12		12-<15y		15-<18y		18-<30y		>=30y		Total		N	%
	F	M	F	M	F	M	F	M	F	M	F	M		
A	2	1	2	4	0	2	0	0	1	1	5	8	13	6.0
B	6	12	8	8	2	5	2	3	3	5	21	33	54	25.0
C	5	2	11	5	7	4	11	6	2	2	36	19	55	25.5
D	0	2	4	4	3	5	11	3	11	5	29	19	48	22.2
E	0	0	3	1	1	0	12	0	18	11	34	12	46	21.3
Total	13	17	28	22	13	16	36	12	35	24	125	91	216	100

Stage A was too small (n=13) to be used as an outcome group on its own and was combined with stage B. There was a statistically significant association between gender and stage (p=0.0010, Cramer's V=0.27; small effect size). The proportion of males in stages A/B was higher than in the other stages, while the proportion of females in stage E was higher than in the other stages. Overall, a higher proportion of females displayed the later stages of maturation when compared to males (Figure 6).

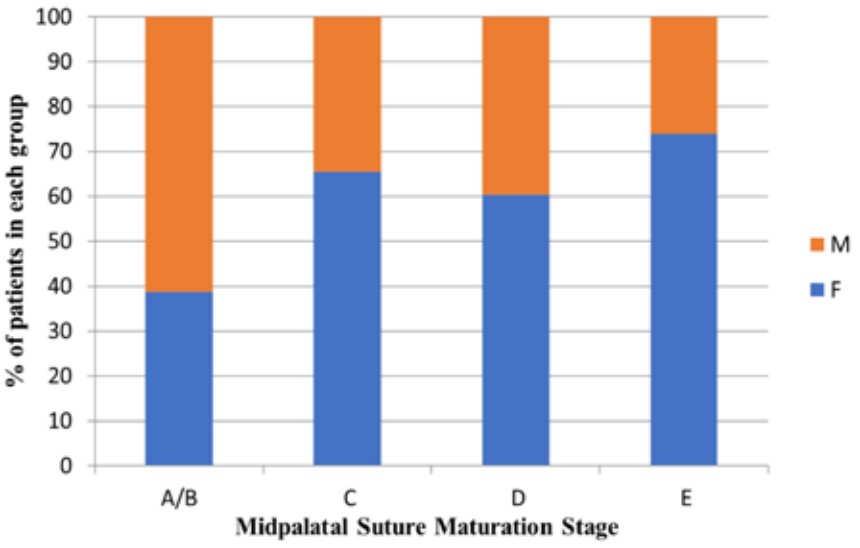

Figure 6: The relationship between gender and MPSM stage.

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Table 4: Age distribution per maturational stage.

Age	Stage			
	A/B	C	D	E
<12 y	31.3%	12.7%	4.2%	0.0%
12-<15 y	32.8%	29.1%	16.7%	8.7%
15-<18 y	13.4%	20.0%	16.7%	2.2%
18-<30 y	7.5%	30.9%	29.1%	26.1%
>=30 y	15%	7.3%	33.3%	63.0%

The association between age group and MPSM stage was significant (p<0.0001; Cramer's V=0.36; moderate effect size); however, great variability was frequently noted. The proportion of those aged <12y was higher in stage A/B, however, stage D was observed in 4.2% of children (2/48) in this age group.

A high prevalence of stage E (63%) was observed in older adults (>=30 yrs). In addition, 14.9% of older adults (>= 30 yrs) had no fused suture (Table 4).

6. DISCUSSION

In the present study, the morphology of the MPS as assessed on CBCT images was correlated to chronological age and gender to ascertain a relationship between age, gender and MPSM stage.

The CBCT images were staged according to the classification proposed by Angelieri et al.[22] The classification is based on the evaluation of the most central cross-sectional axial slice. However, should this slice not be accurately located, the MPSM stage may be misconstrued on the CBCT image. Therefore, in our study, the slice thickness was set to 1mm to allow for a 1:1 ratio. The central most cross-sectional slice was determined by identifying the slice number corresponding to the most superior aspect of the palate; the slice number corresponding to the most inferior aspect of the palate and then subtracting the two. The median of this number was selected as the most central cross-sectional slice.

For this study to be reliable and reproducible there had to be agreement between the examiners. The examiners selected the consensus method as the "ground truth" to minimize the probability of diagnostic errors. When evaluating radiographs, the term "ground truth" is more appropriate than "gold standard" as a gold standard will necessitate a histological specimen of the midpalatal suture as a frame of reference. [22]

The drawbacks that were experienced with the classification proposed by Angelieri and colleagues were differentiating stage A from stage B where stage A is defined as "relatively straight high density line".[22] Relative is a broad term and is subject to opinion. Stage A should rather have been defined in terms of percentage of straight versus scalloped. Stage A and B infer early suture development, prior to suture ossification. The transition from stage A to stage B will not necessitate a change in the treatment plan or prognosis. In both stage A and B, the suture is patent and conventional RME is possible. Therefore, disagreements between examiners regarding the staging between stage A and stage B is not critical.

Furthermore, the demarcation between stage D and stage E was also sometimes obscure. Identification of sutural stage D or E is suggestive of ossification of the MPS.

This study showed that the association between gender and stage was significant; it was observed that the proportion of males in stages A/B was higher than in the other stages whereas MPSM stages C, D and E displayed a greater prevalence in females. This inferred that maturation between the genders differed, with females maturing earlier than males. These observations are in concordance with previous studies on MPSM. 22,29,30 In a sample aged 11 to 15 years stage C was observed in 56.8% of females and 42.5% of males.29 Similarly, de Miranda Ladewig et al. evaluated CBCT images of MPSM in subjects aged 16 to 20 years and reported that a greater percentage of females displayed the late maturational stages of D and E (53.0%), when compared with the males (38.6%).30

The findings of this study validate previous reports that chronological age is not analogous with MPSM. Ossification of the MPS increased with chronological age; the proportion of those aged <12y was higher in stage A/B when the MPS is patent compared to the other stages while the proportion of those aged >=30y was higher in stage E (ossification has occurred in both the maxillary and palatine portions of the MPS). However, large variations in ossification staging of the MPS among subjects of the same age group were observed (Table 4). The results showed that stage A/B was observed in 14.9% of the >=30 yr age groups. This is an important finding, as a fairly sizable proportion of older patients presented with patent sutures at an age where conventional RME is deemed unsuccessful. An observation that was also mirrored by Angelieri et al.22 was the presence of stage D (fusion of the palatine area of the MPS) in 4.2% of subjects <12 years of age.

Stages A and B are characterized by a patent MPS, therefore RME carried out during this stage will have greater skeletal effects than dental effects. Stage C is visualized as two parallel, scalloped, high-density lines that are close to each other, separated in some areas by small low-density spaces. During stage C there is increased interdigitation of bone resulting in greater resistance to separation. Despite the increased sutural resistance encountered during stage C, RME carried out at this stage is still possible. However, RME should be initiated immediately because of the impending start of fusion of the palatine portion of the

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MPS.[31]

The MPS fuses from posterior to anterior [11,12] Therefore, the posterior region of the MPS will show an increased resistance to expansion. Stage D is characterized by fusion of the palatine bone and stage E is characterised by fusion of the entire MPS (palatine and maxillary areas). These patients are more suitably treated with SARPE or MARPE.[31] However, when MPSM was used as a predictor for MARPE success in patients aged 15 years to 37 years, it was found that stages A and B showed successful MPS opening while limited MPS opening was observed in subjects in stages D and E. However, failure of MPS opening appeared in only individuals with MPS stage E.[32] Therefore, the success of MARPE in stages D and E is variable. Clinicians should be cognisant that the greater the area of MPS patency, the greater the potential success of orthopaedic expansion.

Sutural morphology may be a reflection of the loading conditions under which the suture is subjected to.[33] It has been postulated that the age at which sutural synostosis occurs is directly determined by extrinsic functional demands affecting that specific suture area.[34] If a suture functions to reduce stresses transmitted throughout the facial skeleton, the bone at the sutural margins should show more deflection than the surrounding bone.[35] The complexity of sutural interdigitations is proportional to the magnitude of the functional load. Sutures become more interdigitated in areas of high stress to prevent the bones from becoming disarticulated.[36]

Studies have ascribed the patent suture in adults to a decrease in the functional forces from the muscles of mastication. This may be due to the natural processes of aging with the resultant loss of teeth or to the refined, softer diet of western civilizations. Therefore, the maturation and ossification of the midpalatal suture depends on functional forces exerted on the maxillary bone.[37] As a result, chronological age alone is not the sole determinant of the developmental stage of the suture. Consideration should therefore be given to the reciprocal effects from functional forces on suture maturation.

The assessment of the MPS on the CBCT may be a valid tool to aid in the clinical decision between conventional RME, MARPE and SARPE in young adult patients in whom the prognosis of conventional RME is doubtful.[22,28,29] It has been recommended that a report should be requested from a radiologist as MPS assessment showed "potential reliability and reproducibility" but extensive training is required to increase reliability and reproducibility.[38]

LIMITATIONS

There are several limitations to this study:

It was a single centre study; therefore, the ideal sample size was not reached. According to the research design there should have been a 1:1 ratio of male:female patients. After applying the inclusion and exclusion criteria the actual sample size was 216. No patient was exposed to radiation for the purpose of this research. CBCT images were obtained from the archives of the University spanning the period March 2011 to December 2018.

Secondly there was no control group. The control group; namely autopsy specimens should have been the "gold standard".

With respect to the resistance that clinicians encounter when transverse force is applied to the MPS, the maturation and ossification of the circummaxillary sutures are as important as the maturation and interdigitation of the midpalatal suture in decreasing the skeletal response to RME.[39] Only the morphology and maturation of the midpalatal suture was considered in our study.

CONCLUSION

The association between gender and suture stage was significant. The proportion of males in stages A/B was higher than in the other stages, while the proportion of females in stage E was higher than in the other stages. Overall, a higher proportion of females displayed the later stages of maturation when compared to males.

In a patient where age may be a potential limiting factor for the use of conventional RME as a treatment option, the classification proposed by Angelieri *et al*. (2013) may assist in determining prospectively which late adolescent or young adult patient could benefit from such an intervention.

REFERENCES

1. Bishara, S.E. and Staley, R.N. Maxillary expansion: clinical implications. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1987;91(1):3-14.
2. Guest, S.S., McNamara Jr, J.A., Baccetti, T. and Franchi, L., 2010. Improving Class II malocclusion as a side-effect of rapid maxillary expansion: a prospective clinical study. *American Journal of Orthodontics and Dentofacial Orthopedics, 138*(5):582-591.
3. de Silva Fo, O.G., Boas, C.V. and Capelozza, L.F., 1991. Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. *American Journal of Orthodontics and Dentofacial Orthopedics*, 100(2):171-179.
4. Angell, D.H., 1860. Treatment of irregularity of the permanent or adult teeth. *Dental Cosmos*,1:540-544.
5. Haas, A.J., 1961. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. *The Angle Orthodontist, 31*(2):73-90.
6. Timms, D.J., 1999. The Dawn of rapid maxillary expansion. *The Angle Orthodontist*, 69(3): 247–250.
7. Harrison JE, Ashby D. Orthodontic treatment for posterior crossbites. Cochrane Database Syst Rev. 2000;12(2):CD000979.
8. Lagravere, M.O., Major, P.W. and Flores-Mir, C., 2005. Long-term dental arch changes after rapid maxillary expansion treatment: a systematic review. *The Angle Orthodontist*, 75(2):155-161.
9. Proffit, W.R., Sarver, D.M. and Ackerman, J.L., 2013. *Contemporary Orthodontics.* 5th ed. St Louis: Mosby.
10. Melsen B. Palatal growth studied on human autopsy material: a histologic microradiographic study. *American Journal of Orthodontics.* 1975; 68(1):42-54.
11. Persson, M. and Thilander, B. Palatal suture closure in man from 15 to 35 years of age. *American Journal of Orthodontics*. 1977;72(1):42-52.
12. Knaup, B., Yildizhan, F. and Wehrbein, H. Age-related changes in the midpalatal suture. *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie*. 2004;65(6):467-474.
13. Cantarella, D., Dominguez-Mompell, R., Moschik, C., Sfogliano, L., Elkenawy, I., Pan, H.C., Mallya, S.M. and Moon, W., 2018. Zygomaticomaxillary modifications in the horizontal plane induced by micro-implant-supported skeletal expander, analyzed with CBCT images. *Progress in orthodontics*, 19(1):41.
14. Suri, L. and Taneja, P., 2008. Surgically assisted rapid palatal expansion: a literature review. *American Journal of Orthodontics and Dentofacial Orthopedics, 133*(2): 290-302.
15. Yao, W., Bekmezian, S., Hardy, D., Kushner, H.W., Miller, A.J., Huang, J.C. and Lee, J.S., 2015. Cone-beam computed tomographic comparison of surgically assisted rapid palatal expansion and multipiece Le Fort I osteotomy. *Journal of Oral and Maxillofacial Surgery*, 73(3): 499-508.
16. Wertz, R. and Dreskin, M., 1977. Midpalatal suture opening: a normative study. *American Journal of Orthodontics*, 71(4): 367-381.
17. Handelman, C.S., Wang, L., BeGole, E.A. and Haas, A.J., 2000. Nonsurgical rapid maxillary expansion in adults: report on 47 cases using the Haas expander. *The Angle Orthodontist, 70*(2):129-144.
18. Stuart, D.A. and Wiltshire, W.A., 2003. Rapid palatal expansion in the young adult : time for a paradigm shift ? *Journal Canadian Dental Association*, 69(6): 374–377.
19. Lehman, J.J., Haas, A.J. and Haas, D.G. Surgical orthodontic correction of transverse maxillary deficiency: a simplified approach. *Plastic and reconstructive surgery*. 1984;73(1): 62-68.
20. Revelo, B. and Fishman, L.S. Maturational evaluation of ossification of the midpalatal suture. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1994; 105(3):288-292.
21. Baccetti, T., Franchi, L., Cameron, C.G., McNamara, J.A. Treatment timing for rapid maxillary expansion. *The Angle Orthodontist*. 2001; 71:343-350.
22. Angelieri, F., Cevidanes, L.H., Franchi, L., Gonçalves, J.R., Benavides, E. and McNamara Jr, J.A. Midpalatal suture maturation: classification method for individual assessment before rapid maxillary expansion. *American Journal of Orthodontics and Dentofacial Orthopedics*.2013; 144(5):759-769.
23. Baccetti, T., Franchi L., McNamara Jr, J.A., 2002. An improved version of the cervical

www.sada.co.za / SADJ Vol. 80 No.8
https://doi.org/10.17159/sadj.v80i07.17552

vertebral maturation (CVM) method for the assessment of mandibular growth. *The Angle Orthodontist*, 72:316-323.
24. Wehrbein, H. and Yildizhan, F., 2001. The mid-palatal suture in young adults. A radiological-histological investigation. *The European Journal of Orthodontics*, 23(2): 105-114.
25. Korbmacher, H., Schilling, A., Püschel, K., Amling, M. and Kahl-Nieke, B. Age-dependent three-dimensional microcomputed tomography analysis of the human midpalatal suture. *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie*. 2007; 68(5):364-376.
26. Peduzzi, P., Concato, J., Kemper, E., Holford, T.R. and Feinstein, A.R., 1996. A simulation study of the number of events per variable in logistic regression analysis. *Journal of clinical epidemiology*, 49(12):1373-1379.
27. Shoukri, M. M. Measures of Interobserver Agreement and Reliability.2nd edition. Boca Raton, FL: Chapman & Hall/CRC Press;2010.
28. Landis, J.R. and Koch, G.G. The measurement of observer agreement for categorical data. *Biometrics*.1977; 33 (1): 159–17.
29. Tonello, D.L., de Miranda Ladewig, V., Guedes, F.P., Conti, A.C.D.C.F., Almeida-Pedrin, R.R. and Capelozza-Filho, L. Midpalatal suture maturation in 11-to 15-year-olds: A cone-beam computed tomographic study. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2017;152(1): 42-48.
30. de Miranda Ladewig, V., Capelozza-Filho, L., Almeida-Pedrin, R.R., Guedes, F.P., de Almeida Cardoso, M. and Conti, A.C.D.C.F. Tomographic evaluation of the maturation stage of the midpalatal suture in postadolescents. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2018;153(6):818-824.
31. Angelieri F, Cevidanes LH, Franchi L, McNamara Jr JA. Evaluation of facial suture maturation on CBCTs: a predictor of maxillary orthopedic treatment response. In: Kapila S, Nervina J, Hatch N. Expedited Orthodontics: Improving the efficiency of orthodontic treatment through novel technologies. Ann Arbor: University of Michigan. *Craniofacial Growth Series* 2015; 51: 257-80.
32. Oliveira, C.B., Ayub, P., Angelieri, F., Murata, W.H., Suzuki, S.S., Ravelli, D.B. and Santos-Pinto, A., 2021. Evaluation of factors related to the success of miniscrew-assisted rapid palatal expansion. *The Angle Orthodontist*, *91*(2), pp.187-194.
33. Mao, J.J. Mechanobiology of Craniofacial Sutures. *Journal of Dental Research*.2002; 81(12):810–816.
34. Kokich, V.G. Age changes in the human frontoxygomatic suture from 20 to 95 years. *American Journal of Orthodontics*.1976; 69(4): 411–30.
35. Herring, S.W. and Teng, S. Strain in the braincase and its sutures during function. *American Journal of Physical Anthropology*.2000;112(4):575-593.
36. Herring, S.W. Formation of the vertebrate face epigenetic and functional influences. *American Zoologist*.1993; 33(4):472-483.
37. Katsaros, C., Zissis, A., Bresin, A. and Kiliaridis, S. Functional influence on sutural bone apposition in the growing rat. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2006;129(3):352-357.
38. Barbosa, N.M.V., Castro, A.C.D., Conti, F., Capelozza-Filho, L., Almeida-Pedrin, R.R.D. and Cardoso, M.D.A., 2019. Reliability and reproducibility of the method of assessment of midpalatal suture maturation: A tomographic study. *The Angle Orthodontist*, *89*(1), pp.71-77.
39. Zimring, J. and Isaacson, R.J., 1965. Forces Produced by Rapid Maxillary Expansion. *The Angle Orthodontist*, 35(3): 178–186.

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A Historical Review of Impression Materials & Techniques in Complete Denture Fabrication: Part 1

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ABSTRACT

Historically, impression techniques have been fundamental in successful denture fabrication, evolving from rudimentary materials like wax and plaster to sophisticated elastomeric materials that enhance the accuracy and comfort of dentures. Over the years, various impression techniques and materials for denture fabrication have been developed. Advances were based on a deep understanding of oral anatomy and the desire to preserve the integrity of soft tissues while ensuring a stable and retentive fit for the prostheses. The selection of the appropriate impression materials and technique directly influences the biomechanics of the final denture. It is fundamental to producing more detailed and accurate impressions that better serve patient needs. The field of removable prosthodontics is poised for further advancements as digital technology continues to evolve. However, the integration of these innovations must be supported by rigorous research and collaboration among clinicians, academics and the industry.

INTRODUCTION

Despite the increasing popularity of implant-supported prostheses, conventional complete dentures remain the most viable, conservative and cost-effective treatment option for patients who have lost all their natural teeth.[1] This is particularly true for patients with financial constraints, medical limitations, or lack of access to advanced surgical interventions. [2] Complete and removable partial dentures (RPDs) play essential roles in restorative dentistry to replace missing teeth and soft tissues in fully or partially edentulous patients, respectively. Both offer affordable and accessible dental care that addresses patients' aesthetic, masticatory, speech functions and for patients from diverse socio-economic conditions [3].

The first and most fundamental requirement for successful denture fabrication is the accuracy of the initial impression, as this directly influences the denture's support, retention, and stability.[4] These elements ensure dentures remain securely in place during everyday activities, enhancing patient comfort, oral function, and well-being.[5]

Over the years, impression materials and techniques have evolved, reflecting an ongoing effort to improve the precision of fit of dental prostheses.[6] The development of elastomeric impression materials in the 1950s marked a significant advancement in capturing the fine details necessary for high-quality dentures.[7] This paper provides a comprehensive overview of the development and current state of impression materials and techniques used for complete denture fabrication from early development until the latest digital advances. The latter will be reviewed in Part 2.

Historical Timeline of Impression Techniques

Recorded examples of denture fabrication date back to the 18th Century. Since then, the range and types of materials used have changed, as depicted in Table 1.

Biomechanics in Denture Construction

The construction of dentures requires a thorough understanding of biomechanics to ensure optimal support, retention, and stability, all of which directly affect the patient's comfort, function, and overall satisfaction.

Support refers to the denture's ability to resist vertical forces directed toward the alveolar ridges and mucosal tissues, particularly during chewing and swallowing. The primary support areas for maxillary dentures include the flat areas of the hard palate (the horizontal palate) and the posterior ridges, while the buccal shelf and retromolar pad provide primary support in the mandible.[12]

Retention refers to the denture's ability to resist forces that attempt to dislodge it during activities such as eating, speaking, and laughing. Factors contributing to retention include adhesion, cohesion, interfacial surface tension, mechanical locking into undercuts, and the peripheral seal created by the denture's fit against the mucosa.[12]

Stability refers to the denture's ability to resist dislodging forces that act laterally. It may be affected by occlusion, tooth arrangement, and the contour of the denture's polished surfaces. Stability depends on a balanced occlusion and teeth placed within the "neutral zone." Balance is achieved when the forces are evenly distributed across both sides of the arch. At the same time, the neutral zone is considered the area where the inward forces balance the outward forces exerted by the tongue forces from the cheeks.[5, 13]

Adhesion and cohesion refer to the physical forces between the denture base, the saliva film, and the oral mucosa that

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Table 1: A Historical Timeline of Impression Materials

Period	Technique/Material	Description
Pre-18th Century	Early Materials (Wood/Ivory Blocks)[8]	Artisanal approach using wooden or ivory blocks to approximate oral cavity contours. Poor fit led to consideration for more accurate impressions.
1736	Wax (Phillip Pfaff)[7, 8]	It was the first documented use of wax for sectional impressions, setting the 18th and 19th centuries standard.
1782	Wax and Plaster of Paris (William Rae)[8]	The early use of gypsum marks an advanced technique using wax pressed into gums, followed by casting in plaster of Paris.
1842-1848	Gutta-Percha[7, 8]	The discovery and application of gutta-percha improved the accuracy and quality of impressions.
19th Century	Wax and Plaster Wash (Franklin)[8]	A two-step process uses wax for initial impressions, followed by a plaster wash for more precise capturing of oral anatomy.
1907	Modelling Plastic Compounds (Greene Brothers)[8]	Introduction of plastic compounds used with a closed-mouth technique for controlled and consistent impressions.
1920s	Fluid Wax Compounds (Everett)[8]	Using fluid waxes to replicate fine oral tissue details lays the groundwork for more sophisticated materials.
1920s-1930s	Alginate and Agar[8]	Revolutionised impressions with satisfactory detail capture, though alginate required quick handling due to instability.
1930	Zinc Oxide-Eugenol (ZOE)[8]	It was developed for stable, highly detailed impressions, overcoming the limitations of earlier materials.
1950s	Polysulfide Rubber[8]	The first elastomeric material offers excellent flow properties and high accuracy, but drawbacks include unpleasant odour and long setting time.
1960s	Polyether[7]	It provides shorter setting times, better patient comfort, and rigidity, making it ideal for high-precision full-arch impressions.
1970s	Polyvinyl Siloxane (PVS)[9]	They combined high accuracy, good flow characteristics, and dimensional stability, becoming a widely used material in dental practices.
1980s-Present	CAD/CAM Systems[3, 10, 11]	Digital technology should be integrated into dental practices to create digital impressions, offer reduced treatment times, reduce appointments, and improve patient comfort.

help hold the denture in place. Interfacial surface tension and a well-formed peripheral seal contribute to retention by creating a suction/vacuum between the denture and the mucosa.[12]

Orofacial muscles: The oral and facial muscles can assist or hinder denture retention. Properly designed dentures need to consider the physiological movement of these muscles at rest and during function. Dentures must be fabricated to ensure that the muscle movements, particularly those in the lips, cheeks, and tongue, do not dislodge the denture during use. This can be achieved by ensuring special trays are moulded to the functional sulcus, and the impression captures the undistorted tissues in this state of activity.[5]

Occlusion must be carefully balanced to prevent interferences that can cause the denture to rock or shift during function. In complete dentures, this is achieved by having a bilateral balanced occlusion, with the forces evenly distributed across both sides of the denture and evenly over all the occlusal surfaces (with emphasis on posterior teeth).[5] It is also essential to have the teeth correctly positioned and arranged in the arch so that the forces of occlusion are directed along their long axes to enhance stability further.[5]

Impression Trays

Ideally, primary impressions for complete dentures are taken in stock trays, with close-fitting or spaced custom trays/special trays for secondary impressions. Stock trays are prefabricated trays of various sizes and shapes, typically made of metal or plastics, that can provide sufficient rigidity to support the impression material during setting. Early metal trays were made from Britannia metal, lead, copper, tin, silver, and pewter. While metal trays were appreciated for their strength, they also had drawbacks, such as the inability to be adjusted for individual patient needs.[8] Early non-metal stock trays were made from materials like gutta-percha or vulcanite. These trays were softer and more flexible, allowing a limited amount of customisation, and were generally used in conjunction with a final wash impression taken in plaster inside them.[8]

Custom trays are fabricated precisely for a patient's mouth based on the casts poured from the preliminary impressions. Their main advantage is their ability to replicate the entire denture-bearing area more accurately, ensuring an even thickness of secondary impression material and more detailed and precise replication of the oral structures.[14] Depending on the clinical needs, custom trays can be designed as close-fitting or spaced. The former closely matches the

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Table 2: The use, advantages, and disadvantages of the most commonly used impression materials in complete denture fabrication

Impression Material	Use	Advantages	Disadvantages
Impression Compounds [5]	They are used for border moulding and preliminary impressions.	- High viscosity - Supports itself - Compensates for under-extensions - Allows material additions	- Poor surface detail - Limited ability to capture undercuts
Irreversible Hydrocolloids [5]	They are commonly used for preliminary impressions, especially in denture fabrication and orthodontics.	- Captures fine details (e.g., alginate) - Easy manipulation - Reasonably accurate - Affordable	- Cannot absorb mucous secretions - Prone to moisture loss (requires immediate pouring) - Lack of self-supporting properties
Irreversible Hydrocolloids [15, 16]	Initially preferred by 94% of general dental practitioners [15], it was later reduced to 19% as preference shifted towards zinc oxide-eugenol and PVS [16].	- Easy to manipulate - Cost-effective	- Prone to shrinkage if not poured immediately
Elastomeric Materials [7-9]	Used for final impressions in fixed prosthodontics, removable prosthodontics, and implant dentistry.	- Excellent dimensional stability - High accuracy - Good flow characteristics	- Polysulfide: Extended setting time, unpleasant odour [8] - Polyether: Rigid (less suitable for patients with significant undercuts)
Zinc Oxide-Eugenol [5]	Primarily used for final impressions in edentulous patients.	- Creates detailed, stable impressions - Accurately captures soft tissues - Provides a firm base	- Rigid nature makes it less suitable for undercuts or the need for flexibility

final denture base, allowing clinicians to evaluate and adjust retention before taking the impression. This is beneficial in cases where retention is challenging, such as with severely resorbed mandibular ridges. However, close-fitting trays may require chairside adjustments to accommodate the impression material, making the procedure more complex.

Special trays are made by placing a 1 mm wax spacer on the cast before making the tray, creating room for the impression material. This design is easier to manage and helps ensure a uniform thickness of impression material.[5]

Impression Materials

Several impression materials can be used for primary and secondary impressions, each with properties suited to different clinical situations. Table 2 shows the most commonly used materials, their advantages, and disadvantages.

Impression Techniques

The choice of impression technique impacts the final denture's initial fit and possibly its biomechanical behaviour. For example, mucodisplasive techniques apply high pressure during impression-taking, resulting in very closely fitted dentures. In contrast, mucostatic techniques aim to capture the tissues in their passive form, minimising distortion and allowing for a more accurate representation of the ridge anatomy.[17] Regardless of the chosen technique, most clinicians agree that the trays should be adapted with judicious border moulding before making an impression. This step aims to capture the exact shape and contour of the denture borders. This process involves manipulating the peripheral muscles around the denture-bearing area to create a functional and stable impression of the borders. The goal is to record the denture margins accurately, providing a secure peripheral seal. This seal is not just technical but a key factor in enhancing retention and stability and preventing air and food particles from ingressing under the denture. It ensures the denture remains stable during speaking, chewing, and swallowing.

Some different impression methods are described below.

The Open Mouth Technique involves taking the impression with the patient's mouth open. This approach captures the tissues in a relaxed but slightly extended state. It is relatively easy to perform, making it the most commonly taught and used method in dental practice. However, because it does not capture the functional dynamics of the tissues, it may not fully represent how they function during activities like chewing and speaking. As a result, dentures made using this technique may be less stable during use.[18]

Closed mouth technique: The impression is taken with the patient's mouth closed in a biting position, attempting to capture the tissues in a functional state. It can be static or active; the latter tries to capture tissues while doing activities such as chewing and speaking. Although it is more complex and requires careful guidance of the patient's movements, it generally results in a better fit and stability of the dentures, especially in function. Despite its perceived benefits, the closed-mouth technique is less commonly taught, with only 9% of dental schools emphasising it as a standard method.[18]

Mucodisplasive, or high-pressure, impressions involve applying pressure to the oral tissues during impression-taking. The goal is to compress the soft tissues, theoretically providing a snug fit that resists displacement during function. Early advocates of the mucodisplasive techniques claimed that this method would ensure no food particles could find their way under the dentures, thereby improving

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denture comfort and stability.[6] However, there is no way of gauging how much pressure to apply, which could lead to complications. Subsequent research revealed that applying high pressure to the tissues could restrict blood flow, potentially leading to accelerated alveolar ridge resorption. This, in turn, would then compromise the long-term stability and comfort of the denture, making the techniques less favourable for complete denture fabrication.[19] Some still advocate the mucodisplasive technique in specific situations, such as the altered cast technique for free-end saddle partial dentures. In this situation, increased pressure is selectively applied to the distal edentulous ridge, which is believed to help achieve a more stable fit for the partial denture.[19]

The Mucostatic impression technique was introduced in 1937 and was designed to capture the tissues in their natural, undisturbed state without applying stress or causing displacement. It aims to record the tissues in their passive form, resulting in a denture that fits accurately without inducing pressure, distortion or accelerated resorption.[17] This approach relies on surface tension for retention, limiting the denture borders to stress-bearing mucosal areas and reducing tissue damage risk.[20] Other authors further highlighted the effectiveness of this technique in preserving the underlying tissues' health, as it minimises the forces applied during function.[21] The mucostatic technique is especially beneficial in severely resorbed ridges because it prevents tissue distortion, unlike the mucodisplasive technique.

The Selective pressure impression technique combines both the mucodisplasive and mucostatic approaches. It involves applying varying degrees of pressure across different impression areas to achieve a distribution of forces. The premise is that some areas of the maxilla and mandible are better suited to handling the forces exerted during chewing. It thus applies higher pressure to the primary stress-bearing regions, such as the posterior ridges and buccal shelves, while using less pressure on the secondary support regions, such as the anterior ridge and vestibular areas.[22] Patients with significant mandibular ridge resorption are believed to prefer dentures fabricated using this technique.[23]

Functional impressions are designed to capture the oral tissues during functions such as chewing and speaking. Lytle first described it in 1957, as he felt that traditional methods did not adequately reflect the actual condition of the tissues, leading to poor outcomes in denture fabrication.[24] Chase (1961) then introduced the concept of "dynamic adaptive stress," a two-step process that involves conditioning the tissues before taking the final impression.[25] This approach allowed for a more accurate representation of the tissues in their functional state, resulting in a better fit and greater comfort for the patient. Vig (1965) refined Chase's technique into what is now known as **functional impressions.**[26] This is also good for patients with compromised or injured tissues, where a tissue conditioner can be placed to restore health and capture a functional impression.

Modified Impression Techniques

Standard impression techniques may not be sufficient to address the many diverse intra-oral conditions. Various modifications have been developed to accommodate specific anatomical variations, compromised oral tissues, and other complexities that can affect the fit and function of dentures. One problem that is commonly experienced is the flabby anterior m*axillary ridge. This situation presents a unique challenge in denture fabrication*, as the mobile, fibrous tissue can compromise the denture's stability and retention. Several modified impression techniques have been developed and proposed to try to capture the flabby tissue in the most undistorted manner possible, thus ensuring the final denture fits well and remains stable during use.

The Flabby anterior maxillary ridge: Proposed techniques include:

- **Selective Pressure Technique:** This technique involves applying varying degrees of pressure across different areas of the maxillary ridge to capture the flabby tissue accurately while avoiding excessive compression. Custom trays allow the clinician to apply less pressure to the flabby areas and more pressure to the stable regions. One example is the Liddelow technique, which uses two different materials: the fast-setting plaster of Paris for the flabby ridge and zinc oxide-eugenol (ZOE) for the surrounding tissues. Watson modified this original concept and introduced **The "Window" Technique.** It involves creating a custom tray with a window over the flabby tissue. A mucocompressive impression is taken with ZOE, trimmed in the window area, and then re-seated in the mouth. A low-viscosity plaster of Paris mix is applied to the flabby tissue to capture it in a mucostatic manner, ensuring that the delicate tissue is not compressed.[27]
- Walter (1973) adapted the window technique by creating a composite impression using two trays. The first tray does not extend over the flabby ridge area, while the second tray fits over the first and includes perforations in the flabby region. This method involves making a selective impression with ZOE over the normal tissue, followed by a mucostatic impression of the flabby tissue with plaster of Paris.[28]
- Osborne suggested an alternative method involving using two separate trays to record the different tissues individually, thus capturing the flabby and stable tissues more precisely. The separate trays were then related intraorally after both individual impressions had been taken. He believed that this approach would optimise the denture's support and retention. It is not widely used due to its cumbersome nature and potential inaccuracies when the trays are joined.[27]
- Watt and McGregor proposed a method where an impression compound is applied to a modified custom tray to take a mucocompressive impression of the normal tissues, followed by a ZOE wash. This technique also aimed to capture the flabby tissue without compression, providing a stable base for the final denture.[27]

Fibrous Posterior Mandibular Ridge

The fibrous posterior mandibular ridge is characterised by thin, mobile, and often highly resorbable tissue. A selective pressure technique is recommended for accurately recording this ridge, ensuring that the impression captures the tissues in a way that will provide support and stability. McCord and Grant (2000) described first using a custom tray with a modelling compound to record the ridge. Once the impression is made (compound over the crestal tissues and tray material in the fibrous area), the tray is perforated in the fibrous tissue area. Light-bodied PVS is then injected onto the buccal and lingual shelves, and the tray is reintroduced to take a mucostatic impression, allowing excess material

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to extrude from the perforated tray.[29] This technique helps create a stable and comfortable denture by minimising the pressure on the delicate ridge tissues.

Neutral Zone Technique: The neutral zone technique, introduced by Beresin and Schiesser (1976), focuses on capturing not only the denture-bearing area but also the muscle function that shapes the external surface of the denture. This technique benefits patients with severely resorbed ridges or compromised muscle tone, where conventional impression techniques may not be sufficient to achieve a stable denture. In the neutral zone technique, a closed-mouth impression is taken in a specialised tray and modified by adding occlusal rims made from a modelling compound. The patient performs functional movements, such as speaking, swallowing, and sucking, during the impression-taking process to ensure that the dynamic forces of the surrounding musculature shape the denture fitting surface as well as the occlusal rims. [13] This approach allows teeth to then be placed in that area where the outwards forces of the tongue are balanced by the inwards forces exerted by the cheeks, thus resulting in a denture that is well adapted to the patient's unique oral environment and will potentially be more stable during function.

Microstomia or limited mouth opening presents many challenges when fabricating removable prostheses. This condition may arise from various causes, including radical surgery, cleft lips, maxillofacial trauma, radiotherapy, scleroderma, or facial burns. The complexity of creating dentures for patients with microstomia requires innovative approaches to impression-taking.

- Walter (1973) described a **split tray technique** for final impressions. The two tray segments are aligned by their handles. The first segment, which includes a perforated stalk, is inserted into the patient's mouth, and the second segment is then locked into place using a peg that slides through the perforation.[28]

- Cura *et al.* (2003) outlined using a **sectional foldable custom tray** with four stabilisation pins. This tray design allows it to be introduced and seated as a single piece, folded horizontally for the mandible, or as two separate pieces stabilised intraorally with an acrylic resin block for the maxilla.[30] Benetti et al. (2004) proposed fabricating a collapsible maxillary overdenture for patients with microstomia.[31] (Figure 1, above).

Technique for fabrication of Suction-Effective Mandibular Dentures:

To create a mandibular denture with effective suction, it is essential to understand the principles behind suction and how to implement them clinically. The most challenging aspect is achieving a posterior seal, particularly around the retromolar pad. This tissue is prone to deformation from pressure during impression-taking and tends to dislodge the dentures during regular mouth movements. Overcoming this requires precise techniques and tools. Kokubo and Abe described a multi-stepped technique that may be used to obtain a good peripheral seal in mandibular dentures. The process is complex, using precisely modified, well-fitting special trays and different materials during each stage. The fundamental premise is that this functional impression will help enhance suction by ensuring that there is sufficient thickness of material in the sublingual and buccal shelf areas for suction and thicker borders in the labial region for adequate lip support and stability, as well as correct recording and capturing of the buccal tongue contact (BTC) area, to ensure there is a peripheral seal. [32]

Digital Dentures

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 physical 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.[33] 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.[10] This new fabrication process will be discussed in Paper 2.

Conclusion

Over the years, various impression techniques and materials for denture fabrication have been developed. Advances were based on a deep understanding of oral anatomy and the desire to preserve the integrity of soft tissues while ensuring a stable and retentive fit for the prostheses. The selection of the appropriate impression materials and technique directly influences the biomechanics of the final denture. It is fundamental to producing more detailed and accurate impressions that better serve patient needs.

The field of removable prosthodontics is poised for further advancements as digital technology continues to evolve. Integrating artificial intelligence, machine learning, and 3D printing can enhance the customisation and efficiency of denture fabrication, offering even greater precision and personalised care. As these technologies become more accessible and widely adopted, they will likely set new quality and patient satisfaction standards. The future of removable prosthodontics lies in the seamless integration of these innovations, supported by rigorous research and collaboration among dental professionals, leading to better clinical outcomes, higher patient satisfaction, and continued advancements in the art and science of denture fabrication. [2, 3, 10]

REFERENCES

1. Kawai Y, Murakami H, Shariati B, Klemetti E, Blomfield JV, Billette L, et al. Do traditional techniques produce better conventional complete dentures than simplified techniques? *Journal of Dentistry.* 2005;33(8):659-68.
2. Carlsson G, Omar R. The future of complete dentures in oral rehabilitation: A critical review. *Journal of Oral Rehabilitation.* 2010;37(2):143-56.

www.sada.co.za / SADJ Vol. 80 No.8
https://doi.org/10.17159/sadj.v80i07.20944

3. Kattadiyil MT, Jekki R, Goodacre CJ, Baba NZ. Comparison of treatment outcomes in digital and conventional complete removable dental prosthesis fabrications in a predoctoral setting. *The Journal of Prosthetic Dentistry.* 2015;114(6):818-25.
4. Denen H. Impressions for full dentures. *The Journal of Prosthetic Dentistry.* 1952;2(6):737-45.
5. Zarb GA, Hobkirk J, Eckert S, Jacob R. Prosthodontic treatment for edentulous patients: complete dentures and implant-supported prostheses. *Elsevier Health Sciences.* 2012.
6. Fournet SC, Tuller CS. A revolutionary mechanical principle was utilised to produce full lower dentures that surpass the stability of the best modern upper dentures. *The Journal of the American Dental Association (1922).* 1936;23(6):1028-30.
7. Rao S, Chowdhary R, Mahoorkar S. A systematic review of impression techniques for conventional complete dentures. *The Journal of Indian Prosthodontic Society.* 2010;10(2):105-11.
8. Zinner ID, Sherman H. An analysis of the development of complete denture impression techniques. *The Journal of Prosthetic Dentistry.* 1981;46(3):242-9.
9. Al-Ahmad A, Masri R, Driscoll CF, Von Fraunhofer J, Romberg E. Pressure generated on a simulated mandibular oral analog by impression materials in custom trays of different designs. *Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry.* 2006;15(2):95-101.
10. Saponaro PC, Yilmaz B, Johnston W, Heshmati RH, McGlumphy EA. Evaluation of patient experience and satisfaction with CAD-CAM-fabricated complete dentures: A retrospective survey study. *The Journal of Prosthetic Dentistry.* 2016;116(4):524-8.
11. Carlsson GE, Örtorp A, Omar R. What is the evidence base for the efficacies of different complete denture impression procedures? A critical review. *Journal of Dentistry.* 2013;41(1):17-23.
12. Levin B. Impressions for Complete Dentures. *Quintessence Publishing Company.* 1984.
13. Beresin VE, Schiesser FJ. The neutral zone in complete dentures. *The Journal of Prosthetic Dentistry.* 1976;36(4):356-67.
14. Jaggers JH, Javid NS, Colaizzi FA. Complete denture curriculum survey of dental schools in the United States. *The Journal of Prosthetic Dentistry.* 1985;53(5):736-9.
15. Hyde TP, McCord JF. Survey of prosthodontic impression procedures for complete dentures in general dental practice in the United Kingdom. *The Journal of Prosthetic Dentistry.* 1999;81(3):295-9.
16. Al-Ahmar A, Lynch CD, Locke M, Youngson C. Quality of master impressions and related materials for fabrication of complete dentures in the UK. *Journal of Oral Rehabilitation.* 2008;35(2):111-5.
17. Addison PI. Mucostatic Impressions. *The Journal of the American Dental Association.* 1932;31(13):941-6.
18. Petropoulos VC, Rashedi B. Current concepts and techniques in complete denture final impression procedures. *Journal of Prosthodontics.* 2003;12(4):280-7.
19. El-Khodary N, Shaaban N, Abdel-Hakim A. Effect of complete denture impression technique on the oral mucosa. *The Journal of Prosthetic Dentistry.* 1985;53(4):543-9.
20. Salinas TJ. Treatment of edentulism: optimising outcomes with tissue management and impression techniques. *Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry.* 2009;18(2):97-105.
21. Bohannan HM. A critical analysis of the mucostatic principle. *The Journal of Prosthetic Dentistry.* 1954;4(2):232-41.
22. Frank RP. Analysis of pressures produced during maxillary edentulous impression procedures. *The Journal of Prosthetic Dentistry.* 1969;22(4):400-13.
23. Hyde T, Craddock H, Blance A, Brunton P. A crossover randomised controlled trial of selective pressure impressions for lower complete dentures. *Journal of Dentistry.* 2010;38(11):853-8.
24. Lytle RB. The management of abused oral tissues in complete denture construction. *Preventive Dentistry: Syllabus.* 1962:451.
25. Chase WW. Tissue conditioning utilising dynamic adaptive stress. *The Journal of Prosthetic Dentistry.* 1961;11(5):804-15.
26. Vig RG. A modified chew-in and functional impression technique. *The Journal of Prosthetic Dentistry.* 1964;14(2):214-20.
27. Lynch C, Allen P. Management of the flabby ridge: using contemporary materials to solve an old problem. *British Dental Journal.* 2006;200(5):258-61.
28. Walter JD. Composite impression procedures. *The Journal of Prosthetic Dentistry.* 1973;30(4):385-90.
29. McCord J, Grant A. Impression making. *British Dental Journal.* 2000;188(9):484-92.
30. Cura C, Cotert HS, User A. Fabrication of a sectional impression tray and sectional complete denture for a patient with microstomia and trismus: A clinical report. *The Journal of Prosthetic Dentistry.* 2003;89(6):540-3.
31. Benetti R, Zupi A, Toffanin A. Prosthetic rehabilitation for a patient with microstomia: A clinical report. *The Journal of Prosthetic Dentistry.* 2004;92(4):322-7.
32. Kokubo K, Abe J. Effective mandibular dentures. 2014.
33. Thu KM, Molinero-Mourelle P, Yeung AWK, Abou-Ayash S, Lam WYH. Which clinical and laboratory procedures should be used to fabricate digital complete dentures? A systematic review. *The Journal of Prosthetic Dentistry.* 2023.

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

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1. COMPARISON OF DENTAL CURING UNITS AND OUTPUT MODES REGARDING RADIANT FLUX, TIP DIAMETER, RADIANT EMITTANCE, SCATTERING, AND PENETRATION DEPTH

Dental light-curing units (LCU) are important parts of the photocuring process of resin-based composite (RBC) materials, yet the specifications and the proper use of the LCU to achieve success in restorative procedures are often overlooked in daily practice[1] . Although adequate light curing is required for the RBCs to reach the manufacturer's intended properties and thereby long-term clinical success, it is not the only potential reason for failure[1]. Other than the exposure time, the parameters related to the clinical application procedure," such as the inclination of the light tip, the distance of the tip to the restoration surface of the RBC, the location of the restoration, and even the morphology of the restoration surface all may influence the clinical success[1]. In addition, the mechanical and optical properties of the RBC may affect the quality of polymerization, thus having an important effect on the outcome[1] . However, among all these mentioned clinical parameters, clinicians often downplay the parameters related directly to the light-curing unit (LCU), such as the quality and the features.

Light-emitting diodes (LEDs) are the most often used sources in dental LCUs. LED devices are smaller and deliver better luminous efficacy compared to the other light sources, and they can produce light with less heat generation. The parameters related directly to the light-curing unit (LCU) can also significantly impact polymerization of the RBC, hence impacting on clinical outcome measures such as sensitivity, longevity, etc. Some of these features include:-

Radiant flux refers to the total power of light emitted by the curing unit, measured in milliwatts (mW). High-power LCU output modes (radiant flux >1,000mW) deliver more energy than low-power modes. The choice of output mode significantly impacts the total energy delivered, which in turn affects polymerization quality and depth.

The Tip diameter determines the area of coverage: a larger tip diameter can cover broader restorations in a single exposure, reducing the risk of unpolymerized regions. Even small changes in active tip diameter produce large changes in radiant emittance (power per unit area). Narrower tips can create intense "hot spots," risking uneven curing or tissue damage.

Radiant emittance (also called irradiance, mW/cm^2) is calculated from radiant flux divided by the tip area. Greater radiant emittance is positively correlated with deeper light penetration and more effective polymerization.

Light scattering refers to the spread and diffusion of curing light as it exits the LCU tip and passes through dental tissues or restorative materials. Scattering negatively correlates with radiant emittance, tip diameter, and penetration depth, meaning more scattering reduces the effective curing depth and energy reaching deep layers.

Penetration depth—how far light efficiently reaches into the resin-based composite—is critical for optimal curing, especially for "bulk fill" materials designed for 4mm+ cure depths. Greater penetration depth can be expected with higher radiant emittance and larger tips. Top-quality LCUs provide energy that penetrates deeply and uniformly. Depth of cure assessments often compare the bottom hardness to the top (aiming for >95% relative bottom/top hardness), and under-cured regions can be revealed through solvent testing or hardness profiles.

Table 1 provides a summary of these concepts and their clinical importance

Table 1: Important features in your Light Curing Unit to consider before purchase

Factor	Impact on Curing	Clinical Importance
Radiant Flux	Higher flux = more total energy; boosts cure depth	Fast, deep, uniform curing of restorations
Tip Diameter	Larger tip = wider coverage; less risk of missed spots	Match to restoration size for effective curing
Radiant Emittance	Higher irradiance = deeper, more complete cure	Prevents undercured regions, reduces failures
Scattering	More scattering = less penetration, more energy loss	Minimize with optimal tip design/materials
Penetration Depth	Determines how thick a layer can be polymerized	Bulk-fill composites require 4mm+ effective curing

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Korkut and colleagues (2025)[1] reported on a study that compared 10 dental LED polymerization devices and the curing modes quantitatively in terms of radiant flux, spectral emission, radiant emittance, tip diameter, scattering, and related penetration depth. The hypotheses (h1) of the study were: (I) The calculated radiant emittances based on the measured internal tip diameter deviate beyond ±10% of the manufacturers' stated radiant emittances, (II) The radiant emittance and internal tip diameter have positive correlations with the total penetration depth of the dental light-curing devices, (III) Different output modes of the same LCU present significantly different scattering and penetration depth values.

Materials and methods

The radiant flux, spectral emission, radiant emittance, light source width, beam light scattering degree, main penetration depth (MPD), and total penetration depth (TPD) of ten different, brand-new LED light-curing units and different curing modes were quantitatively compared. All the LCUs were in class 2 and type 2 classification, and only the continuous irradiation modes were examined according to the ISO standards. The LCUs and exposure modes are listed in Table 2

A laboratory-grade spectroradiometer, also called the MiniGig radiometer, was used to measure the output from the LCUs. This spectroradiometer measures the radiant flux and the emission spectrum [11] between 360 nm and 830 nm, with a claimed accuracy of ± 4%. Before the measurements, the MSC15-W was calibrated by Gigahertz-Optik's calibration laboratory for spectral responsivity and radiant emittance according to ISO/IEC 17,025. A single operator performed three measurements for each device/curing mode.

The internal tip diameters were measured by a single operator using a digital caliper by placing it at the inner ends of each curing unit's glass tip. It was performed to check if the real tip diameter agrees with the manufacturer's declared one. Then the measured internal tip diameter for each LCU was entered into the meter software. The data from each LCU were exported as an.xlsx file. Then, ten different dental LCUs and output modes were divided into two main groups as high-power and low-power, according to the measured radiant flux (mW) values. Although there is no classification of the LCUs regarding the radiant flux values in the literature, the grouping was needed to perform the statistical analyses more accurately and to observe the possible significant differences between the LCUs. Following many manufacturers' recent polymerization recommendations for the resin-based restorative materials, 1000 mW was considered as the border between the two groups. The LCUs/output modes emitting

Table 2

LED Light-Curing Unit	Emission	Wavelength Region (nm)	Curing Mode	Manufacturer	Serial Number
SmartLite Pro	Single Peak	450–480	Standard	Dentsply Sirona	H04545
Ruby	Single Peak	385–515	P1 P2	Inci Dental	MC7AB0051
Valo Grand	Multi Peak	385–515	Standard Power High Power Plus Xtra Power	Ultradent Products	S14404
Valo Cordless	Multi Peak	395–480	Standard Power High Power Plus Xtra Power	Ultradent Products	S41744
Valo X	Multi Peak	380–515	Standard Power Xtra Power	Ultradent Products	3F001580
Woodpecker Led B	Single Peak	420–480	Standard	Guilin Woodpecker Medical	L14A0373E
Elipar DeepCure-S	Single Peak	430–480	Standard	3 M ESPE	6741744
Bluephase PowerCure	Multi Peak	385–515	H T 3 S	Ivoclar Vivadent	1428009403
Bluephase N	Multi Peak	385–515	Low High	Ivoclar Vivadent	1020014381
D-light Pro	Multi Peak	400–480	LP	GC Corp.	0419

radiant flux above 1000 mW were included in the high-power group, while the rest were in the low-power group.

The radiant flux data collected by the spectroradiometer were used to calculate two different radiant emittance values for each LCU/curing mode and compared to the radiant emittance stated by the manufacturer. One was calculated using the indicated tip diameters, and the other was calculated using the measured internal tip diameters of the LCUs. The calculations used the radiant flux (mW)/tip area (cm^2). Also, the difference in percentage (%) between the manufacturer's stated radiant emittance and the radiant emittance by the measured internal tip diameter was calculated for each LCU/curing mode to assess the deviation from the indicated radiant emittance.

The features of the light-curing units, such as light source width, scattering, and penetration depth (MPD and TPD), were also evaluated using two-dimensional (2D) high-resolution macro photographs of the light paths through a 0.005% solution of Rhodamine B.

Results

Regarding the spectroradiometer results, the Valo Cordless, Valo Grand, Valo X, and Bluephase PowerCure were multiple-emission peak LED units that delivered a broader spectrum of light, while the Ruby had a single-emission peak LED. Of note, the violet emission was greater for the Valo units compared to the Bluephase. The measured internal tip diameters were different than the stated diameters for all LCUs except the Valo X device, which remained the same. The Valo X Xtra Power mode delivered the highest radiant flux value (2704 ± 5^{B}), followed by the Valo Grand Xtra Power mode (2576 ± 6^{F}) and Valo Grand High Power mode (1929 ± 10^{E}), respectively. The lowest radiant flux was from the Valo Grand Standard Power mode (1148 ± 5^{D}). Regarding both the calculated radiant emittances based on the manufacturer's stated tip diameter and the measured internal tip diameter, the Bluephase PowerCure 3 S mode delivered the highest radiant emittances (2312 ± 15.5^{A} and 2719 ± 18.5^{a}, respectively), followed by the Valo Grand Xtra Power mode (2278 ± 5.51^{B} and 2316 ± 5.51^{b}, respectively) and Valo X Xtra Power mode (2203 ± 4^{C} and 2203 ± 4.51^{c}, respectively). The Valo Grand Standard Power mode delivered the lowest radiant emittance (1015 ± 4.4^{H} and 1032 ± 4.51^{h}, respectively) for both calculations. The Valo Grand Xtra Power mode had the largest deviation from the stated radiant emittance (27.6% lower), followed by the Ruby P1 mode (21.3% lower). The Valo X Xtra Power mode (0.2% higher) and Valo X Standard Power mode (0.7% lower) were the devices/curing modes with the smallest deviation from the stated radiant emittance.

Regarding the image processing results for the LCUs, the greatest light source width was from the Valo X device Extra Power mode, while the lowest was observed for the Woodpecker Led B device ($P<.001$) (Table 4). The greatest scattering was from the Bluephase PowerCure device 3 S mode, and the lowest was from the Valo X device Extra Power mode ($P<.001$). The Valo X in the Extra Power mode had the highest MPD and TPD among all ($P<.001$). The lowest MPD was observed for the D-Light Pro device Low Power mode, and the lowest TPD was observed for the Bluephase PowerCure device 3 S mode.

Regardless of the light-curing unit brand or curing mode, positive very strong correlations were observed for Total penetration depth (TPD), light source width, and radiant emittance ($P<.001$). Also, the TPD and the measured internal tip diameter were positively correlated at a moderate level ($P<.001$). However, scattering had a negative correlation with the TPD ($P=.014$). The measured internal tip diameter had a very strong positive correlation with the light source width ($P<.001$). A positive, strong correlation was also found between the light source width and radiant emittance ($P<.001$). Radiant emittance and scattering had a negative correlation ($P=.003$), likely the scattering and tip diameter ($P=.007$). A weak negative correlation was found between the measured internal tip diameter and the radiant emittance ($P<.001$)

Conclusions

Dental LCUs should be selected for clinical use by considering some specific features. The radiant emittance can deviate from the manufacturer's stated values by up to 27.6%. Regular measurements for the radiant emittance by a spectroradiometer are recommended to assess the amount of deviation, adjust the curing time accordingly, and thereby calibrate the clinical curing dose. Greater penetration depth can be expected when using LCUs with greater radiant emittance and tip diameter. The curing mode was considered ineffective on the scattering pattern of the light beam.

Implications for practice

Effective light-curing is a complicated clinical procedure in dentistry requiring many parameters. There might be some deviations in these features from the manufacturer's stated values. Clinicians should select the LCUs by considering the radiant flux, tip diameter, radiant emittance, light scattering, and penetration depth features to succeed in clinical restorative procedures.

REFERENCE

1. Korkut, B., Saygili, C.C., Murat, N. *et al.* Comparison of dental curing units and output modes regarding radiant flux, tip diameter, radiant emittance, scattering, and penetration depth. *Clin Oral Invest 29*, 395 (2025). https://0-doi-org.innopac.wits.ac.za/10.1007/s00784-025-06482-3

2. SPACE CLOSURE AFTER PREMOLAR EXTRACTION USING CLEAR ALIGNERS: A SYSTEMATIC REVIEW WITH META-ANALYSIS

There is substantial evidence from clinical studies and systematic reviews that space closure following premolar extractions in orthodontics is a well-studied and effective phase of treatment. Space closure after premolar extraction is recommended in various situations, such as severe crowding, unilateral agenesis, bimaxillary protrusion, convex facial profiles, and significant cephalometric discrepancies. The most common method for space closure following premolar extraction involves canine distalization and, in some cases, the first premolar, followed by anterior teeth retraction (ATR). This process requires effective anchorage control of molars and, occasionally, second premolars. Distalization, ATR, and anchorage control involve complex movements, such as inclinations, extrusion, torque, rotations, and translation of the teeth. Precise clinical execution is essential to prevent unwanted movements and ensure effective treatment.

Space closure using various orthodontic mechanics, such as en masse retraction (ER) or two-step retraction (TSR), is

generally effective but the time required for closure varies. ER tends to close spaces faster than TSR, with studies reporting closure times ranging from several months up to a year or more depending on technique and patient factors. Bodily movement of teeth to close premolar extraction spaces presents challenges, particularly when using clear aligners, which may be less predictable in producing bodily tooth movement compared to fixed appliances. Stability of space closure and relapse tendencies after treatment have been studied, with some evidence showing relapse can occur, though careful retention and treatment planning mitigate this risk.

Several pre-post studies and clinical trials evaluated the effectiveness of clear aligners in space closure after premolar extraction. Most studies investigated the Invisalign® G6 protocol system, which was specifically designed by Align Technology® to enhance ATR and anchorage control. G6 protocol has optimized retraction and anchorage attachments to maximize posterior anchorage and canine bodily movement. The ATR occurs after 1/3 of canine retraction, and clear aligners are designed to avoid tipping and extrusion of anterior teeth [2]. However, studies suggest that clear aligners can lead to various unwanted effects during space closure, such as crown tipping, extrusion of anterior teeth, and loss of anchorage of molars and second premolars. Invisalign offers patients the advantage of removability, which improves oral hygiene and comfort during extraction space closure, but it requires good compliance for effective results. Thus, clinical evidence supports Invisalign's use for space closure after premolar extraction, though treatment time and success may vary depending on case complexity, and sometimes fixed appliances might be preferred for difficult cases. Due to the high demand for space closure following premolar extraction and for clear aligners' treatment, *Vicioni-Marques et al (2025)[1] and colleagues undertook a* systematic review that sought to synthesize the available evidence from clinical trials and pre-post observational studies to evaluate the efficacy, predictability, and resistance to unwanted tooth movement of clear aligners in space closure after premolar extraction.

Methods

This systematic review was conducted using Cochrane and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The research question was developed using the PICOS format as follows:

- P (Population): Orthodontic patients during permanent dentition requiring extraction of upper or lower first or second premolars.
- I (Intervention): Space closure after premolar extraction using clear aligners.
- C (Comparison): Pre-treatment (pre-post studies), fixed orthodontic appliances, or different computer-aided techniques.
- O (Outcome): Efficacy and predictability of computer-aided techniques in space closing after premolar extraction, focusing on effects on canines, molars, anterior teeth, and resistance to unwanted tooth movement.
- S (Study design): Pre-post observational studies or randomized and non-randomized clinical trials (quasi-experiments).

Narrative reviews, case reports, in vitro, in situ (finite models), opinion articles, and studies that included patients with genetic syndrome and facial malformations were excluded.

The literature search was carried out until November 12, 2024, in five databases (PubMed, Web of Science, Embase, Scopus, Cochrane Library). The gray literature was searched using Google Scholar. Additional studies were identified from the reference list of the included studies. The search strategy was structured.

The selection of articles for possible inclusion involved screening titles and abstracts. Manuscripts meeting the eligibility criteria were retrieved for full-text evaluation. Finally, manuscripts that did not meet the established selection criteria after full-text evaluation were excluded.

The data extraction process was carried out independently by three reviewers. Data collected from each article included: included: the authors, year of publication, study design, clinical setting, sample characteristics, intervention, including clear aligner brand, duration of treatment, and control group, when applicable, methods of evaluation, results, and conclusion.

The Cochrane risk-of-bias tools were used to assess the quality of the included studies. The analysis was conducted by two authors, and any disagreements were resolved by a third reviewer. The ROBINS-I tool was applied to non-randomized studies (pre-post studies and non-randomized clinical trials). For randomized clinical trials, the ROB-2 tool was used.

Meta-analysis was only attempted where data were comparable. The heterogeneity among studies was evaluated using I^2. Due to the pre-post design of studies included in the meta-analysis, the Standardized Paired Difference (SPD) estimated the effect size.

A detailed qualitative synthesis of the evidence of the included studies was performed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE). This tool considered aspects such as the type of study, risk of bias, consistency, directness, and precision of the articles.

Results

The systematic search identified 900 records, including 888 articles and 12 registrations. A total of 23 manuscripts were selected for full-text evaluation of which14 articles, encompassing 510 participants were selected for inclusion. The selected articles were published from 2008 to 2024, all in English.

Four studies had a low risk of bias, while ten had a high risk of bias. The results from pre-post studies indicated that clear aligner treatment was significantly less effective than predicted in achieving Anterior Teeth Retraction (SPD= -0.87; 95% CI = -1.15 to -0.60; 95% PI= -1.14 to -0.59; $p<0.001$; number of studies=4), resulting in more lingual tipping (SPD=1.09; 95% CI=0.46 to 1.73; 95% PI= -1.01 to 3.19; $p=0.001$; number of studies=3) and extrusion of anterior teeth (SPD=0.88, 95% CI=0.47 to 1.29; 95% PI= -0.16 to 1.92; $p<0.001$; number of studies=4) than predicted. The achieved distal tipping of canine (SPD=1.42; 95% CI=0.35 to 2.51; 95% PI= -2.5 to 5.40; $p=0.009$; number of studies=3) and mesial tipping of first molars (SPD=1.68; 95% CI=1.17 to 2.20; 95% PI=0.34 to 3.01; $p<0.001$; number of studies=3;) were also greater than predicted. Clinical trials comparing clear aligner treatment and fixed appliances provide limited evidence.

Conclusion

The findings suggest that clear aligner treatment may not be effective or predictable for space closure following premolar extraction due to its limited capacity to promote the bodily movement of the teeth and control anchorage. *Evidence indicates that fixed appliances might be superior to clear aligner treatment.* Limitations of the evidence include bias across studies, with the certainty of evidence ranging from low to very low. Future research should focus on improving prediction models and exploring the potential benefits of accessories to enhance clear aligner treatment effectiveness.

Implications for practice:

The need for patient demands for clear aligner treatment must be balanced by patients compliance and motivation to use appliance and individual factors such as oral hygiene concerns. However, it is important that the clinicians inform patients of all options and the evidence of efficacy thereof.

REFERENCE

1. Vicioni-Marques, F., Reis, C.L.B., de Almeida, A.P.V. *et al.* Space closure after premolar extraction using clear aligners: a systematic review with meta-analysis. *Clin Oral Invest* 29, 435 (2025). *https://0-doi-org.innopac.wits.ac.za/10.1007/s00784-025-06475-2*

Treating friends and family

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Y Naidoo, Z Sonday

As clinicians in training, many will recall the adage "Treat your patient as you would your mother or your child" being passed on to us as words of wisdom from our seniors.
While the concept is powerful and important in the context of patient empathy and care, it should be clear that this saying does not seek to encourage us to actually treat our mothers or family members as patients.

The law vs reality

At the outset, we must make it clear that there is no law or regulation in South Africa which says that healthcare practitioners are not allowed to treat friends and family as patients. Technically, any such law or regulation would be unlikely to pass constitutional muster on the one hand, and probably unreasonably encroach on a patient's right to autonomy on the other.

But quite apart from these legal and ethical technicalities, perhaps the regulator and the lawmakers have deliberately been silent on this issue for another reason, and that is, the reality of South African society.

That reality is one of a resource-constrained, largely poor population, for many of whom access to healthcare is scarce and limited. In some communities, there may only be a single dentist who is required to serve thousands of patients. Some of those patients may well be friends and family members.
So, to say to a practitioner as a blanket rule that you must not or should not treat friends and family, especially where there is no other choice, would simply not be conscionable or practical in South Africa.

Despite there being no rule against it, and despite the nature of the society in which we live, we would nonetheless caution against treating friends and family as patients – and we say this fully conscious of the unique circumstances which prevail in our country. Let us explain why.

The risks of treating family and friends

When you take on a family member or friend as a patient – even for a simple prescription – you create an additional type of relationship between you and that person. Initially, it was a personal relationship which is not governed by any laws related to your profession, or regulations created by the Health Professions Council of South Africa (HPCSA).

But, when you take on the additional responsibility of providing healthcare to the friend or family member, you create an additional relationship with them: a professional relationship. And with this comes the added obligations and responsibilities imposed on you by the HPCSA and all relevant laws applicable to your profession.

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Once that professional relationship is established, you will be expected to adhere to the same standards and rules as would be applicable to any of your patients. For example, the National Health Act read with the HPCSA's ethical guidelines would compel you to keep records of your interactions with the patient, and include certain compulsory elements as stipulated by the HPCSA.

Those records will need to be kept safely and be accessible to the patient or authorised third parties if necessary in future. One of the compulsory elements of a patient health record is the full biopsychosocial history of a patient, including allergies and idiosyncrasies. Think about an occasion when a friend or family member may have sought your clinical care formally rather than in a casual manner – would you have complied with these basic requirements?

The newly established dual relationship brings with it a myriad of professional responsibilities and obligations. When you see a friend or family member as a patient, your objectivity may be compromised due to your close personal relationship. You may be driven to go to lengths that you would not ordinarily do.

While you may see this as your acting in the patient's best interests, you must bear in mind that one of the HPCSA's rules is that a practitioner may only perform acts for which they are adequately educated, trained and sufficiently experienced, and under proper conditions and in appropriate surroundings. Going the extra mile for a friend or family member may unwittingly take you beyond those bounds – a contravention of the HPCSA's rules.

We would all like to believe that we would never be faced with dentolegal challenges as a result of treating family and friends. Yet, when things go wrong those relationships often become insignificant in the face of an adverse clinical outcome. At Dental Protection we have seen these best intentions come back to haunt practitioners in a number of cases.

Case studies

In one case, a dentist prescribed a topical cream for a friend who was suffering from a skin condition totally unrelated and far removed from the friend's oral or peri-oral area (which is the area that falls under the scope of practice of dentistry). This was done in December, when the friend could not get hold of their dermatologist due to it being the holiday season. The dentist acted compassionately to help a friend in need.
A few years later, when the friendship broke down, the friend lodged a complaint with the HPCSA against the dentist, alleging that the dentist had prescribed treatment outside the scope of practice of a dentist.

In a separate matter, also involving the prescription of medication by a dentist, the HPCSA was once again called upon to discipline the dentist. In that case, a pharmacist declined to fulfil a script by the dentist for certain chronic medication which the dentist had written for a close family

member. The pharmacist's reason for declining, was that the medication prescribed fell outside the scope of a dentist.

The reason why we point out the examples above is to illustrate that, no matter how helpful you may think you are being at the time, you open yourself up to several risks despite no doubt wanting to act in what might seem at the time to you as, your friend's or family's best interests.

Stepping over the line

When asked to treat someone close to you, it is wise to stand back and relate the situation to where on the spectrum the individual's health issue sits.

There are clearly times where it might be reasonable to assist, for example arranging an urgent referral or providing appropriate over-the-counter medication for temporary relief when a family member has an acute dental concern while on holiday. However, it may not be advisable to undertake or continue comprehensive dental treatment for someone close to you on an ongoing basis.

One way to avoid such dilemmas is for all dental professionals to ensure that both themselves and their families have a family GP.

'No, not ever'

Then there are those situations where we are all agreed that dental practitioners must not treat themselves, their families, or those close to them. This would include situations which involve prescribing or administering controlled drugs and those with a risk of addiction or misuse, prescribing psychotropic medication, undertaking psychotherapy or performing invasive procedures. You should also avoid issuing certificates or undertaking dental assessments for third parties.

Some practical steps when considering treating friends or family

1. Be open and honest with the person seeking assistance

Explain the nature of a dentist-patient relationship versus that of a personal relationship. Set out the benefits and risks of the former to both parties. Be clear on what it is they expect from you and be candid as to any potential concerns. Expectation management is critical, outline the limits of your scope and if you cannot reasonably meet the patient's expectations, you should say so and offer to refer to an appropriate clinician.

2. Formalise the dentist-patient relationship

Irrespective of the nature of the underlying connection as either friend or family, when medical advice is sought you are acting in your professional capacity. This must be distinguished and be sperate from a casual, social interaction. A professional interaction assists with maintaining objectivity in assessment, diagnosis, and decision-making. As such, you are now professionally accountable for your actions and in so doing, you are safeguarding both parties.

3. Keep clinical records

Whether the initial request for assistance came at a birthday party on the weekend or via a WhatsApp message, you should keep some form of documentation of the interaction including the presenting complaint or concern, the advice provided, and prescriptions written.

Make it clear from the outset that you will keep records as required by the HPCSA, and that these will be stored securely for future access as needed. Again, this serves to cement the formality of the relationship, and may help to ensure that the patient understands the need to be open, honest and candid with you at all times, and that you will refer to prior interactions with them as and when necessary.

4. Conduct

When consulting or advising family and friends, your conduct regarding history taking, examination and consent procedures should be no different from when you are consulting an unrelated patient in your rooms. An important practical first step is to be objective, which requires an enormous amount of self-awareness. As a practitioner, you should be able to recognise your capabilities, know your limitations and understand that certain requests are inappropriate. If the request from a family member or friend makes you feel uncomfortable– stop. Interrogate the unease.

You should not be providing services or advice to any patient, including family and friends, that fall outside your expertise and scope of practice. Understand that the notion of feeling unwell to being diagnosed with disease is a spectrum, carefully consider where on that spectrum you would best serve the 'patient'.

You are accountable

Ultimately, it will be for the practitioner to account for their decisions and actions. It is important that any current guidance is consulted, understood and borne in mind when deciding whether or not to give advice or offer treatment.

Where you do decide to prescribe or treat someone close to you, it is vital that you document what has been done and why, and notify the individual's GP as soon as reasonably possible. Should the decision be called into question, good record-keeping and communication will greatly assist in justifying your actions.

CPD questionnaire on page 454

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

Oral Health-Related Quality of Life (OHRQoL) of Oral Squamous Cell Carcinoma (OSCC) patients.

1. **Select the CORRECT answer. Which tool was used in this study to measure oral health-related quality of life (OHRQoL) among oral squamous cell carcinoma (OSCC) patients?**
   - A. University of Washington QoL Scale
   - B. Oral Impact on Daily Performances (OIDP)
   - C. Oral Health Impact Profile (OHIP-14)
   - D. WHO Quality of Life Assessment (WHOQOL)

2. **Which option is CORRECT. What was the most frequently reported site of OSCC in the study population?**
   - A. Tongue
   - B. Buccal mucosa
   - C. Lip
   - D. Soft palate

3. **Which is the CORRECT option. Which OHIP-14 domain had the greatest negative impact on patients' OHRQoL in this study?**
   - A. Psychological discomfort
   - B. Physical pain
   - C. Social disability
   - D. Handicap

4. **Select the CORRECT statement. How did later-stage (Stage IV) OSCC patients compare to early-stage patients in terms of OHRQoL?**
   - A. They reported improved OHRQoL
   - B. They reported worse OHRQoL
   - C. No difference was found
   - D. They reported better psychological scores only

5. **Which is the CORRECT option. Which public health measure did the study emphasize as most important for improving patient outcomes in South Africa?**
   - A. More advanced reconstructive surgeries
   - B. Reducing the number of follow-up visits
   - C. Exclusive reliance on chemotherapy
   - D. Strengthening oral cancer screening and early detection

A Historical Review of Impression Materials & Techniques in Complete Denture Fabrication: Part 1

6. **Select the CORRECT statement. In denture design:**
   - A. Support refers to the denture's ability to resist horizontal forces
   - B. The primary support area in the mandible is the alveolar ridge
   - C. Stability may be influenced by occlusal factors
   - D. Support is affected by saliva quality and quantity
   - E. All of the above are true

7. **Which of the following statements is CORRECT. Mucodisplasive, or high-pressure, impressions:**
   - A. Involve applying a standardised amount pressure during impression-taking
   - B. Reduce the rate of alveolar ridge resorption
   - C. Aid in long-term denture retention and stability
   - D. May restrict blood flow to the tissues
   - E. All of the above are correct

8. **Select the INCORRECT option. Which of the following is not suited for taking an impression of a flabby anterior ridge?**
   - A. A selective pressure technique
   - B. Two different impression materials in one tray
   - C. An impression compound impression material
   - D. A tray with an open window over the flabby area
   - E. An irreversible hydrocolloid impression material

9. **Select the CORRECT answer to complete the statement. The neutral zone technique:**
   - A. Is best for patients with minimal ridge resorption
   - B. Records muscle functions
   - C. Is an open-mouth technique
   - D. Does not need a special tray
   - E. Only A. and C. are correct

10. **Choose the CORRECT option. Impression compound**
    - A. Is good for capturing fine surface detail
    - B. Can be used for border moulding
    - C. Has low viscosity when heated to above 500
    - D. Is good for recording deep undercuts as it holds its shape
    - E. All of the above are correct

A Review of Chemical Approaches Inherent to Endodontic Disinfection Protocols: Part 2

11. **Select the CORRECT answer. The efficacy of endodontic irrigants depends on their ability to contact all regions of the root canal system, particularly the apical third. Which of the following factors may impair fluid dynamics and reduce the effectiveness of irrigation?**
    - A. Isthmuses
    - B. Accessory canals
    - C. Wide oval canals
    - D. All of the above

12. **Select the CORRECT statement. In multiple-visit endodontics, intracanal medicaments support disinfection of the infected root canal system.**
    - A. Intracanal medicaments completely sterilize the root canal system, making further irrigation unnecessary.
    - B. Intracanal medicaments primarily act as obturating materials that seal the canal.
    - C. Intracanal medicaments need to eliminate any remaining microbial populations after mechanical instrumentation.
    - D. Steroid pastes and antibiotic combinations are always preferred over calcium hydroxide, regardless of infection type.

Maturation Staging of the Midpalatal Suture using Cone Beam Computed Tomography

13. **Which of the following statements about imaging for assessing the midpalatal suture (MPS) is CORRECT?**
    - A. Occlusal radiographs provide a clear and reliable visualization of the entire MPS, especially the posterior region.
    - B. Hand-wrist radiographs are the most accurate method for directly staging midpalatal suture maturation.

C. CBCT allows a five-stage morphological classification of the MPS and can guide treatment planning.
D. Panoramic radiographs are sufficient for determining whether the MPS has fused.
E. All of the above are correct.

14. Choose the CORRECT statement. Which of the following patients is MOST LIKELY to benefit from conventional rapid maxillary expansion (RME) without surgical assistance?
A. A 32-year-old male with stage E maturation of the MPS
B. A 17-year-old female in stage D with early palatine suture fusion
C. A 14-year-old male with a stage B scalloped but patent suture
D. A 25-year-old female with a fully fused palatal and maxillary suture on CBCT
E. None of the above patients will benefit

15. Which option is CORRECT. Which of the following BEST summarizes the relationship between chronological age and midpalatal suture maturation (MPSM) found in this study?
A. Chronological age is a precise and reliable predictor of MPSM.
B. Older patients (>30 years) never present with a patent MPS.
C. The MPS fuses in all individuals by the age of 18.
D. Although ossification tends to increase with age, significant variation exists among individuals.
E. None of the above are correct.

What's new for the clinician – summaries of recently published papers

16. Select the CORRECT parameter. Which parameter of a dental light-curing unit primarily determines the total energy delivered to the resin-based composite?
A. Tip diameter
B. Radiant flux
C. Light scattering
D. Penetration depth

17. Which answer is CORRECT. How does a larger tip diameter of an LCU tip affect restorative procedures?
A. Creates intense hot spots causing tissue damage
B. Reduces coverage area requiring multiple exposures
C. Enables wider coverage reducing unpolymerized regions
D. Increases light scattering and reduces curing depth

18. Choose the CORRECT option. What is the relationship between light scattering and penetration depth in dental LCUs?
A. More scattering increases penetration depth
B. More scattering reduces penetration depth
C. Scattering does not affect penetration depth
D. Scattering increases radiant flux

19. Select the CORRECT option. What is the most common sequence of tooth movement for space closure after premolar extraction in orthodontics?
A. Anterior teeth retraction followed by molar distalization
B. Canine distalization followed by anterior teeth retraction
C. Molar mesialization followed by canine extrusion
D. Second premolar protraction followed by canine tipping

20. Which of the following is CORRECT. Which challenge is commonly associated with space closure using clear aligners compared to fixed appliances?
A. Excessive bodily tooth movement without tipping
B. Improved anchorage control of molars
C. Unwanted crown tipping and extrusion of anterior teeth
D. Faster space closure time than en masse retraction

Ethics: Treating friends and family

21. Select the CORRECT answer. Which legislation prohibits healthcare practitioners from treating family and friends?
A. National Health Act
B. National Health Insurance Act
C. Mental Health Care Act
D. There is no legislation prohibiting healthcare practitioners from treating family and friends

22. Which statement is CORRECT. How does informed consent apply when dealing with friends and family as patients?
A. It is unnecessary because of the personal relationship
B. It remains essential, just as with any other patient
C. It only applies if prescribing medication
D. It is optional if the treatment is minor

23. Which statement is CORRECT. What is advised in order to reduce instances of a healthcare practitioner having to treat family members?
A. Asking all family members not to discuss health issues with other family members
B. Ensure that both themselves and their families have a family GP
C. Leading a healthy lifestyle
D. Advising all family members to self-medicate if they feel unwell

24. Choose the CORRECT option. Why might it be impractical to avoid treating friends and family in South Africa?
A. Due to abundant healthcare resources
B. Because of a resource-constrained population
C. Because it is illegal
D. Due to strict HPCSA regulations

25. Which is the CORRECT answer. What does establishing a professional relationship with a friend or family member as a patient entail?
A. No change in obligations
B. Added obligations and responsibilities
C. Reduced ethical standards
D. Exemption from record-keeping

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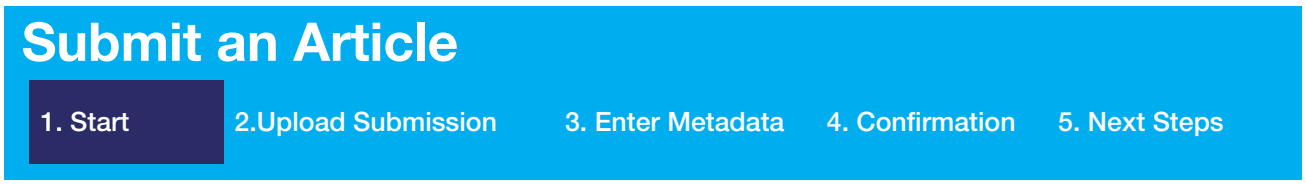

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4	Is the first author under the age of 35 on submission of the article?
5	Have you provided all details of the Communicating Author?
6	Have you submitted questions for the CPD section? (four or five multiple choice, one correct answer)?
7	Have you submitted details of the contribution of each author... can be percentage or descriptive... or both?
8	Is the first author under the age of 35 on submission of the article?
9	Have you provided all details of the Communicating Author?
10	Have you submitted questions for the CPD section? (four or five multiple choice, one correct answer)?
11	Are the references quoted according to Journal policy, both in the text and in the list of references?
12	Have all authors signed the Letter of Submission?

Author's Checklist

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