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The Kruger National Park

Established in 1898 and open to the public since the 1920s, South Africa's Kruger National Park is a wildlife enthusiast's paradise. Covering diverse ecosystems, from grasslands to dense forests, the park boasts a rich variety of wildlife. Highlights include hippo and crocodile spotting at the Crocodile River viewpoint and exploring the reconstructed Iron Age ruins of Masorini village. Kruger is renowned for the Big Five, and visitors can embark on park-run game drives or opt for a self-drive adventure along the Sabie and Crocodile rivers. The park is also a haven for birdwatchers. Plan your visit to this iconic game reserve for an unforgettable wildlife experience.

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Our Front Cover for this Issue...

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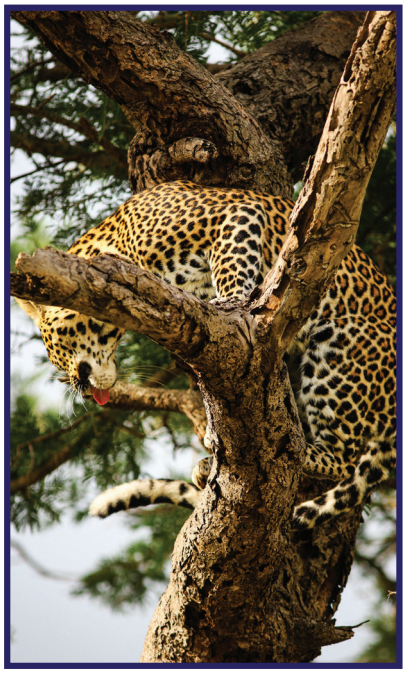

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Blending artistry and science in dentistry: A reflection on 2023

SADJ October 2023, Vol. 78 No.10 p485-486

Prof NH Wood - ***BChD, DipOdont(MFP), MDent(OMP), FCD(SA), PhD***

As we approach the close of 2023, a year that is still testing the resilience of humanity globally, it is fitting to reflect on the path we've traversed in the realm of dentistry. Our profession, inherently entwined with the wellbeing of individuals, has weathered the storms of financial challenges, mental strain and physical hardships. Yet, in the face of adversity, the blend of artistry and science in dentistry stands as a beacon of unwavering commitment to the health and dignity of our patients and their communities.

The artistry of dentistry

Dentistry, often perceived as a clinical science, carries within it an undeniable artistry. The delicate craftsmanship required in restorative procedures, the finesse in cosmetic dentistry and the nuanced skill in creating prosthodontic masterpieces are all expressions of the artistic dimension of our profession. As clinicians, we are akin to sculptors shaping smiles, and our canvases are the oral landscapes of our patients.

In the intricate dance between the handpiece and the canvas of a patient's tooth, the fusion of artistic tendencies and clinical acumen is where the true magic of dentistry unfolds. Beyond the precision demanded by scientific protocols, it is the artistic sensibilities of a dentist that breathe life into every restoration and rehabilitation. Artistic prowess in dentistry is not merely about aesthetics; it is about understanding the subtleties of shape, proportion, function and colour that define a natural smile. From crafting lifelike restorations to harmonising the contours of orthodontic treatments, the artist in a dentist brings forth a dimension that transcends the clinical, elevating the patient experience from a procedure to a form of aesthetic enhancement. The ability to visualise the result, to sculpt with finesse and to appreciate the nuances of individuality in each patient's anatomy underscores the necessity of artistic tendencies in clinical dental practice. It is this artistic touch that transforms a dental intervention from a technical procedure into a personalised masterpiece, leaving an indelible mark on the canvas of a patient's smile.

This year, the South African Dental Journal has had the privilege of showcasing the artistry of our colleagues through a myriad case studies, research articles and reviews. The meticulous detailing of treatment plans, the innovative use of materials and the artistic finesse demonstrated by our contributors illuminate the aesthetic facet of our profession. This intersection of art and science not only advances our understanding but also enriches the tapestry of our collective knowledge.

Navigating the interference: Science under siege

Even as we celebrate the artistry within our profession, we must acknowledge the challenges posed by external interference. The encroachment of non-scientific influences, often driven by personal pursuits, commercial interests or unfounded beliefs, threatens the core principles of evidence-based dentistry. In an era where misinformation spreads as swiftly as legitimate knowledge, or even when fear of reprisal dictates actions, our commitment to the scientific foundations of our practice is more crucial than ever.

Throughout this year, social media presented us with debates on the efficacy of established treatment modalities, the promotion of dubious remedies and the commodification of dental care. This possibly made patient interactions slightly more challenging for some practices, while others could utilise this to their advantage. As one of the custodians of academic integrity, the South African Dental Journal has stood firm in presenting peer-reviewed, evidence-based perspectives to our readers. We have dissected controversies, critiqued questionable practices and reaffirmed the unwavering importance of scientific rigour in our profession.

The harmony of art and science

In navigating the delicate balance between artistry and science, we find the true essence of our profession. The discerning eye of an artist combined with the rigorous mind of a scientist allows us to deliver not just treatments, but transformative experiences for our patients. It is in this synergy that dentistry becomes a vocation, a calling to meld the precision of science with the compassion and creativity of art.

Dentistry, in its essence, stands as a unique amalgamation of art and science. Unlike many other medical disciplines, dentistry demands a level of precision akin to that of a sculptor while navigating the intricate landscape of oral anatomy. The uniqueness of the oral cavity, with its delicate balance of function, aesthetics and structural integrity, requires a practitioner to seamlessly blend the analytical mindset of a scientist with the artistic intuition of an artisan. This fusion is not just a professional choice but a necessity, as every clinical decision reverberates beyond the immediate procedural context. Successful patient outcomes in dental practice are not solely measured by the absence of pathology; they are defined by the restoration of function, the enhancement of aesthetics and the preservation of the patient's overall wellbeing.

The dentist, as both scientist and artist, becomes an orchestrator, ensuring that each intervention harmonises with the broader composition of the patient's oral health. We do not simply recognise abnormalities and treat those. Rather, it is in the synthesis of art and science that dentistry finds its uniqueness, and it is through this harmonious blend that practitioners achieve outcomes that transcend the utilitarian and delve into the realm of transformative care. I have personally interacted with a number of practitioners who proudly recognise they add their own personal touch to a restoration, a graft or a rehabilitation, as if a clinical signature for peers to recognise.

A grateful acknowledgment

As we approach the conclusion of this tumultuous year, the South African Dental Association and the editorial and publishing staff of the South African Dental Journal extend heartfelt gratitude. Our sincerest thanks go to the authors and contributors whose dedication to scholarly excellence has enriched our pages. To the diligent reviewers who have lent their expertise to ensure the quality of our content, we express our deepest appreciation.

Congratulations are due to those whose work has been recognised, commended and cited. Your contributions, whether in elucidating novel research findings or sharing invaluable clinical experiences, have not only advanced our understanding but have also inspired the next generation of dental professionals.

The South African Dental Journal has been honoured to be a platform for disseminating these advancements, and for fostering a community dedicated to pushing the boundaries of our knowledge.

A call to unity

Let us reaffirm our commitment to unity within our profession. In the face of external challenges, our solidarity becomes our greatest strength. Let the artistry of our craft and the precision of our science be the guiding lights that lead us through the uncertainties that lie ahead.

As we step into a new year, we will carry forward the lessons learned and look to find further advancements. The canvas of dentistry awaits our strokes and, with the blend of artistry and science, we shall continue to shape smiles, restore health and contribute to the collective wellbeing of our communities. We wish you a peaceful and prosperous festive season.

Rethinking the NHI Bill: A Call for Prudent Revisions in South Africa's Healthcare System

SADJ November 2023, Vol. 78 No.10 p487

Mr KC Makhubele – CEO, South African Dental Association

South Africa is at a pivotal juncture in its pursuit of equitable and effective healthcare. The proposed National Health Insurance (NHI) Bill, which is presently being reviewed by the National Council of Provinces (NCOP), has raised significant concerns among numerous stakeholders, including financial associations, healthcare providers, and special interests. It is essential to thoroughly evaluate the bill and advocate for its revision, as opposed to rushing to pass it. Below are persuasive arguments reflecting the concerns of the citizens. Despite the fact that SADA aligns with the majority of these, a few are my personal opinions based on my work and interactions in the Oral Health Profession.

Decentralisation to Meet Local Needs: The bill should not employ a centralised strategy. Adopting ward-based primary care would enable regions and provinces to determine their unique healthcare needs and allocate resources accordingly. A centralised system may hinder local innovation and limit tailored solutions to diverse healthcare challenges.

We advocate for increased choice in the private sector: A rigid implementation of the current law could limit the options available to citizens, thereby impeding competition and innovation. Maintaining a balance between public and private healthcare is essential for the nation's overall health.

Avoiding Legal Challenges: We share concerns regarding prospective legal challenges to the bill in its current form. These obstacles could result in protracted legal disputes and delays in the implementation of a universal healthcare system that is truly beneficial to our nation's citizens. By amending the bill in advance, we can avoid such setbacks.

Systematic and Gradual Implementation for Sustainable Progress: We believe that systematic and gradual implementation, as suggested by some, is a prudent strategy. Before withdrawing funds from provincial budgets, pilot programmes ensure that only verified and effective measures are implemented. Rushing into full-scale implementation poses the danger of unforeseen consequences.

We support Universal Health Care coverage: We however believe that a collaborative approach involving both the private and public sectors is essential. The current single-fund model may exacerbate disparities in healthcare. The assets of both sectors can be leveraged through collaboration to provide comprehensive and accessible healthcare.

Addressing Existing Dysfunction: We recognise the urgency of addressing the existing dysfunction in our healthcare system. It is prudent to resolve these issues prior to implementing sweeping reforms. We are adamant that healthcare is not a privilege, but a constitutional requirement, and that resolving extant issues should precede introducing new ones.

Engaging and Seeking Improvement Mechanisms: Our dedication to studying the measure and participating in its development demonstrates our willingness to participate constructively. There may be substantial flaws in the bill, but we are eager to work with the government to find effective ways to address these concerns and make the bill work for everyone.

Opposition to the Proposed Bill : It should be noted that a number of organisations and programmes oppose the proposed NHI Bill vehemently. The urgency of revising the measure to ensure that it truly serves the best interests of all South Africans is highlighted by their concerns.

In conclusion, although the current NHI Bill is not devoid of merit, it requires substantial revisions to address the legitimate concerns raised by a wide variety of stakeholders. South Africa deserves a healthcare system that is both equitable and sustainable, and achieving this objective will require meticulous deliberation and cooperation from all involved parties. Let us choose the path of improvement and inclusion by advocating for a revised NHI Bill that adequately addresses the nation's healthcare requirements.

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Dental undergraduate students' perspectives of online assessments conducted during the Covid-19 pandemic – a report from one South African university

SADJ November 2023, Vol. 78 No.10 p488-495

I Moodley[1], S Sing[2], R Moodley[3]

ABSTRACT

Introduction

Online assessments are commonly used in health sciences curricula worldwide. However, it is unclear on how undergraduate dental therapy and oral hygiene students at a South African university responded to the transition from traditional classroom-based to online assessments, as a result of the Covid-19 pandemic.

Aims and objectives

This paper reports on students' knowledge and practices of, attitudes towards and preparedness for online assessments.

Method

This was a descriptive study, using a mixed methods approach to obtain quantitative and qualitative data through an online questionnaire.

Results

This study indicated most students (n=93, 87%) were familiar with online assessments; however, only (n=68, 63.5%) were confident about taking these tests. Most students agreed that online assessment helped them grasp all aspects of theory, while less than half of third-year students agreed that online assessments helped them to integrate theory into clinical practice. The reported challenges were connectivity problems with online assessment and insufficient time to complete online tests.

Conclusion

This study demonstrated that undergraduate dental students were familiar with online assessments and were confident about taking them. They believed this helped them grasp all aspects of theory despite specific challenges associated with the use of online assessments. This study suggests that online assessments could be a valuable method in measuring student competency of fundamental theoretical aspects of dentistry.

Keywords

Online assessments, undergraduate dental students, Covid-19 pandemic

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1. Dr Ilana Moodley: study conceptualisation, data analysis, manuscript preparation, writing – 60%
2. Prof Shenuka Singh: data analysis and final editing – 20%
3. Dr Rajeshree Moodley: data collection, data analysis, editing – 20%

INTRODUCTION

The Covid-19 pandemic heralded a new era in which people across the world had to quickly adjust to a new way of life while maintaining social distances and avoiding large gatherings.[1] In prohibiting large gatherings, higher educational institutions too were faced with the unprecedented situation of closing their doors to face-to-face student learning, practical/clinical teaching and written examinations.[2] Most universities transitioned to online platforms to continue their teaching and learning programmes during the pandemic, but academics were concerned about student assessments.[3] Assessment is a key component in education which defines a student's mobility through a tertiary programme by means of rigorous formative and summative assessments. While formative assessment strives to improve teaching and learning, summative assessment aims to quantify the overall performance of a student.[4] However, traditional methods of assessment, comprising mainly of classroom-based written tests and exams, were not viable options in light of restrictions in human movement. Furthermore, assessment in health professionals' training is critical in determining how well a student has grasped the fundamental theory and connecting this theory to practice through professional decision making in a clinical setting.[5,6]

Although South African universities adopted online platforms for teaching and learning and sourced alternatives to on-site classroom-based tests and examinations, clinical assessments remained a huge challenge. In undergraduate

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dental training, clinical competency is achieved through practice application of specified repetitive dental clinical procedures to develop technical skills and mastery.[7] Due to Covid-19, students were not able to perform these clinical tasks. Consequently, the measurements of such skills through clinical assessments could not be conducted and more reliance was placed on online assessments.

In facilitating online teaching and learning, the university ensured that no student was left behind by providing students with data bundles on a monthly basis and introduced a new online learning portal with diverse resources to assist students in the transition.[8] However, at the implementation level online assessments were adopted with uncertainty and confusion by both academics and students. Academics set online tasks according to their expertise and convenience with the assumed compatibility of students.[9] In embracing online assessments, academics further grappled with using different assessment methods without sacrificing quality, appropriateness and fairness.[10] This has also raised a question on students' challenges with preparedness, acceptance and ability to navigate through these assessments' tasks. Furthermore, a digital divide exists among the university students, where some students are better equipped and experienced than students who are disadvantaged in terms of computer and technology skills.11 Moreover, some students struggle with understanding the scientific terms and nuances of the English language within the limited time frame of an online assessment when English is their second language.[11]

While a blended learning approach was widely supported for health sciences training in South Africa via the online learning management platforms such as Moodle, it is unclear on how undergraduate dental therapy and oral hygiene students responded to the transition from a traditional method of assessment to online assessments during the Covid-19 pandemic. There is limited published evidence on the contextual influences impacting online assessments in dental undergraduate training during Covid-19 and students' preparedness for this type of assessment. Such information could be critical in guiding and shaping undergraduate dental curriculum development, specifically when responding to sudden disruptions in the teaching and learning environment. Therefore, this study aims to contribute to curriculum planning and review by determining undergraduate dental students' knowledge and practices of, attitudes towards and preparedness for online assessments during Covid-19. In doing so, it could also be ascertained whether online assessments could have a place in undergraduate dental training post-Covid.

METHODS

Research setting and context

The study was conducted among students in a Dentistry discipline in South Africa which offers two three-year graduate degree programmes, namely Bachelor of Dental Therapy and Bachelor of Oral Hygiene. The survey was administered at the end of the second semester in 2020 upon completion of all assessments. Ethics approval (Ref. No. HSSREC/00001601/2020) and gatekeeper permission was obtained prior to commencing the study.

Research design

A descriptive, questionnaire-based study using a mixed methods approach was used. The study employed a dominant status design (QUAN/quali) that investigated the knowledge, attitudes, perceptions and practices of undergraduate dental students regarding online assessment conducted during the Covid-19 pandemic.[12] The study was designed to obtain quantitative and descriptive qualitative data through an online questionnaire with closed-ended and open-ended questions.

Participants

The study was conducted among full-time students (n=156) registered in the Discipline of Dentistry for the academic year 2020 including year 1 (n=55, B. Dental Therapy n=38, and B. Oral Hygiene n=17), year 2 (n=54) and year 3 (n=47) students. The Oral Hygiene programme only commenced in 2020, hence the reason for only first-year student participation. Participants were recruited using the social media platform WhatsApp, through a snowball sampling technique.[13] A message, with an invite to participate in a study, was sent to the first student. The message included a link to the informed consent documents and survey questionnaire. Once the student clicked on the link, he/she had to give consent by clicking on the necessary icon. The participant was then given an option to complete the survey and, on completion, he/she was also given an option to forward the survey link to another student with each participant remaining anonymous. This link stayed opened for approximately six weeks to allow students to participate.[12]

Data collection and analysis

Data was collected using an online, self-administered questionnaire to obtain a better understanding of students' perspectives and preparedness of online assessments during the Covid-19 pandemic. The questionnaire comprised 25 questions: questions 1-5 acquired student demographics, questions 6-10 ascertained if students had the necessary resources for online assessments, questions 11-14 covered knowledge, questions 15-19 covered attitudes and questions 20-23 provided insight into practices regarding online assessments. These questions were closed questions requiring Likert scale format responses ranging from 1 (strongly agree), 2 (agree), 3 (not sure), 4 (disagree) to 5 (strongly disagree). Questions 24 and 25 of the questionnaire were designed to elicit qualitative data through open-ended questions which allowed respondents to report on any other challenges affecting online assessments and express themselves freely on how online assessments could be improved. The returned questionnaires were coded as P1 to P111 to maintain participant anonymity.

The quantitative data (closed-ended questions) obtained from the questionnaire were captured onto an Excel spreadsheet and analysed using SPSS version 27.0 (IBM Corp, USA). Data was analysed using univariate descriptive statistics such as frequency and mean distribution. An inferential statistical technique, the Pearson's chi-squared test, was used to investigate associations between the independent variable (year of study) and the dependent variables (preparedness, knowledge, attitudes and practices). A p-value of 0.05 or less was considered statistically significant.

The qualitative data obtained from closed-ended questions (24 and 25) were analysed using thematic analysis.[14] The responses from each student were transcribed verbatim.

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Two members of the research team independently coded the data, organised the data set into code groups and examined them further for familiar patterns and emergent themes. Then, both members compared their findings and finalised the main themes and sub-themes together. Confirmability was maintained through direct quotes of students' responses.[14]

RESULTS

Among the 156 students, 111 accessed the link to the survey, yielding a response rate of 71%. Most of the participants were female (n=72, 68%), registered for the Dental Therapy programme (97%). The response rates from each year were: Year 1 (n=33, 30.8%), Year 2 (n=33, 30.8%), Year 3 (n=41, 38.3%). More than half of the study sample (n=56, 52%) indicated that they were residing at home, while a quarter (n=27, 25%) were living on campus residences and 21 respondents (20%) lived at private residences, away from home.

Results of quantitative data analysis

Requirements for online assessments

The results showed most students (n=106, 99%) knew how to log onto the Moodle learning platform for assessments (Table 1).

Table 1: Students' knowledge and practices of, attitudes towards and preparedness for online assessments

Questions	Response	First-year students 33(%)	Second-year students 33(%)	Third-year students 41(%)	Total students 107(100%)	p-value (<0.005 – significant)
Resources for online assessment						
I had access to an electronic device for online assessment eg laptop, tablet	Strongly agree	23(69.7%)	20(60.6%)	22(53.6%)	65(60.7%)	
	Agree	9(27.3%)	10(30.3%)	17(41.5%)	36(33.6%)	
	Unsure	0(0%)	0(0%)	0(0%)	0(0%)	
	Disagree	1(3%)	2(6.1%)	2(4.9%)	5(5.6%)	
	Strongly disagree	0(0%)	1(3%)	0(0%)	1(0.93%)	
		33(100%)	33(100%)	41(100%)	107 (100%)	0.23
I knew how to log on for an assessment on Moodle	Strongly agree	24(72.7%)	23(69.7%)	23(56.1%)	70(65.4%)	
	Agree	9(27.3%)	9(27.3%)	18(43.9%)	36(33.7%)	
	Unsure	0(0%)	1(3%)	0(0%)	1(0.9%)	
	Disagree	0(0%)	0(0%)	0(0%)	0(0%)	
	Strongly disagree	0(0%)	0(0%)	0(0%)	0(0%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.13
I had data for continued access during assessments	Strongly agree	9(27.3%)	13(39.4%)	11(26.8%)	33(30.8%)	
	Agree	19(57.5%)	12(36.4%)	22(53.7%)	53(49.5%)	
	Unsure	2(6.1%)	2(6%)	4(9.8%)	8(7.5%)	
	Disagree	2(6.1%)	5(15.2%)	3(7.3%)	10(9.4%)	
	Strongly disagree	1(3%)	1(3%)	1(2.4%)	3(2.8%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.79
I had a conducive work space to perform online assessments	Strongly agree	11(33.3%)	9(27.3%)	7(17.1%)	27(25.2%)	
	Agree	13(39.4%)	12(36.4%)	15(36.6%)	40(37.3%)	
	Unsure	5(15.2%)	3(9.1%)	7(17.1%)	15(14%)	
	Disagree	3(9.1%)	6(18.2%)	8(19.5%)	17(15.9%)	
	Strongly disagree	1(3%)	3(9.1%)	4(9.8%)	8(7.5)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.41
I had connectivity problems during an assessment	Strongly agree	8(24.2%)	12(36.4%)	7(7.1%)	27(25.2%)	
	Agree	15(45.5%)	10(30.3%)	14(34.1%)	39(36.4%)	
	Unsure	3(9%)	2(6%)	13(31.7%)	18(16.8%)	
	Disagree	5(15%)	7(21.2%)	6(14.6%)	18(16.8%)	
	Strongly disagree	2(6%)	2(6%)	1(2.4%)	5(4.7%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.31

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Knowledge of online assessment						
I was familiar with the online method of assessment	Strongly agree	12(36.3%)	15(45.5%)	7(17.1%)	34(31.8%)	
	Agree	17(51.5%)	12(36.4%)	30(73%)	59(55.1%)	
	Unsure	3(9.1%)	3(9.1%)	3(7.3%)	9(8.4%)	
	Disagree	0(0%)	2(6%)	1(2.4%)	3(2.8%)	
	Strongly disagree	1(3%)	1(3%)	0(0%)	2(1.9%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.18
An online test is a formal test that will contribute to my class mark and final exam mark	Strongly agree	20(60.6%)	25(75.8%)	16(39%)	61(57%)	
	Agree	12(36.4%)	7(21.2%)	23(56.1%)	42(39.3%)	
	Unsure	0(0%)	1(3%)	2(4.9%)	3(2.8%)	
	Disagree	1(3%)	0(0%)	0(0%)	1(0.01%)	
	Strongly disagree	0(0%)	0(0%)	0(0%)	0(0%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.04
I do not have to come to campus to do an online test	Strongly agree	22(66.7%)	21(63.6%)	21(51.2%)	64(60%)	
	Agree	8(24.2%)	7(21.2%)	18(44%)	33(31%)	
	Unsure	2(6.1%)	5(15.2%)	1(2.4%)	8(7.5%)	
	Disagree	1(3%)	0(0%)	0(0%)	1(0.9%)	
	Strongly disagree	0(0%)	0(0%)	1(2.4%)	1(0.9%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.10
I could get feedback immediately after I completed the online test	Strongly agree	10(30.3%)	14(42.4%)	11(26.9%)	35(32.8%)	
	Agree	16(48.5%)	13(39.4%)	18(44%)	47(44%)	
	Unsure	7(21.2%)	5(15.2%)	5(12.2%)	17(15.9%)	
	Disagree	0(0%)	1(3%)	5(12.2%)	6(5.6%)	
	Strongly disagree	0(0%)	0(0%)	2(4.9%)	2(1.9%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.30
Attitudes towards online assessment						
I felt confident with using online assessments	Strongly agree	10(30.3%)	7(21.2%)	7(17.1%)	24(22.4%)	
	Agree	16(48.5%)	11(33.3%)	17(41.5%)	44(44.1%)	
	Unsure	3(9.1%)	8(24.2%)	11(26.8%)	22(20.6%)	
	Disagree	4(12.1%)	5(15.2%)	6(14.6%)	15(14%)	
	Strongly disagree	0(%)	2(6.1%)	0(0%)	2(4.9%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.11
I preferred online assessment to class-based tests	Strongly agree	11(33.3%)	4(12.1%)	11(26.9%)	26(24.3%)	
	Agree	13(39.4%)	7(21.2%)	6(14.6%)	26(24.3%)	
	Unsure	5(15.2%)	9(27.3%)	11(26.9%)	25(23.4%)	
	Disagree	3(9.1%)	8(24.2%)	9(27.3%)	20(18.7%)	
	Strongly disagree	1(3%)	5(15.2%)	4(8.75%)	10(0.1%)	
		33(100%)	33(100%)	41(100%)	107 (100%)	0.18

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Online assessments were helpful in making me grasp all aspects of my theory	Strongly agree	12(36.4%)	5(15.2%)	11(26.9%)	28(26.1%)	
	Agree	10(30.3%)	11(33.3%)	17(51.5%)	38(35.5%)	
	Unsure	8(24.2%)	9(27.3%)	4(9.8%)	21(19.6%)	
	Disagree	2(6.1%)	5(15.2%)	7(17%)	14(13.1%)	
	Strongly disagree	1(3%)	3(9.1%)	2(4.9%)	6(5.6%)	
		33(100%)	33(100%)	41(100%)	107 (100%)	0.59
Online assessments helped me to connect theory to clinical practice	Strongly agree	8(24.2%)	6(18.2%)	9(22%)	23(21.5%)	
	Agree	5(15.2%)	7(21.2%)	13(31.7%)	25(23.4%)	
	Unsure	12(36.4%)	9(27.3%)	9(22%)	30(28%)	
	Disagree	4(12.1%)	7(21.2%)	6(14.6%)	17(15.9)	
	Strongly disagree	4(12.1%)	4(12.1%)	4(9.7%)	12(11.2%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.54
I was always honest when I took my online assessment	Strongly agree	22(66%)	20(60.6%)	24(58.5%)	66(61.7%)	
	Agree	9(27.3%)	10(30.3%)	15(36.6%)	34(31.8%)	
	Unsure	2(6.1%)	1(3%)	1(2.4%)	4(3.7%)	
	Disagree	0(0%)	2(6.1%)	1(2.4%)	3(2.8%)	
	Strongly disagree	0(0%)	0(0%)	0(0%)	0(0%)	
		33(100%)	33(100%)	41(100%)	107 (100%)	0.55
Online test practices						
I was able to navigate easily through an online test	Strongly agree	8(24.2%)	6(18.2%)	5(12.2%)	19(17.8%)	
	Agree	19(57.6%)	15(45.5%)	19(46%)	53(49.5%)	
	Unsure	5(15.2%)	7(21.1%)	9(22%)	21(19.6%)	
	Disagree	1(3%)	3(9.1%)	8(19.5%)	12(11.2%)	
	Strongly disagree	0(0%)	2(6.1%)	0(0%)	2(1.9%)	
		33(100%)	33(100%)	41(100%)	107 (100%)	0.22
I understood the layout or structure of the questions	Strongly agree	9(27.3%)	11(33.3%)	5(12.1%)	25(23.4%)	
	Agree	21(63.6%)	14(42.4%)	30(73.2%)	65(60.7%)	
	Unsure	2(6.1%)	4(12.1%)	4(12.2%)	10(19.3%)	
	Disagree	1(3%)	3(9.1%)	1(2.4%)	5(4.7%)	
	Strongly disagree	0(0%)	1(3%)	1(2.4%)	2(1.9%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.17
I was able to grasp the context of the questions in the English language	Strongly agree	8(24.2%)	13(39.4%)	6(14.6%)	27(25.2%)	
	Agree	23(69.7%)	14(42.4%)	27(66%)	64(59%)	
	Unsure	2(6.1%)	5(15.2%)	6(14.6%)	13(12.1%)	
	Disagree	0(0%)	1(3%)	2(4.9%)	3(2.8%)	
	Strongly disagree	0(0%)	0(0%)	0(0%)	0(0%)	
		33(100%)	33(100%)	41(100%)	107 (100%)	0.94
I was able to complete the assessment in the given time	Strongly agree	10(30.3%)	6(18.2%)	3(7.3%)	19(17.8%)	
	Agree	14(42.4%)	13(39.4%)	22(53.7%)	49(45.8%)	
	Unsure	3(9.1%)	4(12.1%)	7(17.1%)	14(13.1%)	
	Disagree	5(15.2%)	7(21.2%)	5(12.2%)	17(15.9%)	
	Strongly disagree	1(3%)	3(9.1%)	4(9.8%)	8(7.5%)	
		33(100%)	33(100%)	41(100%)	107(100%)	0.69

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Although the majority of the participants, across all three years of study, strongly agreed (n=33, 30.8%) and agreed (n=53, 49.5%) that they had data for continued access to online assessments, more than 60% (n= 66) agreed or strongly agreed that they had connectivity problems during an assessment. It was of great significance to note that only 11(33.3%) of first year, 9(27.3%) of second year and 7 (17.1%) of third-year students strongly agreed that they had a conducive work space at their place of residence during the pandemic to undertake online assessments.

Knowledge of online assessments

In this study, although almost 87% (n=93) of the study participants agreed or strongly agreed that they were familiar with the online assessment method, some were unsure about physically being on campus for an online assessment.

Attitudes towards online assessments

Only 66.5% of all study participants agreed or strongly agreed that they were confident when undertaking online assessments. The respondents were divided on whether they preferred online assessments to class-based assessments as 24.3% strongly agreed, 24.3% agreed and almost 20% disagreed or strongly disagreed, while 23.4% were unsure. Almost 62% (n=66) of participants agreed or strongly agreed that online assessment helped them grasp all aspects of theory. Linking theory into clinical practice is integral in final year for critical decision making and holistic patient management, yet only 9 (22%) of third-year participants strongly agreed and 13 (22.4%) agreed that online assessments helped them do this. Interestingly, it was observed that only 22 participants in first year (66%), 20 in second year (60.6%) and 24 in final year (58.5%) strongly agreed that they were honest when taking online assessments.

Practices of online assessments

Only 67.3% of all participants agreed or strongly agreed that they were able to easily navigate through an online assessment. Twenty-one participants from first year (63.6%), 14 from second year (42.4%) and 29 from third year (70.7%) agreed that they understood the structure or layout of online assessments. Among the second-year participants, 14 (42.4%) agreed that they were able to grasp the context of the questions in the English language of online tests, 13 (39.4%) strongly agreed while 5 (15.2%) were unsure. Only 45.8% of all participants agreed that they were able to complete the online assessment in the given time.

Results of qualitative data analysis

Three main themes emerged from the qualitative data obtained in response to the question on the challenges affecting online assessments (Table 2). The main themes included student issues, logistic issues and assessment issues (lecturer-based) with each theme having its own sub-themes. A large percentage of the respondents (33%) reported not having enough time to complete the online tests making this a basis for formulating it as an important sub-theme. Some (20%) felt strongly that face-to-face learning was the best mode of delivery of content and that the home was not a place to study or be assessed in.

DISCUSSION

While adapting to this paradigm shift to online assessments, it was important to gauge student readiness to respond to these changes in the learning environment. Most participants in this study (n= 101, 94.3%) agreed they had access to electronic devices in the form of laptops or cellphones for online assessments. However, from a resource perspective, the challenges that participants in this

Table 2: Challenges experienced with online assessments

Main theme	Sub-theme	Participants' responses
Student issues	Preference for contact learning	"Home is not a conducive environment to study or be assessed in. Contact learning for this particular degree is a must." (P78)
	Stress-related issues	"Online assessment tends to give us more anxiety which in turn needs us to think over that anxiety!" (P22) "My academic performance now has many variables – battery, network and connectivity and the quality of my device." (P39)
Logistic issues	Technical problems in Moodle platform	"I'm unable to go back to previous answered questions to double check my answers before submitting. I also find it difficult to answer questions that require 'drag and drop'." (P47) "I couldn't answer some of the questions because of my network." (P34)
	Insufficient data	"Sometimes data would expire and I would have to find other means to attend an online session." (P21) "The data we receive from the university is not enough to last us the whole month, I spend over R800 on my data every month." (P100)
Assessment issues (lecturer-based)	Online vs class-based test	"Student can only query a question after the test whereas writing a test in class the student may get clarity from the examiner invigilating the test." (P13) "Be given a chance to consult the lecturer when we do not understand." (P86)
	Fairness in assessment	"Questions are sometimes not phrased correctly." (P103) "Lecturers phrase questions to trick students." (P13) "The answers of tests are never specific making us disadvantaged." (P99) "Questions that require you to type one-word answers for example. If the spelling doesn't match what the lecturer has put into the system it's marked wrong." (P3)
	Insufficient time	"Sometimes the time is too little because when doing contact exams, you get time to think and recall what you studied but here sometimes time limits us." (P70) "Lecturers are giving us very short time to complete our quiz. How can you answer six questions in 3 minutes, this means each is 30 seconds? I still have to read a question and given options and answer in 30 seconds." (P20)

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study experienced were the lack of continuously available data for assessments, irregular connectivity and poor network. While the institution made attempts to ensure the availability of data for all students,[8] the timeous distribution of the data packages and the amount of data provided was challenging. The issues of inconsistent data availability and intermittent internet connectivity could have a serious impact on online assessments because students could have challenges completing their assessment tasks within a given time. More importantly, this can create a further divide in student learning where the learning environment and access to learning resources are inconsistent. These findings were consistent with similar studies conducted by other researchers[15,16] who identified internet access and connectivity as the main challenges students encountered with online learning. Other authors have noted that not having internet access is a significant factor limiting the feasibility of online learning and assessments in a South African context.[16,17]

In this study, about 40% of participants did not have a conducive learning environment. This suggests that not having a conducive learning environment could impact negatively on a student's overall academic performance. This finding was similar to findings of a literature review conducted by Pokhrel and Chetri on the impact of the pandemic on teaching and learning where the authors reported having issues with physical workspaces conducive to learning.[9]

Although participants in this study were knowledgeable on the online assessment method, some were not aware that these could be done remotely and did not require physical presence in the campus setting. These findings imply a gap in student awareness of the value, role, structure and processes of online assessments. These findings were consistent with that of a study by Mpungose (2020), who found that adequate training on the use of online resources was required to keep all students well informed and to avoid confusion.[18]

This study findings showed that just more than 60% of the study sample expressed confidence in engaging with online assessments while 50% agreed that they preferred online assessments to traditional written tests. This finding is in contrast to other studies by Laine et al. (2016),[19] who found that students were satisfied with online assessments, and Elmehdi and Ibrahem (2019),[20] who showed that students had positive attitudes towards online examinations.

Moreover, about 60% only felt that online assessments helped them understand and grasp all theoretical knowledge and less than 25% of final-year students believed that these assessments contributed to the integration of theory to clinical practice. This finding reveals a theory-to-practice gap and suggests the need for further interrogation of other assessment methods. To overcome this, Rawlusyk (2018) proposed including more case-based scenarios in assessments to encourage a greater depth of learning from students and application of their understanding in real-world tasks or settings.[21]

Overall, about 60% of the study participants strongly agreed that they were honest when taking online assessments, which raises an important question of the reliability of this method of assessment. In a recent study by Cerimagic and Hasan (2019), it was observed that 81% of learners cheated or attempted to cheat during online assessments.[22] Cheating during online assessment is a major issue and calls for stricter control measures to be implemented. Some researchers eg Bawarith et al. (2017) implemented an e-exam management system, which aimed to detect and prevent cheating in online assessments.[23] However, Backman (2019) argued that academics could also take steps to reduce the occurrences of cheating.[24] These could include the addition of more demanding questions (that focus on analysis, synthesis and evaluation), selection of random questions and the allocation of less time for completing the assessment.

Although the majority of the participants could grasp the layout of questions and understand the context of the questions, only 60% of them agreed that they could easily navigate through the online assessments. Navigating through an online assessment requires cognitive skills as well as technical and computer skills. This finding suggests that all students do not have the same level of computer skills and understanding of technology, and is similar to that observed by other authors who found that students were disadvantaged in terms of computer skills and technology, especially those from rural or remote areas.[11,18] This could explain why participants in this study struggled with navigating an online assessment as most of them were at home for the academic year, with some residing in rural areas.

In this study, less than 50% of study participants could complete the test within the time given. The issue of insufficient time was a major concern for students, even highlighted in the qualitative data collected. This finding is similar to a study by Khalaf et al. (2020) who found that students struggled to complete multiple choice questions in a given time frame.[25] Another challenge experienced was the format of certain questions that disadvantaged students due to technical problems and not being able to go back to correct answers. This finding was consistent with that of Sadeghi (2019) who noted interruptions or other system errors appearing during the course of an online assessment.[26]

A further important aspect that students reported was not being able to query a question which they did not understand as is the case with sit-down assessments on-site. This finding was consistent with a study by Hsiao & Watering (2020) who recommended that the online assessments should be made clear to students with procedures and expectations clearly explained and related examples or sample questions be given to students prior to the assessment.[27] This is supported by Khalaf et al. (2020), where students believed mock tests were acceptable and helpful.[25]

Some of the recommendations made by the study participants included extending the time given for online tests, reviewing the types of questions in assessment tasks, appropriate scheduling of tests and setting up mock assessments. All of these factors should be carefully considered to produce efficient online assessments and consequently to gain students' acceptance and satisfaction of online assessments.

In one of the recommendations to improve online assessments, students expressed preference for only the multiple-choice format (MCQs) and not the "drag and drop" or "short answer" question type. However, Gülbahar (2017) argues that multiple-choice questions are only useful for acquiring basic information about learning.[28] This is

further supported by Struyven et al. (2005) who reported that the multiple-choice format discourages students from studying diligently for a test, as they perceive it would be easier to prepare for when the correct answers would be given anyway.[29] This could paradoxically lead to students adopting a surface approach to learning rather than a deep approach.[29] The surface approach to learning is described as memorising facts or reproduction of content (rote learning) in an assessment, whereas the deep approach requires meaningful engagement with the content to obtain a better understanding, so as to apply this knowledge gained in different contexts.[30] Surface learning may be detrimental to a dental student as grasping fundamental knowledge gained in the first two years of study is required for clinical application in the final year. Therefore, other authentic assessment methods such as online assignments, case-based scenarios and clinical portfolios should be considered for a deeper assessment of learner performance in addition to assessments having only multiple-choice questions.

One suggestion for future teaching and learning practice is that online assessments be integrated into a menu of assessments used to measure student competency. Online assessments have the potential to test lower order thinking of remembering, understanding and applying as postulated by Bloom's taxonomy (Bloom 1956)31 and "knows" and "knows how" as proposed by Miller's Pyramid (Miller 1990)32. This iterates the value of online assessments, specifically when they are combined with other assessments such as clinical or oral assessments to evaluate overall student competence.

STUDY LIMITATIONS

This study has two imitations, the first being that it was conducted at a single training site, thus affecting the generalisability of the findings. Second, it was conducted only among students and not academics as well. Academics could have also experienced challenges with the sudden transition from traditional methods of assessments to online assessments. Therefore, further research is required to determine their perspectives as well.

CONCLUSION

This study demonstrated that undergraduate dental students were familiar with online assessments and were confident about taking them. They believed that this helped them grasp all aspects of theory despite specific challenges associated with the use of online assessments. This study suggests online assessments could be a valuable method in measuring student competency of fundamental theoretical aspects of dentistry.

Authors' contributions

Dr Ilana Moodley devised the project and the main conceptual ideas. Dr Rajeshree Moodley compiled and uploaded the survey instrument and collected the data. Dr Ilana Moodley and Prof Shenuka Singh were responsible for data analysis. Dr Ilana Moodley was responsible for drafting and writing of the manuscript. All authors participated in the interpretation of data and revision of the paper. All authors read and approved the final manuscript.

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Declaration of interest

All three authors declare they have no conflict of interest.

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Reporting rates and presence of dental pathology on CT brain examinations at a tertiary hospital in Johannesburg, South Africa

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ABSTRACT

Introduction

South Africa is burdened by a high prevalence of dental pathology. It is common to encounter this dental pathology on computed tomography (CT) brain scans.

Aims and objectives

To determine the presence of dental pathology on CT brain scans performed in a tertiary hospital and to assess whether radiologists reported on the encountered pathology. The study aimed to raise awareness among radiologists on reporting dental pathology and highlight the impact this has on oral and general health.

Design

A retrospective observational study.

Methods

Reports of CT brain scans performed between September 2019 and October 2019 were reviewed for dental findings. Two radiologists, Reader 1 and Reader 2, blinded to the reports' findings, reevaluated the corresponding CT images. Their findings were compared with the findings of the reports.

Results

None of the 160 reports reviewed had dental findings. Reader 1 and Reader 2, respectively, reported dental pathology in 92% and 79% of the CT scans. The most common dental findings were dental caries (79% and 53%), followed by missing teeth (66% and 53%), periodontal disease (59% and 38%), periapical disease (54% and 29%), odontogenic sinusitis (19% and 3%), restorations (11% and 9%) and dental injuries (4% and 4%).

Conclusions

Radiologists do not report on dental pathology encountered on CT brain scans. Recognition of dental findings may alter patient management and reduce related morbidity and mortality.

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Author's contribution

1. Dr Evidence Ndou-Van Zyl – was the principal investigator, conceptualised the project, drafted the research protocol, collected data and drafted the manuscript. Contribution- 50%
2. Dr Daniel Nicholas Prince- conceived the original idea, contributed to interpreting the results and supervised the research project. Contribution – 25%
3. Dr Suma Rajan- co-supervised the project and contributed to editing the research manuscript protocol and final manuscript. Contribution – 25%

INTRODUCTION

South Africa (SA) is a developing country with a high burden of oral health disease coupled with a severe shortage of healthcare professionals.[1] The SA healthcare system has two sectors: public and private.[2] Radiology services are primarily found in urban areas, with most radiologists in the private sector.[3] SA has 0.085 dentists per 1000 individuals.[4] In addition, only 10% of dentists are employed by the public sector, which treats 84% of the SA population.[2,5] The inequalities in oral healthcare access significantly burden the public sector to provide cost-effective, equitable, preventative and curative oral health services.[6]

Computed tomography (CT) of the brain scan is the most frequently performed CT in the world. Most CT brain (CTB) scans are performed to evaluate brain pathology, with far fewer scans dedicated to facial bones, orbits and sinuses.[7] The scan range of a CTB is from the top of the first cervical vertebrae lamina to the vertex.[8] However, teeth (entirely or partly) are usually inadvertently included in the field of view (FOV).

Regardless of the high burden of dental pathology, disease of the teeth and supporting anatomy frequently seen on CTB scans are often overlooked and underreported by radiologists. Reporting dental disease can alter patient treatment plans and help to avoid further complications.[7,9-10]

Dental caries (DC) is the most common dental pathology in SA.[1,11-12] Caries affect nearly 100% of adults between 35 and 44 years in most countries.[13] Untreated caries is the most common reason for patient consultations at oral healthcare

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centres in SA and indication for most dental extractions.[11,12] The development of DC is strongly associated with sugar consumption and a lack of oral healthcare services within communities.[1,6,14]

Periodontal disease (PD) is the most common cause of tooth loss among adults. There are two significant groups of PD: periodontitis and gingivitis.[9] Recent studies have reported on the systemic impact of PD and linked it to cardiovascular disease, stroke and hypertension in certain patient population groups.[7,15] A retrospective study performed in Cameroon between 2013 and 2015 found PD in 93.8% of patients with cardiovascular disease versus 70.5% of the general population.[15] In 2014, a case-control study in Senegal reported PD in 73.3% of stroke cases compared to 40.8% in controls.[16]

Periapical disease (PAD) is a spectrum of diseases resulting from an inflammatory reaction to bacteria within the root canal system. A common complication of untreated PAD is maxillary sinusitis. Other rare complications include deep neck infection, which may be life-threatening, orbital inflammation, intracranial complications from septic emboli and osteomyelitis.[17]

Radiologists, dental professionals and clinicians frequently miss odontogenic maxillary sinusitis (OMS).[18] It is estimated that PD and PAD cause 5%-38% of maxillary sinus disease. Failure to identify OMS on CT leads to incorrect treatment and disease recurrence even after completing antibiotics.[9]

SA has a high burden of injuries, with an injury-related mortality rate seven times the global rate.[19] Most emergency CTB scans in SA are trauma related.[20] Traumatic dental injuries comprise of crown and root fractures, luxations, intrusions or avulsions.[10,21] Maxillary incisors are the most commonly affected by dental trauma (DT).[21] About 85.4% of traumatic dental injuries in teeth are untreated.[22]

Dental implants and restorations have become popular due to their ability to restore nearly normal tooth function.[21] Most dental restorative material is more radiopaque than dentin and enamel, making it easier to see on imaging. However, dental restorations (DR) may also source severe streak artefacts that may obscure adjacent dental anatomy. When assessing restored teeth, one should look out for overhanging ledges, defective contact points, poor contours and secondary caries.[23] In addition, failed DR can migrate and cause damage to adjacent structures and inflammation of adjacent soft tissues.[21]

This study aimed to assess the presence of dental pathology on CTB scans within a selected SA population group and to determine whether radiologists reported the encountered dental pathology.

The study's primary objectives were to record dental pathology mentioned on original CTB reports, reevaluate CTB images for dental pathology, compare the findings from the original CTB reports to those from the revaluation and determine the presence of different dental diseases from the selected population group. The secondary objective was to recommend solutions for improving the reporting of dental findings.

MATERIALS AND METHODS

This retrospective cross-sectional study was conducted at a tertiary hospital in Johannesburg, SA, where all CT examination reports compiled by registrars were reviewed and approved by consultants. Registrars were defined as doctors undergoing training to become radiology specialists. Consultants were defined as qualified radiology specialists. All CTB scans with at least one set of visible teeth and approved radiology reports performed between 1 September 2019 and 31 October 2019 were compiled from the picture archiving and communication system (PACS). CT scans were obtained using a 128-slice Siemens, Phillips or Aquilion CT scanner following the CTB protocol. The exclusion criteria included CTB scans with incomplete sets of teeth, scans with severe streak artefacts from DR obscuring dental pathology, complete edentulism, scans initially reported by any of the authors or acknowledged persons and scans with incomplete reports. Incomplete radiology reports were defined as reports compiled by registrars and had not been approved by a consultant.

The principal researcher assessed the original radiology reports and recorded dental findings reported by registrars and consultants. Two consultants blinded to the findings of the original reports reevaluated the corresponding CT images for the presence of dental pathology. In this study, these two consultants, referred to as Reader 1 and Reader 2, are general radiologists with three years and one year of experience as qualified specialists, respectively. Their findings were categorised into DC, PAD, PD, OMS, DT, missing teeth and DR. Demographics in terms of sex and age of the participants were collected.

Ethical consideration

The Medical Human Research Ethics Committee of the University of the Witwatersrand granted ethics approval. The ethics approval number is M2111111. The study did not disclose the patients' personal details or identifying factors. All data retrieved from PACS and interpreted for this study was anonymised.

STATISTICAL ANALYSIS

The original radiology reports' dental findings were compared to those from Readers 1 and 2. The paired samples proportions test was used to compare the two groups, with the dependent variable being the detection of dental pathology by the radiologist who generated the original radiology reports or the Readers. Inter-rater agreement between Readers 1 and 2 was evaluated using Cohen's kappa statistics. Cohen's kappa statistic measures agreement between two assessors. It computes inter-reader reliability by calculating the percentage of items the readers agree on while accounting for the fact that they may have agreed on some items purely by chance.[24] Statistical significance was evaluated at $p<0.05$.

RESULTS

One hundred and sixty CTB scans met the inclusion criteria. Figure I illustrates the potential number of scans identified on PACS, the number and reasons for excluding scans based on the predetermined criteria.

The achieved sample size had a higher frequency of males than females, with 117 males (73.1%) and 43 females (26.9%). The participants' ages ranged from 18 to 81 years,

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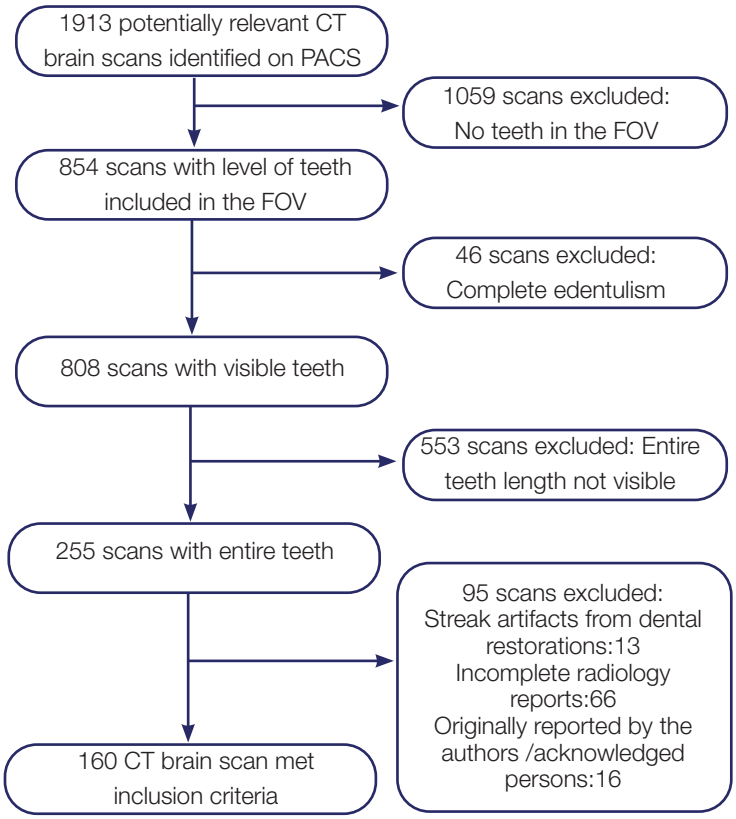

Figure I: Flow chart documenting the inclusion and exclusion criteria.

mean age of 39.6 years (standard deviation:14.5 years) and a median age of 37.5 years (interquartile range: 22.0 years).

The principal researcher reviewed the original radiology reports and found no dental findings reported by registrars and consultants who approved the reports. Two consultants, Reader 1 and Reader 2, who reinterpreted the CT images reported dental pathology in 92% and 79% of the scans

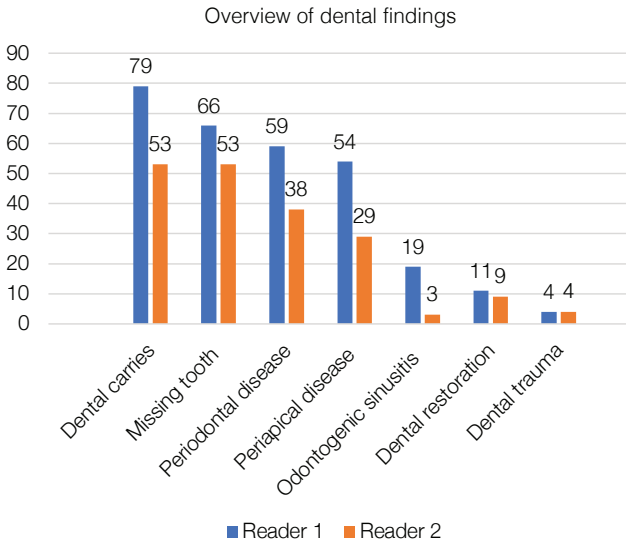

Figure II: Bar chart demonstrating an overview of dental findings by Reader 1 and Reader 2.

respectively and this was a statistically significant difference ($p<0.001$). The paired samples proportion test demonstrated a statistically significant difference between the findings of the original radiology reports a nd those of Readers 1 and 2, $p<0.001$ for both readers.

The most common dental findings by Reader 1 and 2 were DC, followed by missing teeth, PD, PAD, OMS, DR and DT (see Figure II below).

The inter-rater reliability was evaluated for the overall presence of dental disease. The number of cases in which both readers reported dental pathology was 125 (85%). Cohen's kappa coefficient was 0.45 (95% CI 0.25 - 0.61, $p<0.001$) and indicated a moderate agreement strength according to Altman guidelines.[25] The inter-rater reliability between Reader 1 and 2 for the spectrum of dental diseases was also calculated and indicated variable levels of agreements, see Table I below.

Pathology	Cohen's kappa	95%CI		P-value
		Lower	Upper	
Dental caries	0.38	0.26	0.51	<0.001
Periapical disease	0.39	0.26	0.51	<0.001
Periodontal disease	0.35	0.22	0.48	<0.001
Odontogenic maxillary sinusitis	0.06	-0.05	0.20	0.24
Dental trauma	0.60	0.18	0.89	<0.001
Missing tooth	0.67	0.56	0.78	<0.001
Dental restoration	0.58	0.33	0.79	<0.001
Overall dental pathology	0.45	0.25	0.61	<0.001

Table I: Inter-rater reliability for the spectrum of dental findings

DISCUSSION

Forty-two percent of reviewed CT scans had teeth either partially or entirely included in the FOV. However, to avoid the uncertainty of diagnosis, only CTB scans with the entire teeth length visible were considered for this study. Most dental findings can be reported even when the entire teeth are not included in the FOV. For example, a retrospective study by Bulbul et al. on detecting dental pathology on routine paranasal CT scans included any visible parts of maxillary teeth with mostly only roots of incisors seen. They reported a statistically significant prevalence of DC, developmental anomalies and PD within the selected population group.[26]

We would like to declare that although there is a significantly high number of CTB scans with teeth visible in the FOV, our institution adheres to the CTB protocol. There are various reasons beyond our study's scope which may result in teeth being accidentally included in the FOV.

This study identified complete nonreporting of dental pathology by radiology registrars and consultants. The original radiology reports did not mention dental pathology by the registrar and consultants. Overall, the study population had a high presence of clinically significant dental pathology. Readers 1 and 2 reported dental pathology in 92% and 79% of the reinterpreted CT scans, respectively.

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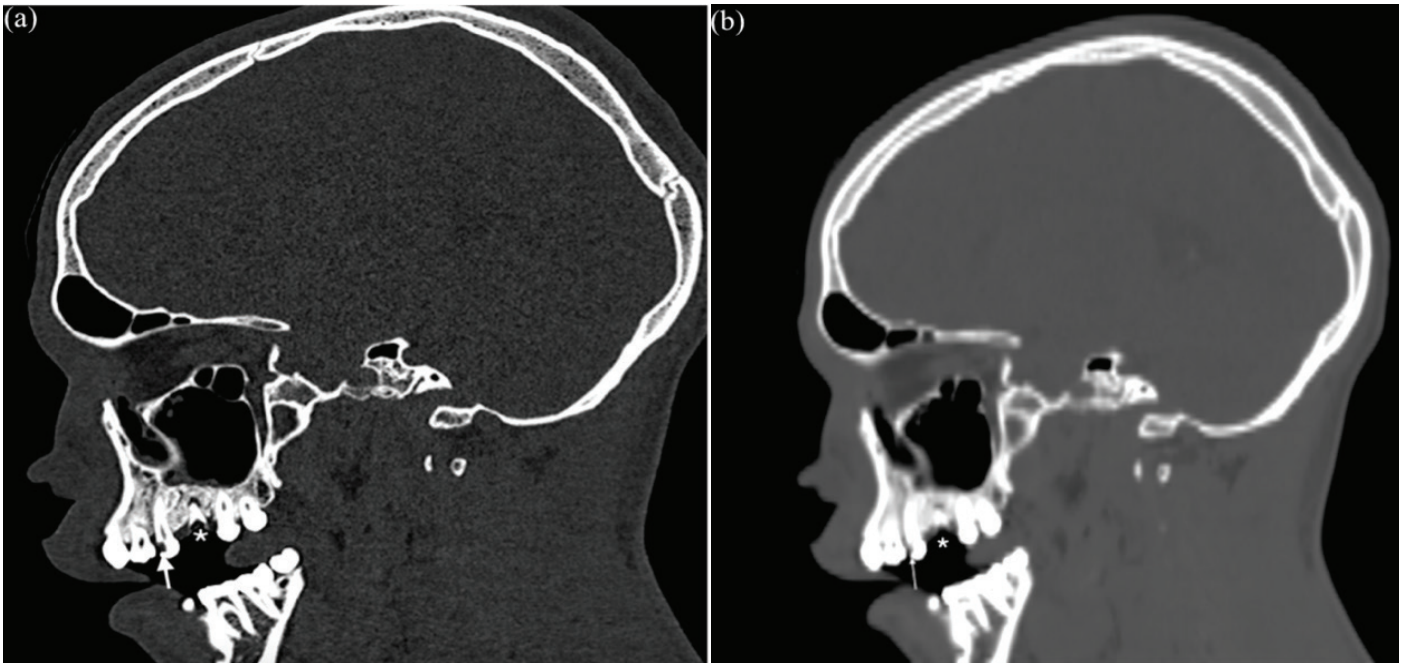

Figure IIIa: Sagittal CTB bone reconstruction image of a 22-year-old man scanned to exclude a traumatic brain injury illustrates occlusal dental caries of the left maxillary first molar (asterisk) and an approximal carious lesion of the second premolar (white arrow). Figure IIIb illustrates the same pathology on a soft tissue reconstruction bone window. Note how this reconstruction makes detecting dental pathology more difficult.

Our results conceded with those of a similar study done overseas by Hammond et al. in 2018. Their study reported underreporting of dental disease by radiologists on routine CTB scans, even after attempting to increase reporting rates by implementing a dental field in their CTB reporting template.[7]

DC was the most common dental pathology in our study population group, with Reader 1 and Reader 2 reporting a prevalence of 79% and 53%, respectively. In 2020 a cross-sectional analytic study on patients utilising dental public health services in KwaZulu-Natal districts by Mthethwa et al. also reported that carious disease was the most prevalent pathology in adults at 85% and the most common reason for patients' consultation for oral health services.[12] Another study in Cape Town in 2020 by Chikte et al. also reported DC as the most prevalent dental disease affecting 93.7% of the study population.[27] The presence of DC in our study was lower than that of Mthethwa et al. and Chikte et al. The significant difference between our study and these two studies was that they included oral examinations by dental experts. No comparable local study has yet been published on the prevalence of DC on CT.

In 2018 a similar study conducted overseas investigated the prevalence of DC in CTB scans performed in the emergency department and reporting practices by neuroradiologists in their department after noticing that the patients clinically presented with more caries than what was often reported by the radiologist. The findings of their study were similar to ours. They further discovered that the presence of untreated DC was higher in their study population than what has been documented in the general public statistics.[28]

On CT scan, DC will appear as a hypodense focal area of enamel and dentin loss on CT imaging, extending from the tooth's surface; see Figures IIIa and IIIb. Caries located on the chewing surface are called occlusal caries and are best visualised on sagittal and coronal planes. In contrast, approximal caries located in between teeth are easily identified in axial and coronal planes.[9,29] Early diagnosis of DC may lead to early intervention and restorative treatment, probably at a lesser cost. Our study's objective was merely to report on the presence or absence of dental carries; however, in daily practice describing the depth of the carious lesions may be crucial information to the referring clinical. This characterises the carious lesion on whether there is involvement of enamel, pulp or dentin and assists with prioritisation of patients on dental consultations.[28]

PD was the second most common dental disease found in our study. Previous studies have also identified PD as the most common dental disease after caries.[12] On CT scan, periodontitis is recognised by the expansion of the periodontal ligament space because of the destruction of the periodontal ligaments and inflammatory resorption of the lamina dura and cementum (Figure IV). In addition, furcation defects caused by bone loss at the anatomical site where roots divide on multirooted teeth are common.[9,30] CT scans are limited in diagnosing gingivitis, as it only affects the soft tissues and does not result in any measurable tissue or bone loss.[30]

A commonly encountered dental condition that was not recorded in our study is pericoronitis. Pericoronitis is inflammation of the soft tissues surrounding the crown of a partially erupted tooth and most commonly affects the mandibular third molar. The condition initially manifests as localised gingivitis and can spread to the local alveolar bone, even resulting in abscess formation in the deep neck spaces.[9,21] On imaging, pericoronitis typically appears as thickening and enhancement of peri-coronal tissues.[31]

In this study, PAD refers to odontogenic lesions that are evident on CT as lucencies around the apex of the teeth (see Figure V). These included periapical granulomas, abscesses and cysts. Radiologists should recognise acute PAD, manifesting as a periapical abscess from chronic PAD, for treatment prioritisation. A periapical abscess may result in acute osteomyelitis, which will appear as a permeative pattern of bone destruction.[9] This study reported statistically significant PAD present in up to 54% of the study population group. This is within the range of a 2021 systemic review and meta-analysis, which reported that 52% of the global population had PAD in at least one tooth, and the

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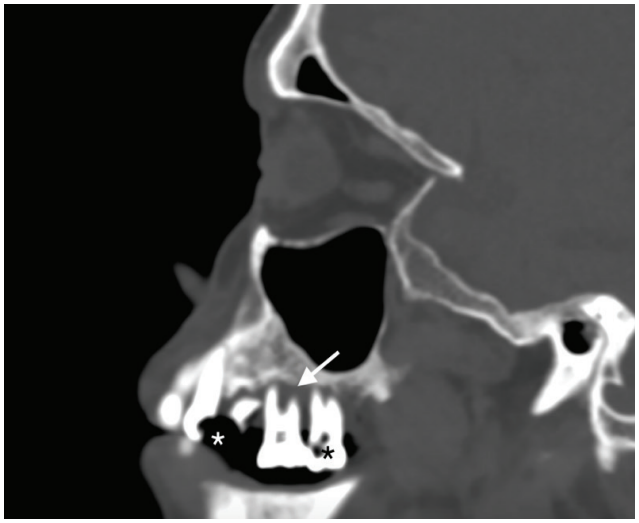

Figure IV: Sagittal CT image of a 67-year-old man demonstrating multiple dental caries (asterisk) and periodontal disease (white arrow), causing widening of the periodontal ligament space, bone loss and furcation defect uncovering the roots of the teeth.

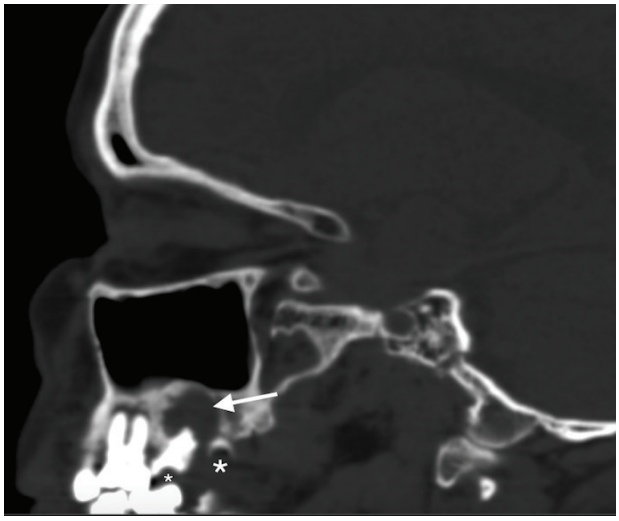

Figure V: Sagittal CT image of a 78-year-old woman illustrates right maxillary molar peri apical disease (white arrow) with severe thinning of the surrounding maxilla bone and dental caries (asterisk).

number was even higher in individuals from developing countries.[32]

Diseases of non-odontogenic origin may also cause lucencies around the tooth apex. Radiologists should be familiar with imaging findings of non benign lesions that present as periapical lucencies and differentiate them from PAD secondary to an infectious or inflammatory process.[17] No lesions with features suspicious of a non benign origin were reported in our study.

CT examination is essential in the diagnosis of odontogenic sinusitis. According to Bomeli et al., the presence of PD in adjacent teeth, periapical abscess, an oroantral fistula and a projecting premolar or molar tooth root is highly suggestive of odontogenic sinusitis.[33] The relationship between the maxillary sinus and teeth is best visualised on sagittal and coronal CT images.[9,34] While our study managed to identify clinically significant odontogenic sinusitis, Cohen's kappa value and Altman guidelines indicated disagreement between Reader 1 and Reader 2 on the frequency of odontogenic sinusitis.

Our opinion is that the absence of an identifiable dental source may make it difficult for radiologists to commit to diagnosing odontogenic sinusitis. Nevertheless, radiologists should always consider the possibility of OMS, especially in severe radiologic findings, unilateral maxillary sinusitis and interruption of the maxillary sinus floor, see Figures VIa and VIb.[33,35] A study on patients with confirmed OMS found that 36% of the participants had no apparent dental infection on CT.[18] When odontogenic sinusitis is diagnosed and both dental pathology and sinusitis are treated, complete resolution can occur in 90%-100% of cases.[35]

DT contributed a small percentage of our dental findings, with a moderate level of agreement between Reader 1 and Reader 2. Although traumatic dental injuries are prevalent, our study looked at the general population of patients and not solely trauma patients. A recent retrospective study

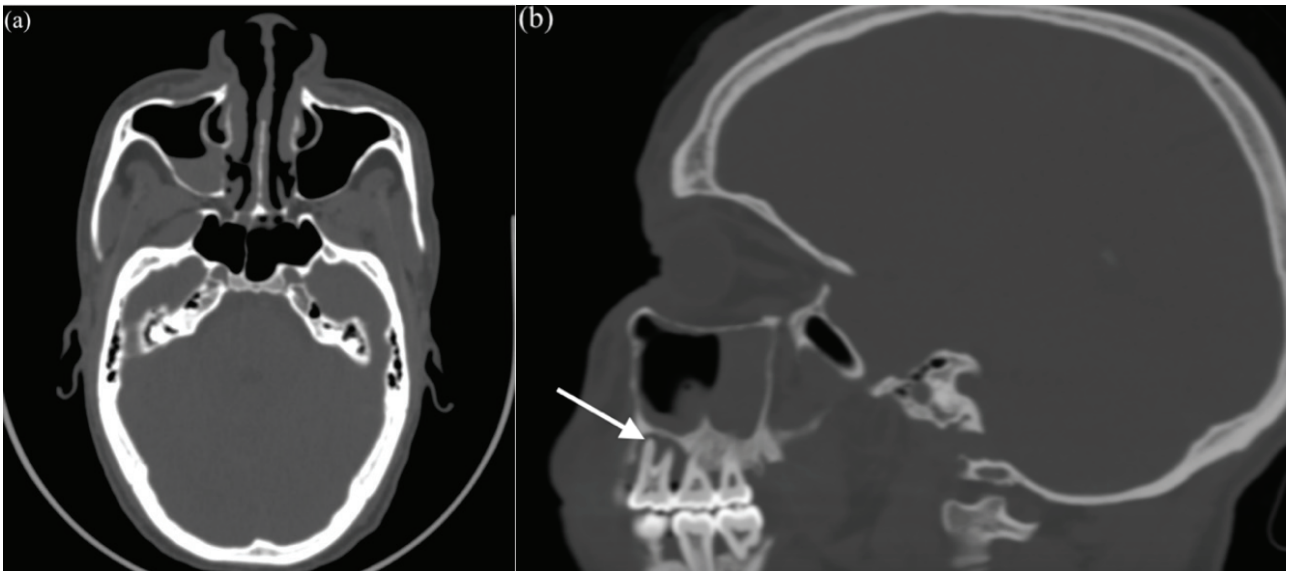

Figure VIa: Axial CT image of a 32-year-old man with odontogenic maxillary sinusitis illustrates unilateral opacification of the right maxillary sinus. Figure VIb is a sagittal image of the same patient illustrating apical periodontitis of the underlying right maxillary third molar (white arrow).

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by Meyer et al. on polytrauma patients who had whole-body CTs (ie, CT trauma series) identified dental injuries in 124 out of 994, with only 15 findings reported in the radiology reports. The correct diagnosis of DT in an acute setting is vital as injuries may complicate acute treatment like intubation, and aspirated tooth fragments may compromise the airways.[10] Therefore, timeous diagnosis and treatment of dental injuries can result in a more favourable outcome.

Delayed treatment for traumatic dental injuries may lead to devastating complications such as pulp necrosis, crown discolouration and root canal infection.[36] While injuries like tooth avulsions and luxation may be easily identifiable on CT, teeth fractures may be challenging to detect, especially if the fracture line is non-displaced.[9] Thus, cone beam CT has been proven to have higher diagnostic accuracy for dental injuries than multidetector helical CT.[37] Figure VII illustrates a study participant who had multiple dental injuries; although the mandibular fractures were reported, the dental injuries were not mentioned in the original report.

The presence of DR is an indicator of previously existing dental disease. Readers 1 and 2 identified restorations in 11% and 9% of the CT scans, respectively. Restorations with significant metallic components may cause substantial streak artefacts obscuring dental pathology in other teeth.[9] To avoid the potential underreporting of dental disease, all CT scans with streak artefacts from DR were excluded from this study. High levels of dental pathology with low levels of restorations evident on these scans could be related to a lack of access to dental care. Radiologists should know about the potential complications of DR which may lead to unfavourable outcomes if not addressed such as dislodgement, poor osseointegration and foreign body inflammatory reaction.[21] No complications of restorations were reported in this study.

Reporting missing teeth should be less challenging since the entire tooth does not have to be included in the scan FOV to identify this finding. In non-trauma-related cases, the absence of teeth should prompt radiologists to check for preexisting dental disease.[9] Both Readers reported a high presence of missing teeth among the study participants. The high prevalence of untreated DC and PD, both of which were reported in this study, is a major cause of tooth loss.[38] Many studies have associated tooth loss with a negative effect on the quality of life and functional capacity. In addition, the location and distribution of teeth loss affect the severity of impairment.[10,39] Interestingly, in 2021 Kimmie-Dhansay et al. conducted a study in Cape Town, where there is a high prevalence of tooth loss, and found that almost half of their 1615 study participants had no natural teeth. Their study concluded that loss of teeth did not impact the study subjects' oral health-related quality of life.[40]

There was a moderate level of agreement between Reader 1 and Reader 2 on the overall prevalence of dental pathology in reference to Altman guidelines. Agreement ranged from good to poor for the specific categories of dental findings. A good level of agreement was observed for missing teeth. The agreement was moderate regarding quantifying DR and DT. A fair agreement was observed for PD, PAD and DC. Lastly, there was disagreement on quantifying OMS.

The poor agreement on quantifying odontogenic maxillary sinusitis is most likely a result of the known difficulty in identifying OMS on multidetector CT. Fair agreement on the most prevalent dental diseases in the country and the world raises concerns as underdiagnosis and delayed treatment lead to serious

Figure VII: Sagittal image of a 22-year-old man who was assaulted illustrates an oblique fracture (white arrow) of the mandible involving the root of the mandibular third molar.

complications. In addition, most of the CT scans (67.5%) had no bone window reconstruction, which could have resulted in inferior resolution for identifying some of the dental pathologies. Figure IIIb demonstrates the difference in resolution when dental pathology is viewed from soft tissue reconstruction bone widow. Overall, the variance in interpretation between Readers 1 and 2 highlights unfamiliarity with dental pathology, a lack of experience in reporting dental findings by radiologists, and a need to raise the degree of certainty among radiologists. Educating radiologists on detecting dental pathology on CTB and implementing a dental field on the departmental CTB template may improve the reporting rates.

We recommend future studies to determine if the recommended solutions resulted in any changes in the radiologists' reporting rates of dental pathology.

LIMITATIONS

The study had a relatively small sample size. Further limitations include that this is a single-centre study, which means the findings on the radiologists' reporting rates are specific to this tertiary hospital and may not represent those of registrars and consultants from other academic institutions. In addition, due to the cross-sectional nature of the research, causal relationships may not be reliably determined.

CONCLUSION

Our study demonstrated a high prevalence of dental pathologies that were completely missed or ignored by the original interpreting registrars and consultant radiologists. This is highly concerning as underreporting dental pathologies can cause a delay in patient treatment and lead to significant morbidity. Therefore, training registrars and creating awareness among specialist radiologists regarding the imaging findings of dental disease should be prioritised.

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Conflicts of interest

There are no competing interests to declare.

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List of abbreviations

CT	–	Computed tomography
CTB	–	Computed tomography of the brain
DC	–	Dental caries
DR	–	Dental restorations
DT	–	Dental trauma
FOV	–	Field of view
OMS	–	Odontogenic maxillary sinusitis
PD	–	Periodontal disease
PAD	–	Periapical disease
PACS	–	Picture archiving and communication system
SA	–	South Africa

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Root and canal morphology of the mandibular first molar: A micro-computed tomography-focused observation of literature with illustrative cases.

Part 2: Internal root morphology

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ABSTRACT

The endodontic intervention of the mandibular first molar can be challenging. Once root canals or any portion of them remain undiscovered and untreated, the risk of treatment failure greatly increases. The consensus is that mandibular first molars may have three or four main root canals. However, variations have been noted between populations, which include the mid-mesial canal (MM) and the mid-distal canal (MD). Authors have also attempted to classify root canal configurations to identify common patterns for diagnostic and treatment planning purposes. The introduction of micro-computed tomography (micro-CT) to root and canal morphological studies revolutionised observation of complex root canal anatomy in three dimensions and high definition. This paper is the second of two providing an overview of literature on various aspect of the external and internal root and canal morphology of the mandibular first permanent molar. The aim is to provide an overview of relevant aspects of the internal root morphology of the mandibular first molar in different populations. The content is supported by illustrative micro-CT images and a report on clinical cases where anomalies have been treated.

Keywords
Accessory canals, apical deltas, chamber canals, micro-CT, middle-mesial canal, middle-distal canal, root canal configurations

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INTRODUCTION

During root canal treatment clinicians aim to remove irreversibly inflamed or infected tissues from the entire root canal system using a combination of mechanical and chemical disinfection techniques.[1,2] Treating clinicians find molars particularly challenging to treat due to the complexity of their root and root canal morphology. Aspects of the internal morphology of the root canal can easily be overlooked during the diagnostic phase but, even if they are discovered, they can be challenging to treat. Once root canals or any portion of them remain undiscovered and untreated, the risk of treatment failure greatly increases.[2-4]

The mandibular first molars are often mistakenly identified as primary teeth, leading to their neglect and an increase of carious pulpal involvement requiring root canal treatment.[5] According to the literature, the treatment of human mandibular molar teeth can be quite complex and there are several variants in the number of canals and roots.[2,6,7] The consensus is that mandibular first molars may have three or four main root canals.[7] Figure 1 depicts different clinical scenarios that may be encountered during treatment of these molars where three or four canals are present.

However, variations have been noted between populations.[8-11] Barker *et al*. and Vertucci and Williams[12,13] were some of the first investigators to discover an additional mesial canal in the mesial root; there can also be additional canals in the distal root.[14] Authors have also attempted to classify root canal configurations to identify common patterns for diagnostic and treatment planning purposes.[15,16]

Authors used clearing and staining techniques to explore root and canal morphologies[13,15] and radiographs.[17] More recently, high-resolution three-dimensional (3D) techniques

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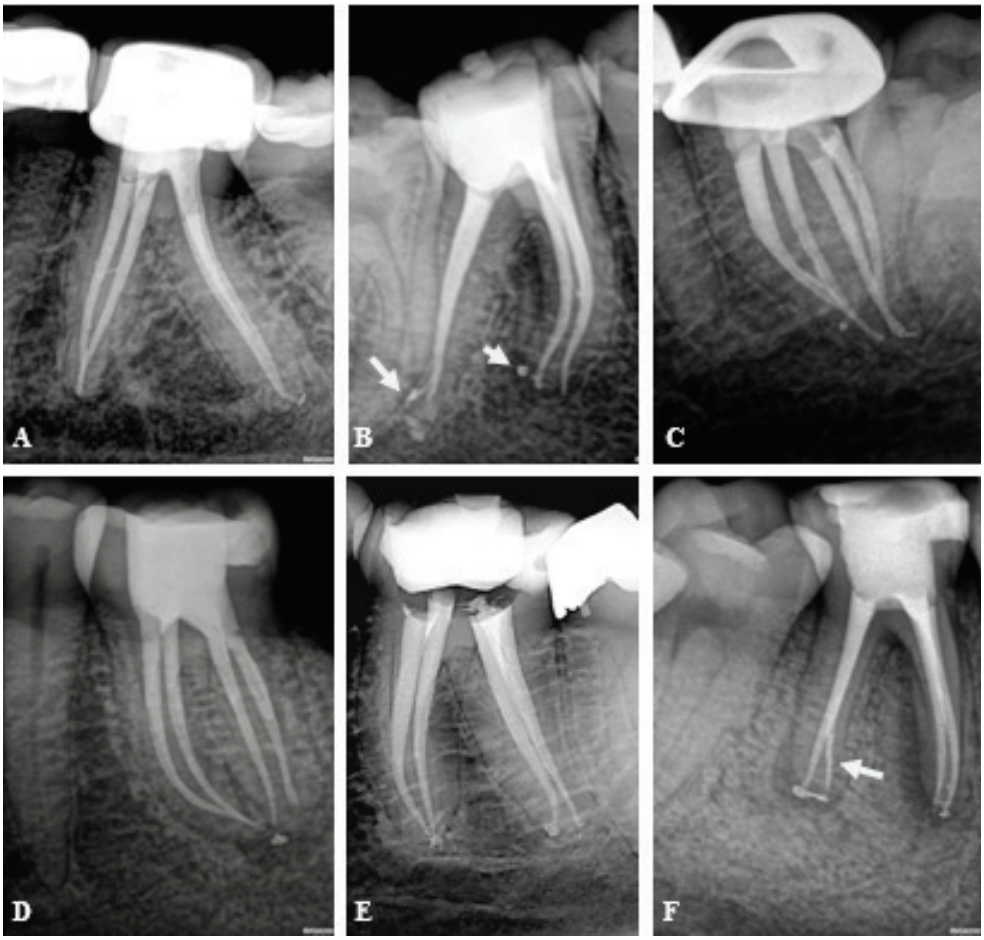

Figure 1: Different root canal configurations encountered during endodontic treatment of mandibular first molars; **(A)** Two mesial root canal systems joining in the apical third of the mesial root and a single distal root canal system; **(B)** Two separate mesial root canal systems and one single distal root canal system with an accessory canal in the apical third of the mesio-lingual (ML) and distal canals (white arrows); **(C)** Two separate mesial and two distal root canal systems joining in the apical thirds of the mesial and distal roots respectively; **(D)** Two mesial root canal systems joining in the apical third of the mesial root and two canal systems in the distal root that are separate; **(E)** Two separate mesial and two separate distal root canal systems; **(F)** Two separate mesial canals and a distal canal that bifurcates in the apical third (white arrow).

have been used such as cone-beam computed tomography (CBCT) and micro-computed tomography (micro-CT).[18] Micro-CT revolutionised the way root and root canal morphology are observed with the superior accuracy it offers. The pixel resolution of micro-CT data allows the detection of the finest root canal detail and can also detect calcifications at different levels of the root canal system.[19] Nielsen *et al.*[19] pioneered this technology in 1995 by describing the root and root canal morphology of a maxillary first molar. Since then it has become a popular method to describe complex morphological features in human dentition.[7,19-22] With the use of software (for example Avizo[23]), a tooth can be viewed from different angles, individual components can be isolated and colours can be allocated to the enamel, dentine and pulp to increase diagnostic accuracy (Figure 2).

The aim of this paper is to provide an overview of available literature on the root canal morphology of the mandibular first molar supported by illustrative images and clinical cases. Although a variety of investigative methods are used to report on different populations, the focus is on the use of micro-CT.

The middle-mesial canal (MM)

An additional canal can be present in the mesial root of

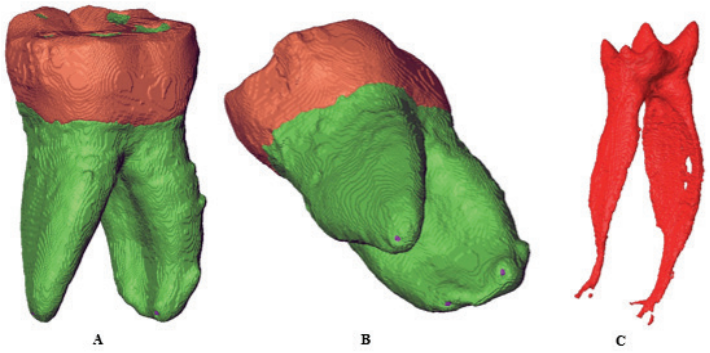

Figure 2: Micro-CT display of a typical mandibular first molar; **(A)** Virtually extracted right mandibular first molar using Avizo[23] viewed from buccal; **(B)** Apical view of the same tooth illustrating the benefit of virtual rotation; **(C)** Virtually extracted pulp with the enamel and dentine removed. Micro-CT images originates from the PhD thesis by the main author for which ethical clearance (reference number: 298/2020) was obtained.

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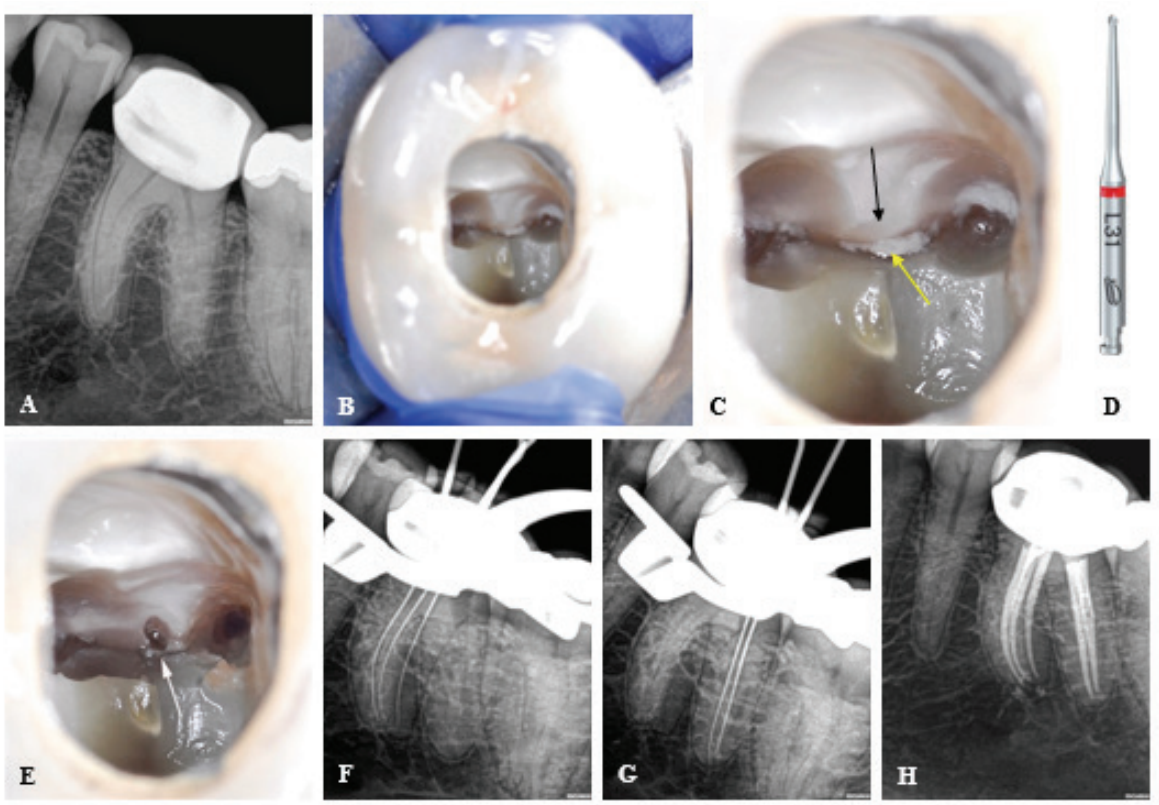

Figure 3: A clinical case presentation of a mandibular first molar with an MM canal; **(A)** Pre-operative periapical radiograph of a left mandibular first molar; **(B)** Access cavity preparation through the ceramo-metal crown; **(C)** High-magnification view of the mesial aspect of the pulp chamber. Note the dentine ledge (black arrow) and pulp tissue remnants (yellow arrow) in the groove connecting the MB and ML root canal orifices; **(D)** A size 010 EndoTracer bur (Komet) was used at a speed of 1500rpm under microscope magnification to remove the coronal aspect of the dentine ledge; **(E)** High-magnification view of the mesial aspect of the pulp chamber after removal of the dentine ledge exposing the orifice of the MM root canal system; **(F)** Periapical radiograph to determine the length of the three mesial root canal systems; **(G)** Periapical radiograph to determine the length of two distal root canal systems; **(H)** Postoperative periapical radiograph after obturation of the five located root canal systems. Note the three separate mesial canals (3-3-3 configuration in mesial root).

mandibular molars, namely the middle-mesial canal located between the mesio-buccal (MB) and mesio-lingual (ML) canals.[2,6] The incidence of this type of morphology has been a focus of investigations for years. Authors have reported on the prevalence in different populations ranging anywhere from 0%[24] in a Vietnamese population and as high as 59% in an Indian population.[25] The different percentages noted could reflect the methods of investigation: for example, in an unknown population in the US a prevalence of 11.5% was reported during clinical treatment;[26] a clearing technique in a Pakistani population revealed 3.3% prevalence;[27] 17.2% was reported using a dental operating microscope on extracted teeth in a Brazilian subpopulation;[28] 2.2% was reported in a Chinese population using CBCT;[10] and a clearing and staining technique was used on extracted Sri Lankan first molars and revealed a prevalence of 0.2% for an additional mesial canal.[29]

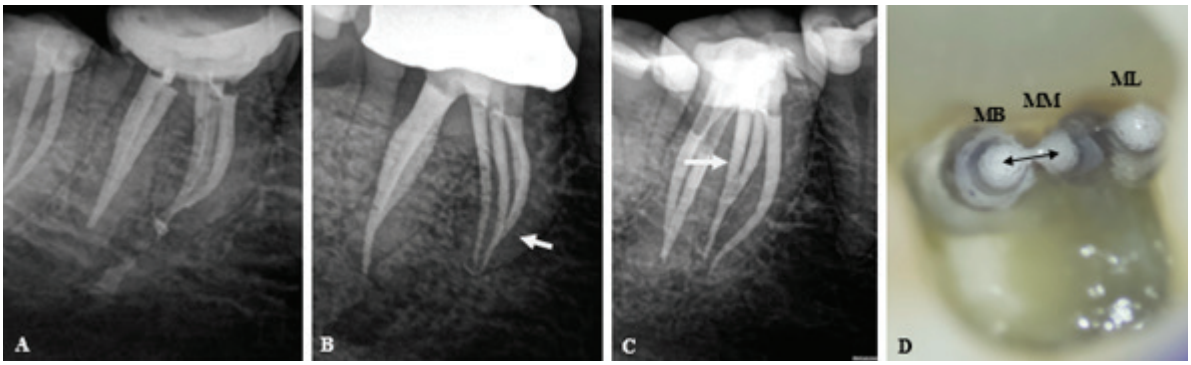

Figure 4: MM root canal configurations encountered during clinical management of mandibular first molars in South African individuals; **(A)** Postoperative periapical radiograph after obturation of five root canal systems in a right mandibular first molar. Note that the three separate mesial root canal systems join in the apical third of the root to exit in a combined apical foramen (3-3-1 configuration in mesial root); **(B)** Postoperative periapical radiograph after obturation of five root canal systems in a right mandibular first molar. Note that the MB and MM root canal systems join in the apical third of the root (white arrow) to exit in a combined apical foramen, while the ML canal system remains separate (3-3-2 configuration in mesial root); **(C)** Postoperative periapical radiograph after obturation of five root canal systems in a right mandibular first molar. Note that the ML and MM root canal systems join in the middle third of the root (white arrow) to exit in a combined apical foramen, while the MB canal system remains separate (3-2-2 configuration in mesial root); **(D)** High-magnification view of the mesial aspect of the pulp chamber of a left mandibular first molar. Three mesial root canal systems were located; the MB and MM orifices are very close together (arrow) and joined as one canal in the coronal third of the root.

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Table I: Micro-CT investigations in different populations including sample size and prevalence.

Author(s)	Year	Population	Number of teeth investigated	Prevalence of MM (%)
Gu *et al*.[38]	2010	China	122	0.8
Harris *et al*.[39]	2013	USA	22	36.4
Versiani *et al*.[6]	2016	Brazil	136	22.1
Versiani *et al*.[6]	2016	Turkey	122	14.8
Moe *et al*.[40]	2017	Burma	181	18.7
Marceliano-Alves *et al*.[41]	2019	Brazil	140	7.7

In a more recent global study, Hatipoglu *et al.*[30] invited 15 countries to participate in a CBCT study on the prevalence of the MM canal. Although CBCT devices did vary, this study reduced the possible variable of using different methodologies to identify the MM canal. Their findings were: Poland 1%, Germany 15%, Croatia 1%, Portugal 4%, Turkey 8%, Kazakhstan 5%, Pakistan 8%, India 10%, Malaysia 2%, Saudi Arabia 13%, Yemen 2%, Libya 23%, Jordan 2%, South Africa 2% and Egypt 1%.

Only a few authors have reported on the prevalence of the MM canal in African populations. In general the MM canal is either absent or has a low prevalence in African groups: no MM canal was found in Senegalese,[31] Ugandan[32] and Tanzanian[33] populations using a clearing and staining technique. In a Kenyan study a prevalence of 0.5% was reported,[34] 1% in an Egyptian using CBCT[30] and 20% in a CBCT study from South Africa.[35] Two African groups presenting with a higher prevalence were Arabs in Libya[30] (23%) and a mixed South African group[35] (20%).

Case reports describing the clinical management of this additional root canal are also available.[36,37] Figure 3 illustrates the clinical procedure to remove the dentine ledge and uncover the middle mesial canal system on a mandibular first molar. Figure 4 depicts more examples of MM canal configurations treated in South African individuals.

Micro-CT studies, which are expected to detect MM canals more accurately, are scarce. Although higher prevalences are reported using this technique than with other techniques, results vary even within one country (Table I). For example, in Brazilian micro-CT studies figures of 7.7% and 22.1% are reported. The demographics of the individuals in these studies are unclear, but it seems that extracted teeth from individuals from different regions, namely Rio de Janeiro and Sao Paulo, were used. There were also differences between scan resolutions.[6,41] Other authors mention that differences between resolutions in scans should also be considered when interpreting results.[14,19] No studies were found reporting on the presence of MM canals in African or South African populations using micro-CT.

The middle-distal canal (MD)

An additional canal can be present in the distal root outside the expected number of one or two. It is not clear whether the reported variance in prevalence of an MD canal can be attributed to different populations or the use of different techniques. Micro-CT seems to improve the detection of an additional canal and revealed the highest percentages: 11%[42] in first molars in a Brazilian population and even 22.5% in unspecified molars in an Egyptian sample.[43] The prevalence of additional distal canals in other global populations found using other techniques is: radiographic: 1.7% in India[44] and 0.6% in a Spanish population[45] (clearing and staining); 1.7% in Burma,[46] 1% in Turkey[16] and none in Uganda, Kenya and Tanzania[32-34] (CBCT); 0.5% in UAE[47] and none in Portuguese,[48] Brazilian[49,50] and Vietnamese groups.[24]

In Africa, a few studies were identified reporting on the presence of the MD canal. In Senegal individuals of African descent were investigated and a prevalence of 0.2% was noted by direct observation.[31] Clinical investigation in a Kuwaiti population revealed no teeth with additional distal canals.[51] In South Africa, a group of authors using CBCT

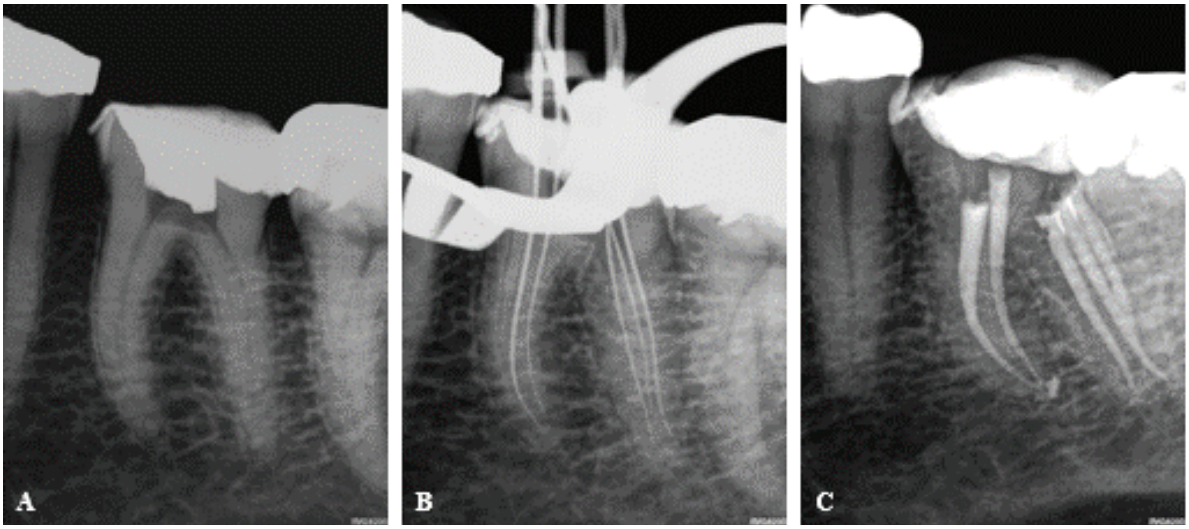

Figure 5: The clinical management of a mandibular first molar with an MD canal; **(A)** Pre-operative periapical radiograph of a left mandibular first molar; **(B)** Length determination periapical radiograph. Note the three distal root canal systems in the distal root; **(C)** Postoperative periapical radiograph after obturation of the five root canal systems. Note that the MD and MB canals join in the apical third of the root while the distolingual canal is separate (3-3-2 configuration in distal root).

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reported a 7.3% prevalence of more than the expected one or two canals.[35] It is not known why a greater prevalence was noted in this study compared to others using CBCT. Resolution of the CBCT scans could be different or techniques and experience could vary.[14,52] In the US, using micro-CT Harris *et al*.[39] found a single tooth that contained a three-canalled configuration, giving a prevalence of 4.5% from 22 teeth. As with the MM canals, no studies that focused on African or South African populations using micro-CT were found. A number of case reports describe the clinical management of additional distal canals.[53,54] Figure 5 shows a clinical example of a case with a middle distal canal in the distal root of a mandibular first molar.

Variants in canal numbers

Apart from the norm of three or four canals, cases have been reported of unusual internal canal morphology. Most are accidental findings and because of the rarity of the morphology they are published as case reports. These morphologies can range between one and 11 canals in a single tooth (Table II):

Table II: Case reports on variants in the number of total root canals.

Author(s)	Year	Number of canals
Reeh[55]	1998	7
Ryan *et al*.[56]	2011	6
Nagaveni *et al*.[57]	2015	1
Arora *et al*.[58]	2015	8
Chandra *et al*.[59]	2017	11

Figure 6 illustrates a clinical example and management of a mandibular first molar that presented with six root canal systems. Three canals were identified in the mesial root and three in the distal root.

Accessory canals

Ahmed and co-workers[60] describe an accessory canal as a small patent, blind or looped canal leaving the main canal that usually (but not always) communicates with the external root surface or furcation area. The description includes what were previously known as lateral canals.[61] As long ago as 1984, Vertucci,[15] one of the first to report on root canal morphology, used a clearing and staining technique to report on accessory canals in different teeth. He determined that the mesial root of the mandibular first molar contained the highest number of accessory canals, and the apical region was the most likely area to find them. These findings were repeated in more recent micro-CT studies of various populations (Chinese, Brazilian and German).[38,41,62-65] Other studies report the presence of accessory canals in both roots using a clearing and staining technique[16] in a Turkish population and using micro-CT[39] on a US population. On the extracted Turkish first molars, sex variations were noted in the number per region of the root.[16] On the other hand, Gu *et al.*[38] report that in cases where an additional root is present, accessory canals are less common than in the main mesial and distal root canals. In both an American and a Ugandan sample, multiple portals of exit from accessory canals were noted.[32,39]

Although prevalence of accessory canals between populations varies (Uganda: 2.7% and China: 10% of molars studied) it is not clear if differences in methodology (clearing technique versus micro-CT) contributed to the difference noted. No studies could be found reporting on accessory canals in African or South African populations using micro-CT, but Figure 7 depicts the management of a clinical case in a South African individual where an accessory canal was present in the distal root. The figure also contains a micro-CT image of an extracted first molar from a South African individual with multiple accessory canals.

Chamber canals

Chamber canals may provide portals of communication between the periodontium in the furcation region and the root canal system.[66] Early reports include one from Vertucci,[2] who states that mandibular teeth have a higher prevalence of chamber communication with the furcation region than maxillary teeth (56% and 48% respectively). Other authors also report that patent chamber canals can be present in 29.4% of mandibular molars.[67] In a study from Turkey using a sectioning technique, 24% of mandibular first molars had patent chamber canals.[68] In a micro-CT investigation of German and Egyptian extracted teeth, a combined prevalence of 14.4% was reported.[66]

The prevalence of patent or inter-radicular chamber canals has been reported as 1.8%,[62] 4.2%[66] and 7.7%,[69] while 9.4%[69] and 10.2%[66] were blind-ended.[69] No studies reporting on the prevalence of chamber canals in African or South African populations using micro-CT could be found.

Apical deltas

Ahmed *et al*.[60] describe an apical delta or an apical ramification as a root canal network at or near the root apex where the main root canal divides into more than two

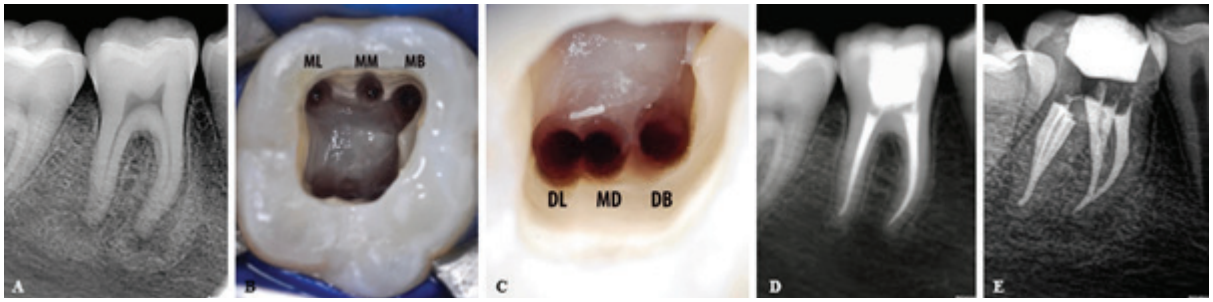

Figure 6: The clinical management of a mandibular first molar with an MM and MD canal; **(A)** Pre-operative periapical radiograph of a non-vital right mandibular first molar that presented with periapical pathology around the mesial and distal roots; **(B)** Magnified view of the pulp chamber showing the MB, MM and ML canal orifices after canal preparation with ProTaper Universal instruments (Dentsply Sirona); **(C)** High-magnification view of the distal aspect of the pulp chamber showing the DL, MD and DB canal orifices after canal preparation; **(D)** Postoperative periapical radiograph of the obturated canal systems; **(E)** Mesial angulated postoperative periapical radiograph showing the six obturated root canal systems (3-2-1 configuration in mesial root and 3-1-1 in distal root).

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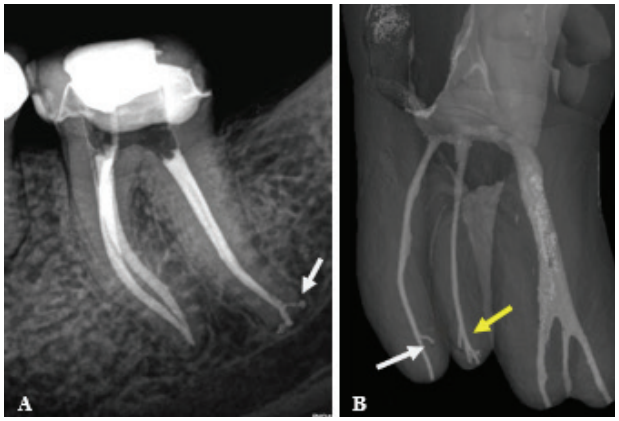

Figure 7: A clinical case and a micro-CT illustration of accessory canals located in the apical region of mandibular first molars; **(A)** Periapical radiograph of a left mandibular first molar that presents with an accessory canal (arrow) branching off from the main root canal system approximately 2mm from the root apex in the distal root; **(B)** Micro-CT image of an extracted first mandibular molar with complex anatomy. The MB root canal system has a blind-ending accessory canal (white arrow) in the apical third and the ML canal terminates into an apical delta (yellow arrow) (Image courtesy of Prof M Vorster).

accessory canals. Distribution of apical ramifications varies between populations, sexes, roots and methodologies used for detection. For instance, a Tanzanian study using a clearing and staining technique reported an absence of apical deltas;[33] a Brazilian micro-CT study found a prevalence between 2% and 12% for each root[65] and 16.5% of teeth (no distinction between first and second molars) in a Chinese population;[70] and in two micro-CT studies much higher percentages were seen – 80% in a Burmese[40] and 100% in a Chinese population.[38]

Apical deltas may be present in both the mesial and distal roots.[16] The literature reviewed did not agree on the predilection of either root. Some researchers report more deltas in the mesial root than in the distal:[70] for instance Vertucci reports an incidence of 10% for the mesial root and 14% for the distal root,[2] while other researchers report more in the distal root of the two-rooted group[38,62] and the main distal root of the three-rooted ones.[38] In a Turkish population the number of deltas was higher in males (19%-22%) than females (6%). In males more deltas were present in the distal root than in the mesial one, but in females the number of deltas was equal for the two roots.[16] No studies reporting on apical deltas using micro-CT in a South African population were found, but Figure 8 depicts a clinical case and management of a mandibular first molar that contained an apical delta. Figure 8 includes a micro-CT image of an extracted first molar tooth with an apical delta in a South African individual.

Root canal configurations

Root canal configurations provide insight into the complexity of the internal root and canal morphology of teeth.[71] To date, authors have used a variety of classification systems to describe common patterns and variants in mandibular first molars. The Vertucci system, which contains eight configuration types, is used by many as the gold standard for calculating a variety of teeth and methodologies including the mandibular first molar.[15,35,72-74] Vertucci[15] found that most American individuals studied contained type II (two canals joining at the apex) and type IV (two canals from orifice to apex) in the mesial root and type I in the distal (one canal from orifice to apex). Similar findings were reported in a micro-CT investigation on the mesial roots of Brazilian individuals.[75] In contrast, other findings are quite diverse.

For instance Salli and Egil,[74] using micro-CT, found more type III configurations (single canal dividing into two and joining again into one exit) in the mesial roots of Turkish individuals and Marceliano-Alves *et al*.[41] found more type IV configurations in the same root. In African studies, Rwenyonyi *et al*.[32] calculated more type IV configurations in the mesial root and only type I in the distal root of Ugandans; Madjapa and Minja[33] calculated more type II in the mesial and type I in the distal roots (n=146) of Tanzanians; Muriithi *et al*.[34] found predominantly type IV in the mesial root and type I in the distal (n=189) of Kenyans; and Sperber and Moreau[31] calculated more type III in the mesial root and only type I in the distal of Senegalese individuals. In South Africa, Tredoux *et al*.[35] used the Vertucci classification system with additions from Sert and Bayirli.[16] They found several configurations distributed between[23] configuration types, but type IV in the mesial roots and type I in the distal were more prominent (n=371).

Recently the Ahmed classification system has been accepted in morphological studies.[76] In this system, classifications are made by considering the orifice, canal(s) pathway and foramen (O-C-F) and can include complexities (Figure 9).

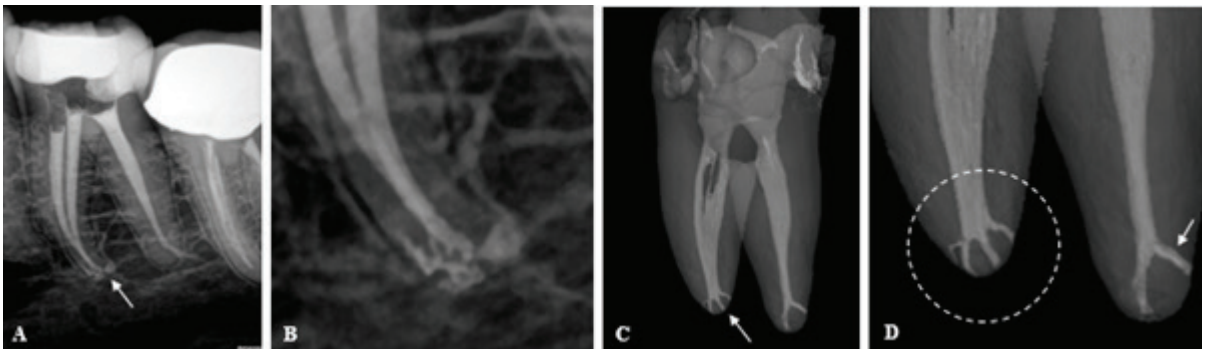

Figure 8: A clinical case and micro-CT images of an extracted tooth illustrating the presence of apical deltas; (A) Periapical radiograph of a left mandibular first molar that presented with one distal and two mesial root canal systems that joined in the apical third ending in an apical delta (arrow); **(B)** Magnified view of the apex of the mesial root of the same tooth showing the apical delta; **(C)** Micro-CT image of an extracted first mandibular molar. Note the MB, MM and ML root canal systems that join in the midroot area into one canal and then terminate at the root apex into an apical delta with four portals of exit. The distal root canal system has a single patent accessory canal branching from the main canal in the apical third of the root; **(D)** Magnified view of the apices of the mesial and distal roots. Note the combined mesial canals that exit as a delta (circle) and the accessory canal that branches off from the main distal canal system (arrow) (Image courtesy of Prof M Vorster).

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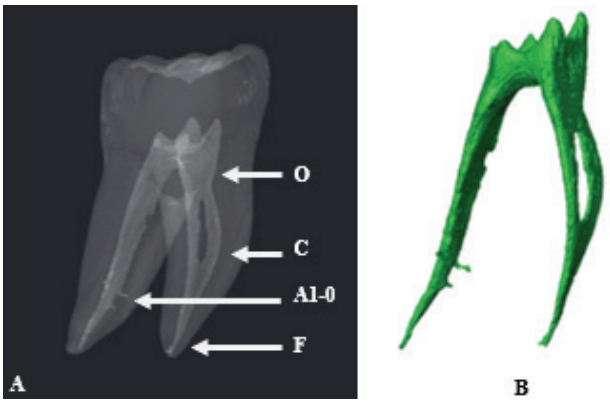

Figure 9: A summary of the root canal configuration calculation according to criteria of Ahmed et al.;[60,76] **(A)** Root canal configuration of a mandibular first molar to include main and accessory root canals. In this example, there is one orifice in both the mesial and distal root canal systems (O). In the mesial system, the canal divides into two and joins again into one. In the distal there is only one canal with no divisions (C). In both the mesial and distal systems there is one main foramen at the apex (F). In the distal system there are blind-ended accessory canals in the apical third (A1-0). The configuration for this tooth is therefore ^{2}MFM M$^{1\text{-}2\text{-}1}$D$^{1(2A1\text{-}0)}$ indicating a two-rooted mandibular first molar with its internal root canal morphology; **(B)** Extracted pulp from the same tooth displaying the internal canal morphology. Micro-CT images originate from the PhD thesis mentioned earlier.

Most studies using the Ahmed classification system used CBCT as the investigative method.[72,73,77-79] However, studies applying this new classification system in mandibular first molars are scarce. Using CBCT, Abarca *et al*.[77] determined that most molars had a ^{2}MM M$^{2\text{-}1}$ D^{1} configuration; in other words, in this configuration there are two orifices, two canal pathways and one apical foramen in the mesial root and a single canal from orifice to apical foramen in the distal root. To the best of the authors' knowledge, no micro-CT studies using the Ahmed system to calculate root canal configurations to include complexities (for example accessory canals and deltas) are available.

DISCUSSION

The root canal morphology of the mandibular first molar is highly diverse and can differ greatly among populations and even individuals within populations. Genetic factors could account for the variations noted in the anatomy of molars between ethnic groups and those from different geographical areas, but external factors could also contribute.[72,79,80] These differences are not just interesting but could play an important role in treatment approaches and, ultimately, successful treatment outcomes. In cases where root canals remain undiscovered or where additional roots are undiagnosed, it is very likely that treatments will fail. Hidden morphology can harbour infected or irreversibly inflamed tissues.[2,81]

The findings on various populations are invaluable as they provide insight into the anticipated root and canal morphology within each population. In the literature reviewed, the prevalence of three canals for mandibular first molars ranges between 42.2%[82] and 89.4%[83] and between 6.6%[83] and 57.8%[82] for four canals: two in the mesial root and one or two canals in the distal root.[2,7,84]

Using CBCT, an additional root has been reported in up to 59%[25] of some populations but is absent in others.[24] Locally, two CBCT studies report incidences of 5.2% and 1% respectively for additional roots in a mixed group of South Africans.[14,35] As a mixed group was used it is not known what the prevalence in individual populations is. Interestingly, in studies on several African populations where clearing and staining were used, no teeth were identified containing an MM canal (Senegal, Uganda and Tanzania) or very few (0.5% in a Kenyan study).[31-34] The cause of this low prevalence of the MM canal, whether it stems from inherent characteristics of the population or the clearing technique employed, remains uncertain.

Study design and methodology, including sample sizes, could cause the variations noted in the internal root and canal morphology of the mandibular first molar. Investigators have used a variety of methods to study root and canal morphologies of mandibular first molars. In the past, clearing and staining was the method of choice and was advocated by some of the most influential researchers of their time.[13,15] However, this technique has limitations that could have affected the discovery of hidden anatomy.[85] Other techniques are radiography,[17] Scanning Electron Microscopy (SEM)[31] and magnification.[86] In recent years, morphological studies have been dominated by 3D techniques such as CBCT and micro-CT.[18] Although CBCT has a clinical application benefit and micro-CT cannot currently be used on live patients, micro-CT is now the modality of choice for investigating complex internal root morphology, as it can identify very fine detail of the pulpal complex that is easily missed using other techniques.[18,76,87]

A very important discovery was made in a micro-CT study that found that 7.5% of MM canals were 2mm or more inferior than the cemento-enamel junction.[88] The clinical dilemma is that the orifices of MM canals are often covered by dentine, which must be removed with burs to uncover and gain entrance to them. Removing additional tooth structure can increase the risk of perforation and proper magnification is paramount.[89,90]

The MD canal is another example of how micro-CT improves the visualisation of root canal morphology. Global prevalence of the MD canal varies from 0%[48] in a CBCT study to 11% in a micro-CT study.[42] It is also interesting to note that the same authors who reported no teeth containing an MM canal in African populations (Uganda, Senegal, Tanzania and Kenya) also found no additional canals in the distal root when using a clearing technique. Using CBCT, more than two canals were noted in 7.3% of South Africans while in a Brazilian micro-CT study this was 11%.[31-35,42] Finally, sometimes these teeth can have either one, six, seven, eight or even 11 canals in total (Table II). These findings appear to be quite rare and reports are available where they have been treated.[58,59] Clinicians should also be mindful of the presence of additional canals in the distal root and, although the incidence is lower than for MM canals, it is easy to assume that when one or two canals are discovered a complete diagnosis has been reached. There must be a proper diagnostic protocol and a treatment strategy to deal with any number of canals that can be present. Additional canals should be assumed to be present until proven otherwise.

It is important to consider accessory canals, chamber canals and deltas during endodontic treatment. These root canal morphologies are relatively common and often create a pathway between the pulpal space and the outside of the

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root (the periodontal ligament space). Accessory pathways encapsulate blood vessels during the development of a root and exist as interrupted areas of development of the Hertwig root sheet.[64] These canals are often out of reach of root canal instruments and isolated from the flow of irrigation solutions. This could be problematic, as causative organisms and their by-products can move from infected root canals to the periodontal ligament creating periodontal disease or the pulp can be infected when periodontal disease is present.[91] Clinicians should always be mindful of this and follow a strict mechanical and chemical approach for optimal cleaning, shaping, disinfection and eventual 3D obturation of the prepared spaces.

There is consensus that the mesial root contains the most accessory canals, mainly in the apical third,[15,16,38,39,41,63-65,92] although both roots can contain them even where additional roots are present.[16,38] It has also been reported that the apical 3mm of roots contain the most accessory canals. This finding is important to consider in cases where apical surgery is required to remove at least 3mm of the root apex.[39,93] The presence of accessory canals in the apical 3mm may be linked to the high prevalence of biofilms of organisms in the apical part of root canals of teeth diagnosed with apical periodontitis.[91]

There is another type of accessory canal that could create a communication channel between the pulp space and the furcation region, namely the chamber canal. If patients suffer from periodontal disease, a seemingly healthy tooth can become infected through these channels.[94] The prevalence can be as high as 29.4%[67] for mandibular first molars. Clinicians should be mindful of the potential risk of contamination when a tooth is obturated and restored. Chamber canals have been observed using radiographs,[95] clearing and dyes[69] and SEM.[96] A few micro-CT investigations are also available. The first micro-CT study was conducted in 2022 using Egyptian and German extracted teeth.[66] The chamber canals were described as patent (inter-radicular) or blind-ending (diverticulum) which is similar to terminology suggested by Ahmed *et al*.[22,60,76] Any form of chamber canal can contain organic tissues that can ignite an inflammatory response.[66]

The presence of apical deltas is also an important morphological component of root canals. They provide the main root canal with multiple portals of communication with the outer surface of the root at the apex. To qualify as a delta according to Ahmed *et al.*,[60] the main canal must divide into multiple smaller branches and contain more than two accessory canals.[22,60,76] It does seem that the distal root may contain more apical deltas than the mesial root, as high as 16%. Micro-CT studies focusing on apical deltas are not common but a Chinese study reported that apical deltas are more common in the distal roots of two and three-rooted first molars but less common in the additional roots.[38]

Root canal configurations can play an important role during the diagnostic and treatment planning phase of endodontics. Over the years several classification systems have been suggested. One of the earliest is that of Weine *et al*.,[97] which laid the platform for future developments but contained only three configuration types. Since then, systems have evolved to include more complex configurations.[15,16,21,46,63,98-101] Unfortunately, shortcomings have been noted, especially the inability to include detail.[71]

The introduction of the Ahmed *et al*. system made it possible to include fine detail in calculations, such as accessory canals, apical deltas, complex connections and many other morphological findings.[60,76] The Ahmed *et al*. classification is accepted by the research community and has clinical and academic applicability to undergraduate and postgraduate training.[102,103] Despite its numerous advantages and although the inclusion of fine detail could be beneficial, it can add to the complexity of classification and create confusion for researchers and a degree of subjectivity,[76] which can make it difficult to compare findings.[18]

No micro-CT studies were found that described configurations including accessory canals, chamber accessory canals or apical deltas on any tooth using the Ahmed *et al*. classification system. It seems that current challenges lie in developing a classification system that accommodates micro-CT and includes as much detail as possible without increasing complexity, though such a system would have to be universally accepted. A classification system or modification using the criteria of Ahmed *et al*. to include fine detail in an understandable and repeatable way could be beneficial for researchers. It might provide an additional advantage in the ability to compare the complexity of various teeth in different populations, although standardised landmarks and descriptions will be required for calculation purposes.

In conclusion, the root canal morphology of the mandibular first molar is complex and varies according to population. Clinicians should be mindful of possible additional root canals and accessory root canal anatomy that may include MM and MD canals, accessory canals, chamber canals and apical deltas. Currently, there is a shortage of research on African and South African populations using micro-CT.

Declaration

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Conflict of interest

We declare that there is no conflict of interest.

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A simplified and evidence-informed approach to designing removable partial dentures. Part 3. The biomechanical basis of retention

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C Peter Owen[1]

SUMMARY

For many decades the literature has regularly reported that there is a discrepancy between what is taught in dental school and what is practised, especially in the field of removable partial dentures. Not only that, but for more than 60 years reports from around the world have shown that, usually, most clinicians abdicate their responsibility to design a removable partial denture (RPD) and instead leave this to the dental technician, who has no knowledge of the clinical condition of the patient and works only from a cast. The majority of patients around the world who require RPDs to improve aesthetics and chewing can only afford a removable prosthesis simply because the majority are poor. But RPDs can improve these aspects and contribute to an improved quality of life.

The purpose of this series of articles is to derive the basic, evidence-informed principles of partial denture design and to suggest a simplified explanation and application of those principles in the hope that clinicians will increasingly take responsibility for the design of partial dentures. Part 1 summarised studies revealing what can only be described as the malpractice of abdication of responsibility for design by clinicians, and then explained the evidence-informed basic principles of design; Part 2 looked at the biomechanical basis of those principles in terms of support; this part will do the same for the biomechanical basis of retention; Part 4 will provide a simple seven-step approach to design, applied to an example of an acrylic resin-based and a metal framework-based denture for the same partially edentulous arch; and Part 5 will provide examples of designs for RPDs that have been successfully worn by patients, for each of the Kennedy Classifications of partially dentate arches. Much of this is referenced from an electronic book on the Fundamental of removable partial dentures.[1]

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Running title
A simplified approach to designing RPDs

The biomechanical basis of retention in RPDs

All dentures move in function, and that includes RPDs (apart from dentures retained on telescopic crowns, but that is in the realm of the specialist). All removable dentures therefore need to give the patient the best opportunity to control that movement and therefore to be able to use the denture. The previous part has provided the means to resist most movements from occlusal forces by providing support. This part will provide the means to resist all other movements as optimally as possible.

Most practitioners are familiar with the use of clasps to retain RPDs, but less familiar with two other forms of retention – the use of guide planes and guiding surfaces, and the concept of indirect retention. The latter has given many a headache to students and has created a large amount of literature mostly derived from laboratory studies with no clinical evidence. So, this part will try to deal simply with each of these different methods to achieve retention.

Direct, or active retention

This is about clasps. Called active, because this requires movement of the clasp as the denture moves, and that movement creates a force against a tooth, thus resisting the movement. Simple. Well, not so simple, because it is necessary to know what force is exerted, and what potential damage that force could cause.

A word of caution about the "class" of clasps: in Part 1 when discussing the principles, it was stated "Pre-formed and cast gingivally-approaching clasps were shown some time ago to be potentially more damaging to gingival health than circumferential clasps[2] so their use is not advocated here".[3] So what will be discussed from here on is the circumferential or "C-clasp", an occlusally approaching clasp for which there is much evidence for its efficacy.

To know what force is exerted by a clasp it is necessary to understand the behaviour of wires when they bend, from seating passively with the terminal third of the clasp in an undercut, to being bent while passing over the bulge of the tooth. Fortunately, there are now published guidelines – at least for the most popular cast material and the readily available wrought wires.[4] It is necessary to understand that a clasp needs to be able to bend while it moves over the bulge of the tooth, and then return to its original shape and to do this many times. This elasticity has a limit, the proportional limit, beyond which it will deform permanently, and so a clasp must remain well within its proportional limit, which is determined by the clasp material and its dimensions. The guidelines referred to above take into account the length of the clasp, its material and the force exerted when bending in and out of an undercut (Table 1).

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Table 1 Guidelines for the use of cast and wrought wire clasps. The wrought wire diameter is given in mms. The numbers in parenthesis show the mean force in grams. Co/Cr: Cobalt-chromium stellite alloy; S/S: Stainless steel (from [4]).

	Premolars	Molars		
Undercut:	0.25mm	0.25mm	0.5mm	0.75mm
Clasp material	Co/Cr cast (Vitallium) (1179) S/S round wire (Leowire) 1.0mm (676)	Co/Cr cast (Vitallium) (773) S/S round wire (Leowire) 1.0mm (657)	S/S round wire (Leowire) 1.0mm (657)	
For nickel sensitive patients	S/S round wire (Noninium) 0.9mm (360)			S/S round wire (Noninium) 0.9mm (363)

There is one caveat: the study calculated a realistic safety limit of 82% of the proportional limit, but the cast clasp of premolar length was within 1% of this safety limit so the conclusion is that, for short clasps, wrought wire would be a better choice.

Incorrect choice of wire/undercut combination can lead to permanent deformation of the clasp (Figure 1), and this can also happen when patients use the clasps to pull on to first release the denture, and they should be warned that this can sometimes lead to distortion and sometimes injury to the mucosa.[5]

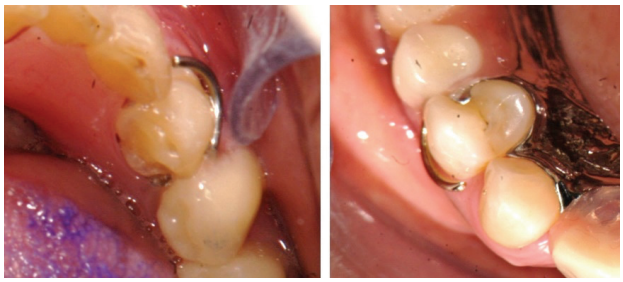

Figure 1. These clasps have exceeded their proportional limit and no longer contact the tooth and therefore provide no retention.

Reciprocation

During function, and of course during insertion and removal, the force exerted against the tooth is not dissimilar to the force used in orthodontics to move teeth. It for this reason that an active clasp arm's action needs to be resisted to prevent tooth movement and this simply requires another part of the denture – a cast arm, or the base itself – to be in contact while the clasp is exerting its force (Figure 2).

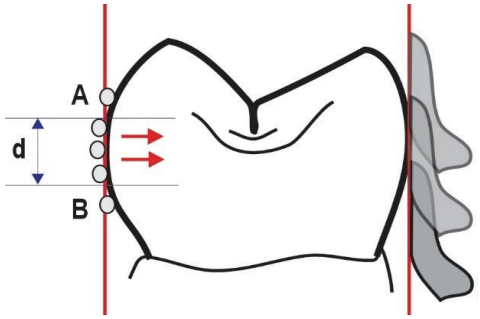

Figure 2. A clasp sits passively in the undercut at position B. As it moves over the bulge of the tooth over a distance d, it bends and therefore exerts a force (arrows) on the tooth until it returns to being passive at position A. During the distance d, a component of the denture, R, must contact the tooth to resist the force as the denture moves.

Ball clasps

Having said that pre-formed clasps should not be used, there is one type that does have its place, and that is the ball clasp (Figure 3). It provides support as it passes over the embrasure between two teeth, and retention by engaging the interproximal area, contacting both teeth. It is used mainly in orthodontics and maxillofacial prostheses but does also have an application in young teeth with short clinical crowns. Such a tooth does not have a large enough bulge area for a circumferential clasp to be effective (hence their use in orthodontics). Although the ball clasp is placed in the interproximal area where there are undercuts, they are generally so stiff that the retention they provide is more akin to frictional resistance which is the next type of retention.

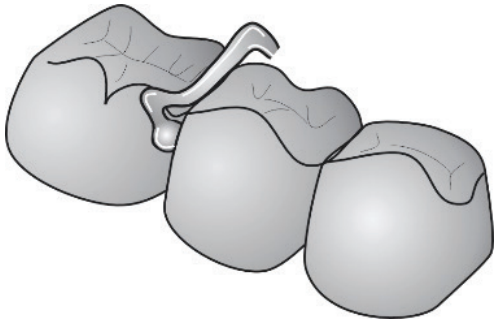

Figure 3. A preformed ball clasp passes between two posterior teeth and is bent back so that the ball portion sits in the interproximal area where there is a slight undercut.

When there is no undercut

Sometimes even a 0.25mm undercut is simply not there where you really want it, and there is no alternative. In this case an undercut can be created in two ways. The first, and easiest, is to recontour the tooth, always staying within enamel. Fine diamond burs are preferred, and you must use binocular vision to view the tooth along the path of insertion – place a pencil mark where you want the terminal third of the clasp to be, and be sure that you cannot see it when viewed along the path of insertion. The second method is to add a fine composite resin to create a suitable contour, but this is usually not necessary, and the evidence is that although this is quite feasible, retention will be lost over time.[6]

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Guidelines for indirect retention

1. Any movement that induces a rotation of the denture needs to be resisted.
2. The means of resistance is by the placement of an occlusal rest in such a situation that a favourable lever system is created.
3. The lever system in a mandibular distal extension base with a simple distal rest and circumferential clasp must be converted from a Class I lever to a Class II lever.
4. This is best achieved by placing a rest to act as a fulcrum anterior to the clasp; this increases the effective retentive force exerted by the clasp.
5. The rest is best placed one tooth anterior to the clasp assembly.
6. The lever system in a maxillary Class IV situation with a posterior clasp assembly with a mesial rest and circumferential clasp must also be converted from a Class I lever to a Class II lever.
7. This is best achieved by 'turning around' the clasp assembly so that the fulcrum is distal to the clasp; the clasp assembly now has a distal rest and the clasp arm engages the mesial undercut.
8. The lever system in a mandibular Class IV situation with a posterior clasp assembly with a mesial rest and circumferential clasp is favourable if the predominant movement is a tendence for the anterior segment to move down and posterior segment to move up.
9. However, if the predominant movement to be resisted is that of the anterior segment moving up, then the lever system must be converted to a Class II lever by 'turning around' the clasp assembly so that the fulcrum is distal to the clasp; the clasp assembly now has a distal rest and the clasp arm engages the mesial undercut.

Passive retention

When two opposing surfaces, such as the tooth and the denture base, are in close contact, the denture will bind against the tooth when it is moved away along any direction other than the path of insertion/withdrawal. This is similar to a desk drawer – you only need very slight finger pressure to open or close a drawer, provided you do so along its path of withdrawal. However, if you try to open the drawer in any other direction, you will end up moving the whole desk, but not the drawer, especially as the path is a long and well-constrained one.

This is the principle of passive retention. The surfaces used will help to determine the path of insertion and withdrawal: on the tooth this is in the form of a guide plane, and on the denture, it is referred to as a guiding surface (Figure 4).

A recent study found that by preparing guide planes on the teeth only, the retentive force increased by 1.6 times, but when the denture guiding surfaces were modified to intimately contact the guide planes on the teeth, the retentive force increased by 10.2 times.[7] This has huge implications and should become a routine part of treatment with RPDs. If the edentulous spaces are favourably dispersed then the retention is sufficient to do away with clasps altogether. This is especially the case for acrylic-based dentures because the preparation of the denture guiding surfaces is relatively easier than for framework-based dentures.

Preparation

Teeth

The guide plane preparation is a simple one, but necessary to smooth out the natural contours of the teeth. It is not, though, just a question of flattening the surface adjacent to the saddle, as the bucco-palatal or bucco-lingual contour must be preserved (Figure 5).

As illustrated in Part 2,8 when teeth are to receive a rest seat and a guide plane, these two features should be continuous. It should be noted that the design of the denture precedes the tooth preparations: all preparations should be completed before the final impression is taken. And before the denture is waxed up, the technician should have blocked out all unwanted undercuts.

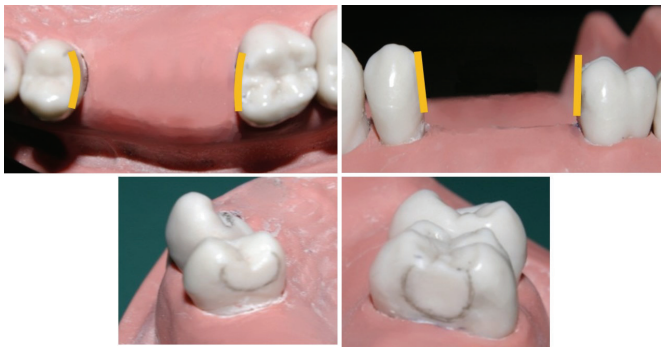

Figure 5. Guide planes demonstrated on typodont teeth. Top left: the guide planes follow the bucco-palatal contours. Top right: they must diverge slightly in an occluso-gingival direction. Bottom: the prepared guide plan shapes.

Denture

In *acrylic-based dentures*, it is a simplew procedure at the delivery stage to ensure intimate contact between the denture and the tooth. This is illustrated in Figs. 6-7.

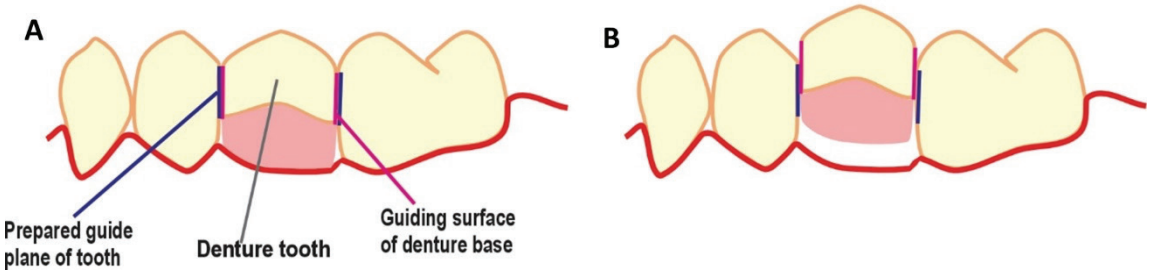

Figure 4 A: When a prepared guide plane on the tooth (blue line) and the surface of the denture (red line) are in close contact, they help define the path of insertion, and during withdrawal (B) will provide frictional resistance along that path, but much greater resistance to any deviation from that path.

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Figure 6. Left: with a round bur, drill retention holes where the guiding surface will be. Right: add autopolymerising acrylic, and then insert in the mouth, having lubricated the guide plane on the tooth. The procedure is similar to that of making a provisional crown in the mouth. Be sure to remove before the resin has set!

In *framework-based dentures*, it is generally considered that the minor connector to the clasp assembly or to the occlusal rest will be sufficiently accurate to provide adequate contact, but the fact is that the contact can never be as good as providing the guiding surface intra-orally as above. There is, however, a solution to this, and that is to provide sufficient space between the minor connector and the tooth to be able to apply acrylic resin in the same way as in the acrylic-based RPD. The disadvantage of this is that the framework, when tried in on its own, will have no retention; this is fine for the mandibular denture but the maxillary denture will just fall out so has to be held in place while assessing the fit.

So when the master model is being blocked out by the technician, the blocking-out wax needs to be built up against the guide plane to provide a space, and it would be preferable to use a perforated mesh for the minor connector. This will provide retention for the autopolymerising acrylic (Figure 8).

Guidelines for guide plane retention

1. The guide plane is the re-shaped surface of the tooth adjacent to an edentulous area.
2. When a rest is also required on the tooth, the guide plane should be continuous with the rest.
3. Guide plane retention is most effective when there is intimate contact between the guiding surface of the denture and the guide plane of the tooth.
4. This is best achieved intra-orally by adding autopolymerising acrylic resin to either retentive preparations in the acrylic of an acrylic-based denture or to the acrylic and mesh in a framework-based RPD, when space has been created between the minor connector and the tooth.
5. With sufficient edentulous spaces, guide plane retention would be sufficient to obviate the need for clasps in both acrylic-based and framework-based dentures.

Indirect retention

There are three myths about indirect retention. The first is that it is not necessary; the second is that an axis of rotation must be determined and the furthest point from that is where a fulcrum must be placed, in the form of a rest; the third is that it only applies to mandibular distal extension bases. Each of these will be dealt with.

Indirect retention is not necessary

The goal with all removable prostheses is to limit the movement that inevitably occurs during function. Movement along or away from the path of insertion has been covered by providing support, guide plane retention and active retention. But rotatory movements also occur, and it is these movements that indirect retention helps to reduce, by changing any lever system that tends to create rotation. The next sections will show, therefore, that indirect retention is indeed necessary.

Figure 7. Left: the widely spaced edentulous areas make this an ideal case for the use of guide plane retention only; note that cingulum rests have been prepared on the 13 and 22, and occlusal rests have been prepared on the 16 and 27 for half-round wire. Right: appearance before and after.

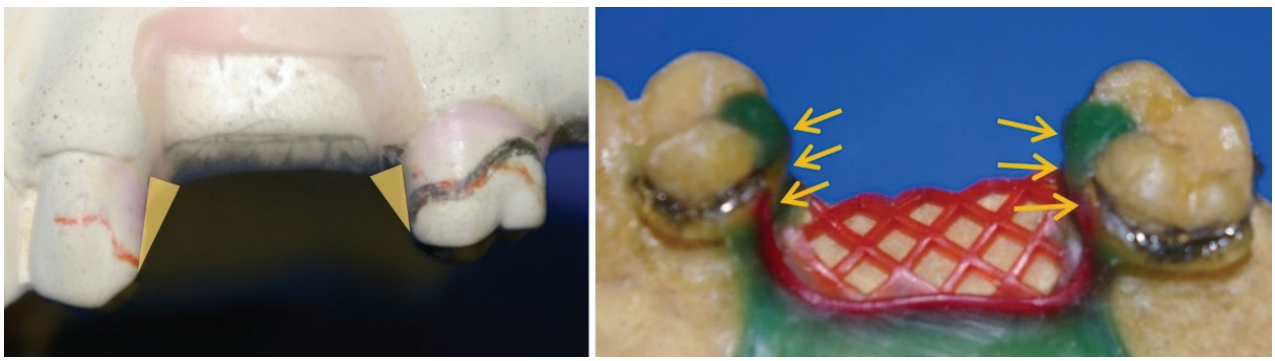

Figure 8. Left: it is suggested that a "wedge" of additional block-out wax be placed to provide a space between the minor connector and the tooth and that the minor connector (arrows, right) be perforated.

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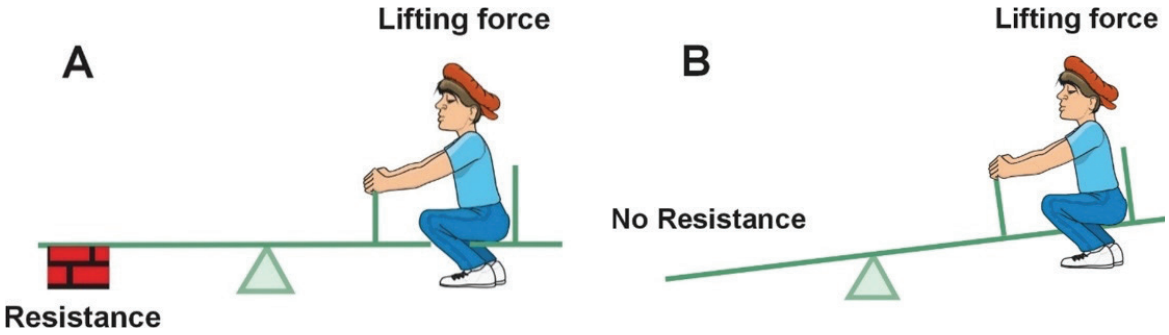

Figure 9 A: The person at the end cannot push up because the pile of bricks resists that. B: without the bricks, he can lift up easily.

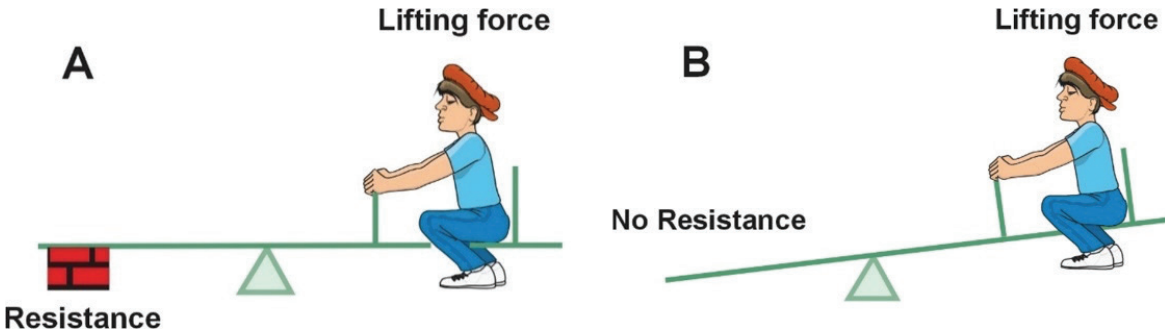

Figure 10 A: The clasp, in reality, is the fulcrum as well as the resistance. B: but it rotates downwards away from the bulge and provides no resistance.

Axes of rotation and the fulcrum: it's all about levers

Almost 60 years ago a seminal paper made this observation: "Indirectly then, partial denture units preventing … rotation retain the denture bases in contact with the underlying tissue, hence the name 'indirect retention'."[9] It is a concept, though, that many students have found difficult to grasp, perhaps because the analogies used of a see-saw representing a Class I lever, and wheelbarrow representing a Class II lever are difficult to apply to the mouth. So, the following is an attempt to provide an explanation thus far not found in the literature. The first analogy, of the see-saw, is shown in Figure 9. For the person at the end to push himself up there can be nothing to stop the end of the plank on which he sits from going down: the pile of bricks is the resistance to his going up. So, the explanation usually given is that if the person at the end represents a mandibular distal extension base then something furthest away from him must be placed to resist that movement.

But in terms of the reality of a partial denture and not a see-saw, it is necessary to realise that the fulcrum is in fact the clasp assembly, as that is the natural resistance to a lifting movement caused by something sticky at the distal extension, because that's how clasps work. We can take it that the fulcrum is the clasp (in engineering, considering solid body rotation, it is probably the tip of the reciprocal arm but it's close enough!). So, we will superimpose the active clasp arm as in Figure 10, and now this is, in reality, the resistance. But see what happens to it when the distal end lifts up – it goes down away from the bulge of the tooth and provides no resistance to the lift.

The conclusion is that the clasp assembly providing the fulcrum is no help, and everything is working at a mechanical disadvantage. To turn that into an advantage, the clasp assembly has to move up as the distal extension moves up so that it can encounter the bulge of the tooth and provide the resistance it is supposed to provide. This is done by moving the fulcrum *away* from the clasp assembly, which converts the lever from a Class I lever to a Class II lever.

Now the classic analogy for a Class II lever is the wheelbarrow (Figure 11). The fulcrum is the wheel and the resistance is whatever is in the barrow, the equivalent of the pile of bricks now on top of the original see-saw, making it not impossible for the person to push upwards, but just more difficult.

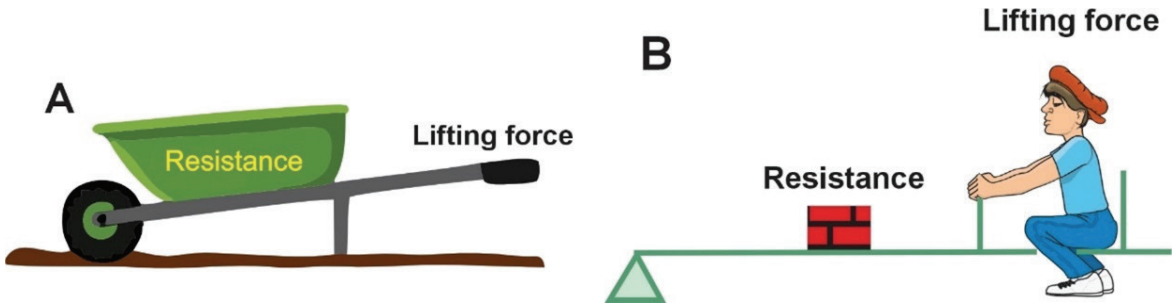

Figure 11 A: The classic example of a Class II lever. B: the equivalent in the see-saw.

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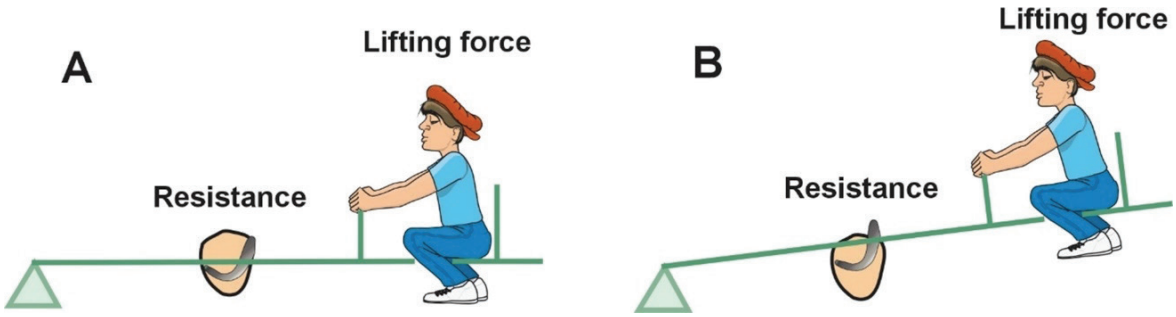

Figure 12 A: The fulcrum is now in front of the clasp assembly, so that when the distal end moves upwards as in B, the clasp arm also moves upwards, engages the bulge of the tooth and provides the resistance to the movement.

Now for the reality: the resistance is, in fact, the clasp assembly and with the fulcrum moved away, in front of – ie anteriorly to – the clasp, now the clasp tip moves up with the distal extension, engages the undercut, and provides the resistance (Figure 12).

Axes of rotation and the fulcrum: where to put it

As with many aspects of RPD design over the years, much of what would seem obvious from looking at diagrams of tooth arches has resulted in some strange designs with no clinical evidence for their efficacy. For many years it was accepted that a fulcrum line would exist between the distal abutment teeth in a Class I, II or IV denture and between the rests of saddles of a Class III denture. In fact, to this day, in the latest edition of a popular textbook which first appeared in 1960 little has changed: "An indirect retainer should be placed as far from the distal extension base as possible in a prepared rest seat on a tooth capable of supporting its function." A diagram similar to Figure 13 shows the favourable location for an indirect retainer to be "at 90 degrees to the fulcrum line between primary rests", to provide "efficient resistance to a denture base lift based on the longest distance to resistant rest support and because the occlusal rest is perpendicular to the load".[9]

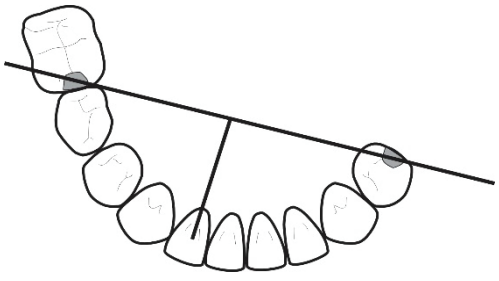

Figure 13. The fulcrum line is assumed to be between the distal rests and the indirect rest is recommended in a well-known textbook to be at right angle to the fulcrum.

However, this has been shown to be quite unnecessary, overcomplicates the design and actually reduces the effectiveness of the indirect retainer. The reason is that a simple analysis of beams and levers reveals a simple truth based on mechanics. The mechanical advantage of a lever is defined as the effort arm divided by the resistance arm and is quite easy to understand when dealing with a simple Class I lever, but not so easy (apparently) when trying to work out a Class II lever. So, consider a Class I lever first as a beam with equal weights each equidistant from the fulcrum (Figure 14). Everything balances but clearly a change in one of the weights or one of the distances will upset that balance, unless the weight and distance compensates for that, and restores balance again (Figure 15). There is no mechanical advantage in the latter: 5 x 20 divided by 100 x 1 is zero.

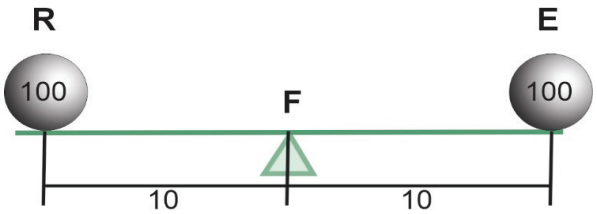

Figure 14. The beam is in balance because the weights (100 units) are equal and are of equal distance (10 units) from the fulcrum.

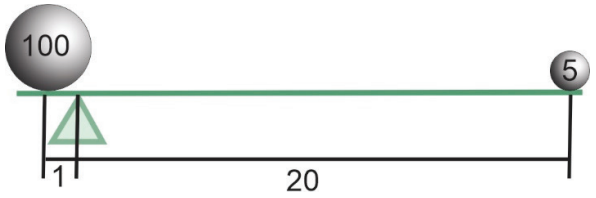

Figure 15. This beam is also in balance but because the right-hand weight is far from the fulcrum, the weight can be considerably reduced. Increasing the weight would create a mechanical advantage and the beam would tilt.

Now if we move the fulcrum to create a Class II lever (Figure 16), we have a mechanical advantage as the resistance arm is part of the effort arm: the weight on the left will have to increase to maintain balance.

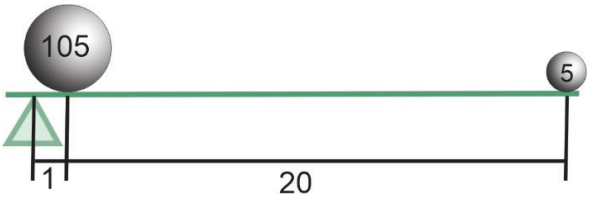

Figure 16. Moving the fulcrum to create a Class II lever means that the weight on the left must be increased to maintain equilibrium.

The principle is that the resistance arm, being part of the effort arm, is always going to be smaller, so the mechanical advantage will always greater than 1 in a Class II lever, which is why it is called a force multiplier. This is precisely the effect required in a distal extension base (Figure 17), we are trying to multiply the resistance created by the clasp when a lifting force is applied to the distal extension base. Let us assume that the lifting force at the end of the base is 6 units from the clasp, and the fulcrum is one unit away from (anterior to) the clasp (Figure 17).

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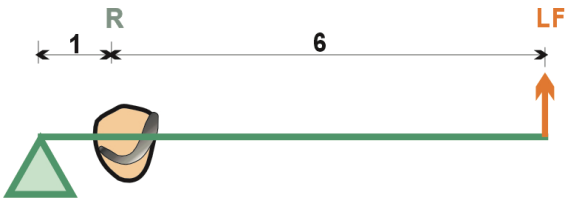

Figure 17. The beam of a mandibular distal extension base as a Class II lever. The effort arm is from the lifting force (LF) to the fulcrum, the resistance arm R is from the clasp to the fulcrum.

Ignoring the strength of the force, and just taking the distances into account, means that the multiplier effect on the resistance, ie the clasp, is 6 + 1 divided by 1, ie 7. A 7 times increase is surely going to make a difference to resist the lifting of the base. This is why the conversion from a Class I lever to a Class II lever is important because it effectively multiplies the resistance of the clasp. However, if the fulcrum is moved further away, as recommended in the literature and many textbooks, the multiplier effect is reduced, not enhanced. Taking the same units into account, if the lifting force is still 6 units away from the clasp, moving the fulcrum 2 units away reduces the multiplier effect to 4; to 3 units, it becomes 3; to 4 units it is 2.5, and so on.

So, it is only necessary to place a rest one or two teeth anterior to the clasp in a mandibular distal extension base to provide indirect retention.

Does it only apply to mandibular distal extension bases?

No, it applies to any force applied to the denture that has the potential to cause rotation. Or any tendency for the denture to rotate. Typical of this is the Kennedy Class IV maxillary denture. Retention anteriorly is reliant mainly on the guide planes and, to some extent, on the edentulous ridge. Guide planes on anterior teeth are small, and so the use of autopolymerising acrylic to create guiding surfaces on the denture is imperative. So, if the denture does tend to rotate downwards anteriorly, then a similar lever system prevails and, if a molar is clasped (as it should be), then the positioning of the clasp and the occlusal rest needs to convert a Class I lever into a Class II lever. This is shown in Figures 18-19.

For a mandibular Class IV denture, the situation is a little different. There is still a problem of limited retention anteriorly, but now you must decide which is the predominant movement to resist, because the denture could either move upwards anteriorly as a result of something sticky attaching itself, or the posterior part could move upwards as a result of an occlusal force angled against the anterior segment, which is what happens during incising. The fact is that both these rotating movements could occur, and the only evidence for one predominating over the other, is anecdotal and relies on the experience of clinicians and patients. In the author's experience, the movement most likely to occur is a rotation where the posterior part of the denture tends to rise. If you agree with this then the clasp arrangement has to be as per Figure 20, otherwise if you want to resist the anterior segment rising up, then the clasp assembly has to be as per Figure 21.

Guidelines for indirect retention

1. Any movement that induces a rotation of the denture needs to be resisted.
2. The means of resistance is by the placement of an occlusal rest in such a situation that a favourable lever system is creat ed.
3. The lever system in a mandibular distal extension base with a simple distal rest and circumferential clasp must be converted from a Class I lever to a Class II lever.
4. This is best achieved by placing a rest to act as a fulcrum anterior to the clasp; this increases the effective retentive force exerted by the clasp.
5. The rest is best placed one tooth anterior to the clasp assembly.
6. The lever system in a maxillary Class IV situation with a posterior clasp assembly with a mesial rest and

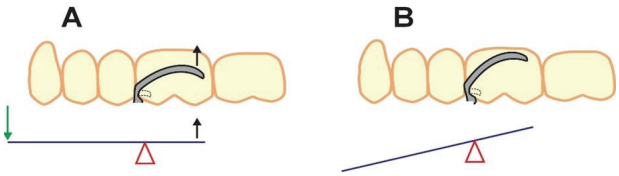

Figure 18 A: If the denture rotates downwards anteriorly and a clasp assembly has a mesial rest with the clasp engaging the distal undercut, a Class I lever is created with the mesial rest as fulcrum. B: this means that the clasp now moves in the wrong direction and does not engage the bulge of the tooth and so provides no retention.

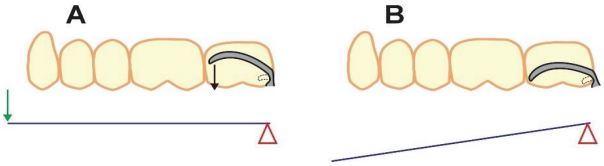

Figure 19 A: If the clasp assembly now comprises a distal rest, and the clasp arm engages the mesial undercut, a Class II lever is created. B: this means that the clasp now moves in the same direction as the denture, encounters the bulge of the tooth and therefore exerts a retentive force to reduce the movement of the denture.

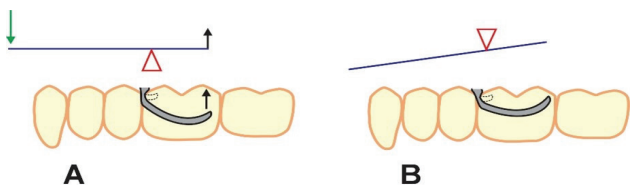

Figure 20 A: If the predominant action to resist is a rotation around the anterior segment from an occlusal force, then the fulcrum is the mesial rest and the clasp arm engages the distal undercut. B: the Class I lever created is in this case favourable as the clasp arm moves up to engage the bulge of the tooth and provide a retentive force.

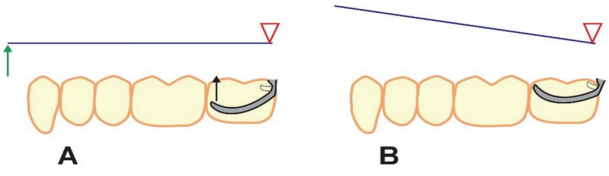

Figure 21 A: If, however, you believe that the movement to resist is an upward movement of the anterior segment, then it is necessary to create a Class II lever with a distal rest and the clasp arm engaging the mesial undercut. B: now the clasp arm will move in the same direction as the denture and provide retention.

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circumferential clasp must also be converted from a Class I lever to a Class II lever.
7. This is best achieved by 'turning around' the clasp assembly so that the fulcrum is distal to the clasp; the clasp assembly now has a distal rest and the clasp arm engages the mesial undercut.
8. The lever system in a mandibular Class IV situation with a posterior clasp assembly with a mesial rest and circumferential clasp is favourable if the predominant movement is a tendence for the anterior segment to move down and posterior segment to move up.
9. However, if the predominant movement to be resisted is that of the anterior segment moving up, then the lever system must be converted to a Class II lever by 'turning around' the clasp assembly so that the fulcrum is distal to the clasp; the clasp assembly now has a distal rest and the clasp arm engages the mesial undercut.

The mythology of the clasp system for mandibular distal extension bases

Distal extension base dentures derive their support from both the mucosa over the ridge, and the teeth. This creates a problem, because the mucosa displaces up to 20 times more than the periodontal ligament. This fact has historically caused considerable concern, because if the abutment tooth – the tooth next to the saddle – is clasped (as it has to be) and the base of the denture moves further than that tooth under an occlusal load, then there is the potential for some rotation around that tooth. And if that tooth is tightly gripped by a clasp assembly then, theoretically, tipping and torquing forces could be transmitted to that tooth. This is made worse by the fact that there is most likely to be a distally placed rest (as rests are usually placed next to the saddle), which could have the effect of tipping the tooth around its axis. These tipping and torquing forces have been thought to contribute to the periodontal problems often associated with the abutment teeth of partial dentures in general, and of distal extension bases in particular.

The entire explanation will only be summarised here and has been given elsewhere.[1] The first idea, proposed 60 years ago, was that a mesial rest and a gingivally approaching I-bar would reduce the tipping forces on the abutment tooth.[10] This was later refined into the RPI clasp system which was a mesial rest (R), a proximal plate (P) which was to disengage the tooth under occlusal load, and an I-bar (I) which was also supposed to disengage the tooth under load.[11] These ideas were presented without any clinical evidence, but were purported to be verified by photo-elastic stress analysis.[12] Then, in 1985, a seminal paper pointed out that there was no evidence either in vitro or in vivo for any of the claims that the RPI system was supposed to solve, and furthermore pointed out that the literature even at that time was showing that any periodontal problems associated with abutment teeth were not related to the RPD but to the oral hygiene of the patient.[13] This has, of course, been corroborated many times in the literature since then, yet, astonishingly, the RPI system is still in use today.

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CPD questionnaire on page 534

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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Sodium hypochlorite as an endodontic irrigant and its effect on dentine: a review of literature

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S Ahmed

SUMMARY

Successful endodontic treatment is achieved by a combination of factors which include acceptable instrumentation, optimal irrigation and disinfection of the root canal system. It is vital that a suitable antimicrobial agent be used during irrigation and sodium hypochlorite emerges as the optimal agent to be used as it complies with most of the criteria of an ideal irrigant. Sodium hypochlorite is a popular choice as an endodontic irrigant due to its solvent activity as well as its antimicrobial action. The tissue dissolving ability of sodium hypochlorite depends on its concentration, volume, contact time of solution with tissue remnants, refreshment and/or activation cycles of solution, as well as the surface area of exposed tissue.

During irrigation, radicular and coronal dentine and enamel are exposed to solutions used during irrigation. Irrigation with sodium hypochlorite during debridement may result in changes to the mineral content of dentine, as it has an effect on the chemical composition, physical and mechanical properties of dentine structure. Irrigants can thus alter surface characteristics of dentine. These changes may influence the integrity and longevity of the tooth. The impact of sodium hypochlorite on the dentine matrix is of particular importance when investigating changes in the dentine matrix. Due to the alterations in dentine structure and mechanical properties of dentine, the effect of sodium hypochlorite can affect the interactions of these surfaces with obturation materials and as well as coronal restorations. Irrigation solutions provide lubrication of root canal walls and thus ease of canal preparation. The effect of sodium hypochlorite to alter dentine surface and chemical structure allows for a change in microhardness, which facilitates ease of root canal preparations.

AIM OF REVIEW

To offer an overview of existing literature on sodium hypochlorite as an endodontic irrigant.

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Author's contribution
Dr S Ahmed – writing of article – 100%

Conflict of interest
The author declares there is no conflict of interest.

SODIUM HYPOCHLORITE AS AN ENDODONTIC IRRIGANT

Aim of canal irrigation

The mainstay of successful endodontic treatment involves the optimal cleaning and shaping of root canals to enable adequate irrigation and disinfection of the root canal system.[1,2,3] Due to the complex anatomy of root canal systems, host defences and different levels of virulence in microorganisms, irrigating solutions must have crucial tissue dissolving ability as well as antimicrobial action. Although root canals are shaped mechanically either by hand or rotary instrumentation, the eradication of microorganisms is completed by adequate irrigation.[4,5,6] The combination of mechanical debridement and the use of an adequate canal irrigant results in an even greater decrease of the microbial population.[7,8,9,10] Sodium hypochlorite, as the irrigant, is responsible for the dissolution of organic pulpal tissue.[11,12,13] With current instrumentation techniques, 40-50% of the root canal may remain untouched and tissue may remain for microorganisms to survive and flourish, thus the aim of irrigation is to optimise root canal disinfection.[14,15] Irrigation is currently the best method for the removal of necrotic tissue and dentinal debri.[16,17] The antibacterial effect, tissue dissolution ability, cleaning and chelating are important features of irrigation during root canal preparation.[17,18,19]

Ideal properties of a root canal irrigant

An antimicrobial agent should have the following properties:

- Have an expansive antimicrobial spectrum and capacity to eradicate anaerobic and facultative microorganisms[6,20,21,22]
- Inhibit bacterial growth[21]
- Ability to penetrate the infection site[23]
- Have a low toxicity level[20,23]
- Dissolve necrotic pulp tissue remnants[6,20,21]
- Inactivate the endotoxin[22]
- Should have adequate concentration to have an antimicrobial effect[6]
- Microorganisms should not be able to develop resistance to the antimicrobial agent[20,23]
- Prevent smear layer formation during instrumentation and/or possess the ability for dissolution of the smear layer once it has formed[21,22]

Sodium hypochlorite as an endodontic irrigant

An important objective of antibacterial irrigation is the effective bacterial disinfection as well as the promotion of debridement of necrotic pulpal tissue and debris from the root canal.24,25 While anaerobes are easily eliminated, the eradication of facultative bacteria like streptococci, enterococci and lactobacilli proves to be more difficult which requires the use of an adequate antibacterial agent; and thus sodium hypochlorite emerges as the

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ideal agent to be used due to its antibacterial and solvent ability.[6,20,21,22,26]

The tissue dissolving ability of sodium hypochlorite depends on its concentration, volume, contact time of solution with tissue remnants, and surface area of exposed tissue.[14,15,16]

In addition, the temperature of the sodium hypochlorite solution as well as refreshment and activation of the solution influences the tissue dissolving ability of sodium hypochlorite.[27]

The sodium hypochlorite reaction

The dynamic balance of sodium hypochlorite is demonstrated by the following reaction:

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

Sodium hypochlorite acts as a solvent by degrading fatty acids and converting the fatty acids into fatty acid salts (soap) and glycerol (alcohol), which causes the reduction of surface tension of the remaining solution.[6,20,22] Sodium hypochlorite neutralises amino acids by forming water and salt. Due to the exit of the hydroxyl ions, there is a decrease in pH. Hypochlorous acid, which is present in sodium hypochlorite solution, acts as a solvent when interacting with organic tissue. This reaction results in the release of chlorine which combines with the protein amino group to form chloramines. Hypochlorous acid and hypochlorite ions results in degradation of amino acids and hydrolysis.

Chloramines are formed due to the reaction between chlorine and the amino group, which then interfere with cell metabolism. Chlorine will lead to antibacterial action by suppressing bacterial enzymes which leads to irreversible oxidation of sulfhydryl groups of essential bacterial enzymes. Sodium hypochlorite (with a pH of more than 11) is found to have detrimental biological effects on bacterial cells. Enzymatic sites are located in the cytoplasmic membrane of bacteria and are essential for functions such as metabolism, cell division and growth. The high pH when hydroxyl ions are released changes the integrity of the cytoplasmic membrane which leads to chemical death. Thus, the key mechanism of sodium hypochlorite depends on the saponification reaction (formation of soap and alcohol), amino acid neutralisation and chloramination reactions that occur when microorganisms are present which progresses to the antimicrobial and tissue dissolution effect.[6,20]

Efficacy of sodium hypochlorite

The path of the sodium hypochlorite reaction is determined by the amount of the organic matter present and the amount and concentration of sodium hypochlorite used.[16,21,28] The second characteristic of the reaction is that there is an initial fast reaction, which is then followed by a slower second reaction. This means that an excess of organic matter can diminish the irrigant of most of its activity and cause a great drop in pH within minutes.[21] The efficacy of sodium hypochlorite means that it needs to respond rapidly and be in excess of the organic matter. Therefore, to ensure the efficacy and maintain a greater ratio of irrigant to organic matter there should be regular use of fresh irrigant and/or increasing the concentration of the sodium hypochlorite solution.[21,26]

Bactericidal action of sodium hypochlorite

The penetration of dentine by sodium hypochlorite is confirmed by the bleaching action of sodium hypochlorite on dye-impregnated dentine and the bactericidal effect of sodium hypochlorite can be observed at depths of 300µm.29 At deeper layers 3% sodium hypochlorite is able to reduce the amounts of viable bacterial cells when compared to 0.5% sodium hypochlorite, thus the bactericidal effect of sodium hypochlorite reaches a greater depth in dentinal tubules at a higher concentration.29,30

Capacity to dissolve organic matter

Tissue dissolving ability depends on the frequency of agitation, the volume of organic matter in proportion to the amount of irrigant and surface area of remaining tissue. Greater concentrations of sodium hypochlorite provide faster dissolution of tissues. Sodium hypochlorite is a strong proteolytic agent, which demonstrates maximum tissue dissolution.[20,31]

Factors which influence the efficacy of sodium hypochlorite

The tissue dissolving ability of sodium hypochlorite depends on its concentration, volume, contact time of solution with tissue remnants and surface area of exposed tissue. Efficacy of sodium hypochlorite for dissolution of tissues can be increased by activation with sonics or ultrasonics, increasing the pH and temperature of the sodium hypochlorite solution, multiple cycles of refreshing solution and increasing the working time.[15,27,32]

i) Altering /adjusting the pH

When sodium hypochlorite is added to water, hypochlorous acid is formed and dissociates into a hypochlorite ion (OCl^{-}). At a pH of 10 most of the available chlorine is in the hypochlorite ion form and at a pH of 4.5 most available chlorine is in the hypochlorous form.[33] Sodium hypochlorite with a pH of more than 11 is found to have damaging effects on microbial populations.[6,20,26]

ii) Temperature of sodium hypochlorite

An increase in the temperature of sodium hypochlorite can increase its effectiveness. A preheated solution of sodium hypochlorite has the following positive effects: short-term stability of sodium hypochlorite, improved tissue dissolving capacity and antimicrobial efficacy.[20,34] Preheated sodium hypochlorite solution removed organic debris from dentine shavings more successfully than an unheated solution. The tissue dissolving capability of sodium hypochlorite is increased by maintaining a temperature of 36°C.[34,35] The tissue dissolution ability of 1% sodium hypochlorite at 45°C is equal to that of 5.25% sodium hypochlorite at 20°C.[34] Sodium hypochlorite solutions need to be disposed of, following increase in temperature, and clinicians should bear in mind to limit the heating of sodium hypochlorite to 50°C.[36]

iii) Agitation of sodium hypochlorite

The efficacy of sodium hypochlorite has been established by its antibacterial activity when it comes into contact with bacterial biofilms, especially in the coronal and middle third of the root canal. The apical third of the root canal has always been challenging concerning sodium hypochlorite penetration and efficacy.[37] The agitation of irrigant solutions is used to increase the efficacy of irrigants.

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These techniques can involve manual agitation with hand instrumentation, manual agitation with gutta percha points, mechanical agitation with plastic instruments and sonic and ultrasonic agitation.[37,38,39] The use of ultrasonic activators to agitate 5.25% sodium hypochlorite within the canal, especially the apical third, increased the efficacy of sodium hypochlorite.37 The use of negative pressure devices such as EndoVac® is especially valuable during the chemical debridement of the apical third of root canals as it allows for better penetration of the sodium hypochlorite solution into the root canal system.[40]

iv) Volume of sodium hypochlorite
During mechanical canal preparation, the root canal space that has been prepared is where irrigating solutions are placed. The efficacy of the irrigating solution is dependent on the dimensions of the prepared canal space, as it determines the irrigant's volume.[41]

v) Concentration and time
Although sodium hypochlorite is widely used, no consensus has been reached with regard to the ideal concentration to be used.[42] The ideal concentration should have a low toxicity level and adequate antibacterial action. Canal preparation is done in a short time period; therefore the antibacterial efficacy of the irrigant will be influenced by the concentration of the solution.[31,43,44,45] Organic matter present in canals that come into contact with sodium hypochlorite will consume the available chlorine and the antibacterial efficacy is reduced. With the use of sodium hypochlorite at a lower concentration, this phenomenon is evident. With a higher concentration of sodium hypochlorite a reserve would be created to maintain the antibacterial activity.[45]

Studies on sodium hypochlorite concentration and time exposure varies from 2-30 minutes and a concentration of 0.5%-5.25%.[46,47] The most effective regimen is found to be a sodium hypochlorite concentration at 5.25% at 40 minutes, especially to remove Enterococcus faecalis. Irrigation with sodium hypochlorite at a lower concentration for an equivalent period of time period is less effective in removing Enterococcus faecalis. Antimicrobial agents require adequate exposure time in the root canal system to yield results.[46] The negative effect of using concentrated solutions is the tissue irritation and damage that may be caused when irrigant is inadvertently forced into the periapical tissues.[22]

The effect of sodium hypochlorite on root canal dentine

Irrigation with sodium hypochlorite has an effect on mechanical effects of dentine including flexural strength, microhardness and elasticity.[4]

Effect of sodium hypochlorite on flexural strength

The ability of a material to resist deformation under load is defined as flexural strength. A decrease in flexural strength would indicate a decreased force is needed for the cohesive bonds within dentine to fragment.[48] Exposure of dentine to sodium hypochlorite results in decreased flexural strength and the modulus of elasticity of dentine. The overzealous use of sodium hypochlorite may increase the risk of fracture in endodontically treated teeth.[29] The dentine surface structure degrades after sodium hypochlorite exposure and this could contribute to the decrease of flexural strength. The exposure of dentine to sodium hypochlorite (at a concentration of 3% and higher) for one hour resulted in changes in dentine flexural strength.[50]

Effect of sodium hypochlorite on microhardness of dentine

The mineral content as well as the hydroxyapatite concentration in the intertubular spaces determines the hardness profile of dentine. A positive relationship is present between dentine hardness and mineral content of dentine.[51] Evaluating the microhardness of dentine can impart information pertaining to mineral loss or gain in dentine. Microhardness values may vary with regard to location, with the value decreasing closer to the pulp. This can be due to the presence of open dentinal tubules closer to the pulp, and these tubules would have less resistance.[19,51,52]

Dentine microhardness (which is determined by the amount of calcified matrix per mm^2) is inversely correlated to tubular density. Determination of microhardness only provides indirect evidence of mineral loss or gain in dental tissues.[53] No consensus/agreement is available in the current literature on the ideal amount of dentine microhardness reduction to facilitate mechanical instrumentation and, at the same time, avoid excessive mineral loss which could lead to weakening of dentine structure.[54] The reduction of microhardness is caused by a reduction of stiffness of the intertubular dentine matrix. This is caused by varied distribution of the mineral phase within the collagen matrix.[55] The dentine microhardness evaluated next to the root canal lumen is higher, where the dentinal tubuli are dense compared to the peripheral area where the tubuli are less crowded.[55] The degree of mineralisation and the hydroxyapatite content in the intertubular substance affects the intrinsic dentine hardness, where a decrease in dentine microhardness may be observed as well as an increase in surface roughness of the root canal dentine.[57] This was observed with concentrations of sodium hypochlorite of 2.5% to 5.25%.[48] Studies have shown that 1% of sodium hypochlorite may decrease dentine microhardness. A Vickers hardness test was used and researchers found that lower Vickers hardness values were obtained at 500µm from pulp. Dentine microhardness is location related, and the value of dentine microhardness decreased as the indentations were closer to the pulp. This can be attributed to the open dentinal tubules (free of peritubular dentine), which are closer to the pulp.19 Various studies confirmed that sodium hypochlorite significantly decreased dentine microhardness. It was found that although the different areas of the root (cervical, middle and apical) are structurally different, all the root thirds displayed the same results with regard to decrease in dentine microhardness.[19,56,56]

Concentration of sodium hypochlorite and microhardness

The greater efficacy of sodium hypochlorite at greater concentrations has influenced clinicians to use higher concentrations of sodium hypochlorite during root canal preparation. However, this may have a deleterious effect on dentine properties.[57] The concentration of sodium hypochlorite has an effect on microhardness where both concentrations of 2.5% and 6% sodium hypochlorite rendered a decrease in microhardness; however, 6% sodium hypochlorite rendered a greater decrease in microhardness than 2.5% sodium hypochlorite.[55] Weight loss of dentine

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after immersion in sodium hypochlorite was greater at a higher concentration of sodium hypochlorite.[19]

Contact time of sodium hypochlorite and dentine microhardness

The decalcifying effect of sodium hypochlorite is influenced by the irrigation period and will therefore have an effect on dentine microhardness.[58,59] During contact with sodium hypochlorite a reduction in dentine microhardness was found in the first 10 minutes. After 20 minutes' contact time there was no statistical significance. The initial decrease may be due to the initial removal of the organic matrix from the dentine during the first 10 minutes.[60]

Effect of sodium hypochlorite on mineral composition of dentine

Dentine comprises approximately 22% organic material which is made up mostly of type I collagen, and this constituent influences the mechanical properties of dentine.[61] Sodium hypochlorite is a nonspecific oxidising agent and deconstructs long peptide chains and chlorinates protein terminal groups which leads to the breakdown of N-chloramines into other species. This leads to adverse consequences for dentine structure.[60] Sodium hypochlorite dissolves both collagen components of dentine and magnesium and phosphate ions and increases dentinal carbonate.[48,51] Research studies has shown that sodium hypochlorite solutions with concentrations varying from 1% to 6% may cause a reduction in dentine microhardness. Sodium hypochlorite can also alter the calcium to phosphate ratio of root dentine which leads to the conclusion that these changes in the mineral content can affect the hardness profile of dentine.[48] The exposure of dentine with 6% sodium hypochlorite for a period of 5 minutes has shown a decrease in dentine microhardness. The decalcifying effect of sodium hypochlorite largely depends on application time, the pH and concentration of the solution as well as the hardness of dentine.58 Sodium hypochlorite has also demonstrated maximum reduction in microhardness compared to other acids such as carbonic citric and tartaric acid. Sodium hypochlorite at 5.25% concentration caused the maximum reduction of microhardness, which could be attributed to the degradation of the organic dentin components.[58]

Effect of sodium hypochlorite on the modulus of elasticity of dentine

Sodium hypochlorite has the ability to deproteinise and disintegrate the organic dentine matrix. Disintegration of the organic dentine matrix results in a reduction in the elastic modulus and flexural strength of dentine. Sodium hypochlorite also increases the permeability of the altered intertubular dentine with a 5% sodium hypochlorite concentration altering the peripheral dentine matrix.[55] The modulus of elasticity of dentine after irrigation with sodium hypochlorite can be determined using ultrasonic wave propagation measurements. To determine changes to the modulus of elasticity of dentine following exposure to sodium hypochlorite, the 3-point bend test and ultrasonic investigation can be used. The results demonstrated a reduction of the modulus of elasticity by 3%. As dentine is anistropic and varies in thickness, a reduction of 3% can have an effect on dentine. At regions of stress concentrations this reduction in elasticity can lead to the propagation of microcracks.[56] Fracture loads were found to be less, with significant deformation of the dentine bars before complete fracture. Although a range of disparity in the behaviour of dentine bars was observed, there was enough significant statistical difference to indicate that both 3% and 5% sodium hypochlorite caused a decrease in the modulus of elasticity and flexural strength.[45]

Effect of sodium hypochlorite on tooth surface strain

Tooth surface strain is measured at the cervical margin of a tooth by using electrical strain gauges during cyclic loading. Sodium hypochlorite at a concentration of 5% has demonstrated an increase in strain value under cyclic loading. The actions of sodium hypochlorite may produce surface flaws in the dentine and subsequent cyclic loading during function may allow crack propagation through fatigue. Tooth tissue loss (demineralisation) causes a reduction of the force required by the tooth to strain and this may lead to crack development and fractures.[57] Dentine exposed to 5.25% sodium hypochlorite displayed a significant decrease in flexural strength and rigidity and a decrease in elastic modulus. This may be attributed to the decrease of the organic matrix within dentine. In addition, an increase in tooth strain may result in changes in stiffness of the tooth which may predispose the tooth to fracture. Increase in tooth strain after sodium hypochlorite irrigation was 15.9% tensile strain and 3.5% compressive strain.[57]

Dentine permeability and penetration

The effect of irrigating solutions may be affected by the permeability of dentine, which may favour or decrease their effect. The floor of the pulp chamber consists of primary and secondary dentine which allows for more uniform penetration of ions. Alternatively, reparative dentine is more amorphous in structure, less tubular and the route of fluids may be obstructed. Thus, the dentine permeability will have an effect on sodium hypochlorite penetration.[59]

Knowledge of the depth of sodium hypochlorite penetration into dentine and factors which may influence the depth of penetration can be beneficial when practicing one appointment endodontic treatment. The penetration of sodium hypochlorite into dentine is outlined by measurement in micrometres. The depth of sodium hypochlorite penetration into the dentinal tubules was recorded as between 77 and 300µm. Factors such as sodium hypochlorite concentration, exposure time and temperature have an effect on sodium hypochlorite efficacy and it stands to reason that these variables can impact sodium hypochlorite penetration.[28]

CONCLUSION

Various studies indicate that sodium hypochlorite is the irrigant of choice of the majority of dentists due to its antibacterial effect, tissue dissolution capacity and acceptable biologic compatibility in less concentrated solutions. The concentration of the sodium hypochlorite varies due to the clinician's preference. Greater efficacy of sodium hypochlorite is observed at higher concentrations of sodium hypochlorite, and thus it is tempting in the clinical situation to use a higher concentration of sodium hypochlorite.

There is also evidence in literature that connects the concentration-dependant effect on mechanical properties of dentine when dissolution of organic dentine occurs. Thus the concentration, exposure time and temperature should

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be taken into consideration during endodontic visits. This is particularly important when practicing single or multiple endodontic visits. The changes to dentine structure and mechanical properties may influence the interaction of the root canal dentine with obturation materials, coronal restorations and cements in the case of post core crowns. There is, however, no consensus with regard to optimal concentration or irrigation time of sodium hypochlorite to eliminate microbial populations in root canal systems.

More research is required in this field to investigate the ideal time, concentration and temperature of sodium hypochlorite use in endodontics.

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What's new for the clinician – summaries of recently published papers (November 2023)

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1. Comparative evaluation of four treatments for post-orthodontic white spot lesions: a randomised controlled trial

Orthodontic treatments have enjoyed growing popularity in recent years, and the white chalky spots, also called white spot lesions (WSLs), that appear after treatment are a major aesthetic problem for patients and clinicians.[1] The prevalence of these unsightly lesions varies from 3% to 97%1. In some cases, these demineralisation lesions may be reversible but often, in the case of orthodontic treatments, these lesions of the enamel evolve progressively and become irreversible, leading to carious processes.[1] An increase in the amount of dental plaque containing cariogenic bacteria is the main etiological factor in decalcifying the enamel during orthodontic treatment. This demineralisation of the dental surfaces results in the appearance of WSLs or even caries.

With the development of penetration technology, the clinical application of resin infiltration has achieved encouraging results.[1] The use of resin infiltration can change the optical properties of damaged enamel by resin penetrating into the space of the demineralised enamel, thus improving its aesthetic appearance.

Wang and colleagues (2023)[1] reported on a randomised clinical trial (RCT) that sought to evaluate the efficacy of fluoride toothpaste alone and those of the adjunctive use of resin infiltration, CPP-ACP and fluoride varnish in the treatment of WSLs. The null hypothesis tested was that there was no difference in the effectiveness of the four treatments in reducing the size of WSLs.

MATERIALS AND METHODS

The study was a prospective, randomised, double-blind, multicentre clinical trial done in China. Assuming on average one patient had 4 lesions and anticipating a 20% drop-out rate, at least 18 patients in each group were targeted for recruitment at baseline.

Seventy-nine patients were recruited from four hospitals. The inclusion criteria were patients who (1) were between 12 and 25 years old; (2) could participate in clinical trials for a period of 24 months; (3) were generally healthy; and (4) had two or more WSLs in the buccal surface of the anterior teeth with significant visual changes in enamel and/or local enamel breakdown and no clinical visual signs of dentin involvement [International Caries System Detection and Assessment System (ICDAS code 2)]. The exclusion criteria were patients who (1) were pregnant or breastfeeding women; (2) had a smoking history; (3) had a systemic disease or syndrome; and (4) were confirmed or suspected to have allergies to fluoride or milk protein and/or to benzoic acid preservatives (components of CPP-ACP products). Baseline examinations were conducted by four calibrated and specially trained dentists.

In this study, stratified randomisation was adopted, which was stratified by centre and then randomised within each centre. Each patient received a randomly assigned sequence of treatments, and the results were placed in sequential, sealed, light-tight envelopes. The envelope would only be opened when eligible patients agreed to enter the trial, and the patients would receive the treatment according to the allocation result. The first unblinding was performed after data collection, and the second unblinding was performed after the statistical analysis report was completed. For teeth with lesions not included in this study and with treatment need, parents were advised to take their children to the dentist for timely treatment.

In this study, a double-blind method was used, in which both the participants and the image processor were unaware of the study group assignments. There were four groups in this study. In the fluoride varnish group, the WSLs received 5% sodium fluoride varnish (Duraphat) every 6 months. In the CPP-ACP group, the lesions received fluorine-free CPP-ACP mousse (GC Tooth Mousse) every 6 months. In the resin infiltration group, the lesions received resin infiltration (Icon infiltration resin) treatment at baseline, and placebo was applied to the lesions every 6 months from the second visit. The control group was coated with fluoride toothpaste (containing 1400ppm fluoride) every 6 months. All the participants in the study were asked to use designated toothbrushes and fluoride toothpaste (Colgate containing 1400ppm fluoride) to brush their teeth twice a day. At each follow-up examination, oral health instructions were given to the patients, and they were asked to use pea-sized toothpaste while brushing teeth.

For the participants in the fluoride varnish, CPP-ACP, and control group, the study agent was applied on the WSLs using a microbrush by trained dentists according to their group allocation at each visit. The study participants were instructed not to drink or eat in the next half an hour after the interventions and to avoid hard food in the next four hours.

At baseline, for the participants in the resin infiltration group, the teeth with WSLs were cleaned, and the operation area was isolated by a rubberdam. The lesions were etched with 15% hydrochloric acid gel for 2 min and rinsed with a large amount of water under pressure. The enamel surface after etching showed a chalky white colour. To dry the tooth surface, the following steps were taken: 99% ethanol was injected onto the lesion for 30 sec, then the operation area was blown dry, infiltration resin was applied for 30 sec, and teeth were left for 3 min. The excess resin

on the interproximal surface was cleaned with floss and light cure was applied for 40 sec. Without further acid etching, the resin infiltration was repeated and left for 1 min. Then, the teeth were cleaned and light cure was applied for 40 sec. The tooth surface was polished after removing the rubberdam.

A modified validated questionnaire was used at baseline to study the patients' oral health-related behaviours and socioeconomic backgrounds. The content included parental educational level, snacking habits, daily tooth brushing habits, use of floss, use of fluoride toothpaste and smoking history.

The area of WSLs was measured by ImageJ Image analysis software and the changes in the lesion area in the four groups were compared.

All intraoral photographs were taken under the same condition. ImageJ software was used to analyse and process the images. The combination of photos and Image J software is considered a reliable measurement method which is easy to operate, economical, fast, intuitive and highly acceptable to patients. By measuring photos, the extent of tooth damage can be directly analysed and the appearance and colour of teeth can be evaluated, better meeting human aesthetic standards and improving patient satisfaction. For the teeth identified as WSLs with ICDAS code 2, the researcher first drew the outline of the whole tooth and calculated the area with ImageJ software on the same computer screen, and then outlined the WSLs on the surface of the corresponding tooth and analysed its area. After determining the values for total tooth area and lesion area, the percentage of the affected area surface was calculated by dividing the area of WSLs by the total tooth area. The percentage of WSLs for each tooth surface provides a relative value to control for the effect of differences in magnification of digital photographs. The reference for measuring the area of WSLs by ImageJ software was calibrated based on ruler photographs obtained at a fixed focal length. To evaluate the method error, the digital oral photograph images of 10 participants were randomly selected among all participants, and the same data analyst measured the digital photographs again after 1 week to perform a consistency test; the intraclass correlation coefficient (ICC) was required to be above 0.9 to ensure the repeatability of the measurement results.

RESULTS

At baseline, 136 patients were screened and 79 patients (31 male, 48 female) with a total of 356 teeth with WSLs meeting the inclusion criteria were randomly allocated into the four study groups. There were 20, 20, 20 and 19 participants in the fluoride varnish, CPP-ACP, resin infiltration group and control group, respectively.

Participants were mainly adolescents, with a mean (±SD) age of 15.9 (±2.8) years (median 15 years, minimum 12, maximum 25 years). Most of them brushed their teeth daily but rarely flossed their teeth and ate sweets or drank sugary drinks at least once a week. More than half of the parents had a university degree or higher level of education. There were no significant differences in oral health-related behaviours or sociodemographic characteristics between the four groups at baseline.

At baseline, a descriptive statistical analysis of oral examination indicators was performed. According to the results of the normality test, the data in the table were skewed, so the form of [median (upper quartile, lower quartile), M (Q1, Q3)] was used for statistical description. After 12 months, 68 (86%) patients remained in the study, with 18, 19, 16 and 15 patients in the fluoride varnish, CPP-ACP, resin infiltration group and control group, respectively.

The dropout rates among the four groups were similar (χ^2 test, $p > 0.05$). There were no significant differences in the mean scores of DMFT, decayed teeth (DT), filled teeth (FT), PI and BOP between the participants who remained and those who were lost to follow-up. No significant differences were found in the tooth brushing habit and snacking habit among the four groups at baseline and at the 1-year follow-up. After 12 months, the percentage of the WSLs area in each group was significantly different from the baseline, and different degrees of reduction in the area of WSLs were observed in all four groups. The percentage of lesion area reduction in WSLs in the resin infiltration group was 46.62%, which was significantly higher than that in the fluoride varnish group (26.57%), CPP-ACP group (28.64%) and control group (29.75%), and the differences were statistically significant ($p < 0.001$). Further pairwise comparison showed that the resin infiltration group had significant differences from the fluoride varnish, CPP-ACP and control group. In the resin infiltration group, the baseline WSL area before treatment (baseline area B) was 26.24 ± 10.78 (mean ± SD), the area immediately after treatment was 17.38 ± 9.87 (mean ± SD) and the area after 12 months was 13.55 ± 7.24 (mean ± SD), indicating that the area of WSLs continued to decrease between baseline and 12 months after treatment. No adverse events were reported in any of the groups.

To investigate the influence of various factors on the results and to account for the clustering effect of the data, multiple linear regression analysis was used. There was a significant difference between receiving resin infiltration treatment and a decrease in WSLs. The treatment effect for this intervention was greater than observed for the other three interventions. Liner regression also showed that as the PI (plaque index) increased, the oral hygiene worsened and the treatment effect decreased.

CONCLUSIONS

This study showed that after a 1-year follow-up period, the use of resin infiltration significantly reduced the area of WSLs. Fluoride toothpaste, with or without the adjunctive use of CPP-ACP and fluoride varnish, also has therapeutic effects to some extent. When conditions permit, resin infiltration would be the best treatment strategy for WSLs.

IMPLICATIONS FOR PRACTICE

Resin infiltration techniques seem to offer significantly better clinical outcomes when used for treating WSLs when compared to other treatment modalities. However, it is important to focus on maintaining good oral hygiene as this trial has shown that poor oral hygiene is associated with smaller treatment gains.

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2. Combining short-onset (lidocaine) and long-acting local anaesthetics(ropivacaine) for better pain outcomes in third molar surgery: a randomised controlled trial

Extraction of mandibular third molars is a common procedure in oral surgery which triggers a cascade of inflammatory events including swelling, redness, functional disability such as trismus and pain.[1] Since pain control has a significant impact on a patient's quality of life, effective analgesia both during and after the operation is crucial to ensure patient comfort. Many third molar surgeries are done in the dental chair without sedation using only local anaesthetic (LA).[1] Although 2% lidocaine with epinephrine is usually the preferred LA for dental procedures, adequate intraoperative anaesthesia and prolonged postoperative analgesia can be achieved by using long-acting LAs such as ropivacaine.1 However, long-acting LAs are known for their slower onset of action. To compensate for this, a mixture of short-onset (eg lidocaine) and long-acting LAs is often used clinically in other types of surgery to block the sciatic nerve and brachial plexus.1 However, the efficacy of such an anaesthetic cocktail has not been elucidated in the field of oral and maxillofacial surgery. Hemmi and colleagues (2023)1 reported on a trial that sought to investigate the efficacy of a lidocaine-ropivacaine mixture in providing analgesia for the extraction of impacted mandibular third molars.

MATERIALS AND METHODS

This was a prospective, randomised, blinded clinical trial involving two groups of 28 patients in each arm of the study. Patients aged ≥16 years, who had been scheduled for the extraction of a mandibular third molar under local anaesthesia from June 1 2021 to March 22 2022 were included in the trial. Patients with a history of allergic reaction to lidocaine and/or ropivacaine, paraesthesia around the area of innervation of the mandibular nerve, active infectious disease in the oral and maxillofacial region, and haemorrhagic diathesis were excluded from the trial. The participants were blinded to the LA used.

Patient allocation was stratified by a combination of two factors, sex and age, and block randomised (block size = 4) in each stratum. Sequentially numbered containers were used for random allocation, which was performed by a statistical specialist.

The primary outcome was the onset of anaesthetic effect. The secondary outcomes were anaesthesia success rate, duration of operation, duration of anaesthetic effect and pain intensity during and after extraction determined using the numerical rating scale (NRS).

The inferior alveolar nerve block (IANB) was given to each patient using a standardised technique. In this technique, the needle was inserted from the medial side of the mandibular ramus and lateral to the pterygomandibular raphe, at the level of the coronoid notch on the anterior border of the ramus. A 3.0mL disposable syringe and 31-gauge 12mm needle were used. Either 2.7mL of 2% lidocaine with epinephrine (lidocaine group) or an equal volume of a 1:1 mixture of 2% lidocaine with epinephrine and 0.75% ropivacaine (mixture group) was used as the LA.

Numbness of the lower lip, tongue and buccal mucosa is considered to indicate the onset of anaesthesia. After confirming the onset of anaesthesia, 0.9mL of 2% lidocaine with epinephrine was infiltrated around the mandibular third molar to reduce bleeding during extraction. If the procedure was completed without the need for additional administration of the LA, local anaesthesia was considered successful. The need for re-administration of LA was noted, and such patients were excluded from postoperative evaluation. All the nerve blocks and extractions were performed by a single oral surgeon using a consistent protocol. All patients were instructed to take 60mg loxoprofen sodium hydrate 8 hourly for 1 week and 250mg amoxicillin 6 hourly for 3 days after the extraction.

The onset of anaesthetic effect, anaesthesia success rate, duration of operation and pain intensity during extraction were recorded on the day of operation. As this study included patients who underwent the procedures in an outpatient setting, the interval between the end of operation and awareness of pain/first intake of analgesic and postoperative pain intensity were recorded using a questionnaire, which was filled in at home.

RESULTS

Of the 56 patients recruited, 52 patients completed the trial. No significant differences were observed in sex and age between the two groups, which indicated uniform randomisation. Also, no significant differences were observed between the groups in clinical features including onset of anaesthetic effect and success rate ($P = 0.59$ and 1.00, respectively).

Since two patients in each group dropped out of the study (one patient in the mixture group was lost to follow-up and one patient in the mixture and two patients in the lidocaine group required additional LA administration due to insufficient anaesthetic effect), 26 patients in each group (total 52) were included in the following statistical analysis. For three patients with insufficient anaesthetic effect, infiltration anaesthesia with lidocaine was added, and the procedure was completed in all patients.

In the mixture group, both duration of anaesthetic effect and time to first intake of analgesic was significantly longer than that in the lidocaine group ($P < 0.01$).

Surgical pain during extraction and 1- and 7-days post-extraction was recorded to compare analgesic efficacy. In the mixture group, maximum NRS scores at each time point were lesser than in the lidocaine group, though the differences were statistically significant only for NRS scores 7 days after extraction.

No significant complication or adverse effect was observed in any group.

CONCLUSION

The Inferior alveolar nerve block (IANB) using a lidocaine-ropivacaine mixture can provide prolonged postoperative anaesthesia and pain control with extraction of mandibular third molars.

IMPLICATIONS FOR PRACTICE

The combination of a short onset and a long acting LA can result in longer-term pain control for patients undergoing third molar surgery without sedation.

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Wilful blindness

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LM Sykes[1], AM Van Zyl[2]

"The most deadly poison of our time is indifference"

Saint Maximilian Kolbe

ABSTRACT

Practitioners who are aware of colleagues carrying out unprofessional activities, yet choose to turn a blind eye to the transgressions, may themselves be acting dishonestly and unethically. This paper explores both the legal and ethical concerns of "wilful blindness" on the part of those who observe potential wrongdoing among others within the dental fraternity, yet remain silent. It also covers the HPCSA regulations regarding the duty to report and the risks associated with being a "whistle-blower".

Introduction

We are all aware of colleagues within the dental fraternity who are not behaving professionally, such as dentists doing specialised procedures for which they have not had adequate postgraduate training; technicians, therapists or oral hygienists performing work outside their scope of practice; clinicians making use of social media sites to advertise their practices; misleading advertisements and/or offers of "special deals"; colleagues posting identifiable before and after patient treatment photographs on public platforms; overservicing or overcharging; and many other practice-related transgressions. Yet for the most part the dental fraternity remains silent. Their "wilful blindness" intimates consent, and allows the perpetrators to continue with their wrongdoing without any fear of repercussions. This "deafening silence" is both an ethical and a legal concern. In this paper, the topic will be presented from a legal standpoint, and juxtaposed by ethical considerations (in italics), as well as in terms of the HPCSA rulings on the duty to report.

1. The Law and Ethics

A delict is a complex legal entity that is traditionally divided into key elements.

These are: 1. Conduct (the commission or omission of an act); 2. Wrongfulness (the act is unlawful or wrongful); 3. Fault (it was committed negligently or with a particular intent); 4. Causation and Liability (it results in or causes a harm); 5. Damage (harm or damage that ensues).[1] A delictual inquiry is a loss-allocation exercise, in which a person claims for damages caused by a harm. The harm itself may be a patrimonial loss or due to pain and suffering associated with bodily injury. The usual remedy sought is for some form of compensation.[1-3]

Each of these elements will be briefly discussed in terms of the South African Law, and how they relate to the dental practitioner who witnesses the delict. It will not cover the conduct of the wrongdoer.

1.1 Conduct may be in the form of a positive act (a commission), an omission or even a statement. It is usually wrongful if it causes harm to a person or property. The conduct of the professional who witnesses wrongdoing but remains silent, and thus allows the perpetrator to continue, is one of omission rather than a commission. If the courts were to evaluate their conduct they would need to determine if the act itself was wrongful, if the person in question had mental capacity to know this, and if their actions were voluntary.[4] The degree of wrongfulness is often a question of "social policy" and requires those deliberating over it to "make a value judgement as to its social acceptability". To do this they would consider the interests of both parties involved, as well as society in general, the possible consequences of the conduct and the implications of a decision in favour of any party involved. However, where the conduct is due to an omission or negligent statement, it is usually not considered wrongful even if some form of physical harm resulted. An omission will only be considered legally wrongful if there was a duty to act positively to prevent the harm. Even so, the courts will still consider possible defences such as "self-protection, necessity, justification, statutory authority or consent".[1-4]

While it may not be possible to rule an omission wrongful legally, at most it is usually considered negligence. However, ethically it may be felt that they did not show "adequate or consistent levels of care towards the patients" in question.[5] To at least hold them accountable from a professional and moral standpoint one would have to consider their inactivity under the "objective reasonable person" rule and asses it in terms of two main criteria, foreseeability and preventability. The former refers to the "likelihood or extent of risk created by the conduct, and the gravity of the possible consequences". In instances where the "likelihood of harm is relatively great, or the consequences are serious, the possibility of harm is foreseeable". The opposite is also true in that it is difficult to foresee harm where the risks are small or the potential damages would not be serious.[4,6]

Preventability is judged by considering if they could feasibly have done anything to prevent the harm, and the degree of burden suffered by the patient by their lack of intervention. It also considers what the costs to them personally would be if they did have to take any actions. If the burden to them personally of trying to prevent the harm outweighs the significance of the risk, they cannot be expected to take any actions to try to prevent it.[3,4]

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1.2 Wrongfulness, in that the act must be objectively unreasonable, unlawful or wrongful. In this instance, the practitioner who is carrying out the unlawful or unethical act is behaving in a wrongful manner, but so too is the one who allows this to continue without trying to intervene in some way to prevent possible future harm.[1-4]

Wrongfullness in terms of ethics in this situation is mostly linked to the concept of non-maleficence which obligates practitioners to either refrain from causing harm, to attempt to remove harm or to prevent possible harm.[5]

1.3 Fault refers to the blameworthiness of the action and whether it was committed negligently or intentionally. For a person to be at fault it needs to be proven that they were accountable for their actions, that they knew the act being witnessed was wrong and they knew their inactivity was wrong. The fault in this instance is one of omission, where they failed to do or say something about the wrongdoing. However, in terms of the SA law it is rare for them to be held liable as there is no legal duty to prevent harm. As mentioned, fault may be apportioned if the person was in any way duty bound by society to try to prevent the harm. Examples of such include "where the person has direct control over a potentially dangerous object, persons in public office, where there is a contractual assumption of responsibility, where there is a statutory duty and where the harm is foreseeable".[1-4]

Ethically a person can only be at fault if they have "the mental and emotional capacity to distinguish between right and wrong, and the ability to act in accordance with that insight and understanding".[4] Evaluating this is very subjective as it deals with an assessment of mental rather than physical attributes of the person being judged. These, in turn, may be influenced by extraneous outside circumstances such as emotional distress, "mental or physical illness, immaturity, intoxication or provocation". Here we would consider whether the silence was due to apathy, or some form of unwillingness to get involved, or if there was an overt and conscious intention to see harm done. In the case of the latter the motive for that intention needs to be established.[4] Perhaps the dentist wanted a harm to occur so that the guilty practitioner would run into trouble. However, they knowingly placed patients at risk to achieve this end goal, which is cowardly and ethically deplorable.

1.4 Causation must prove that the action resulted in harm. This needs to be both factual and legal in that the law needs to show that there is a direct causal connection between the conduct and the harm. It is almost impossible to prove that a person's inactivity directly caused the harm sustained by someone else in situations where they were outside observers. Here the questions to ask would be if there was any form of direct connection between the two parties and, if so, if the harm was connected closely enough to them in any way.[4]

Liability is measured in terms of the degree of harm incurred, the wrongfulness of the conduct and the intention behind the action which resulted in the impairment. Not every damage or loss will incur liability especially if it is the result of carelessness rather than unquestionable fault. The law will only prescribe remedies if all of the above five elements are present. In terms of the law conduct is generally divided into either factual or legal causation. The former is determined by the court's ability to prove that the person's silence caused the harm or loss. If so, is the harm linked sufficiently closely to confer legal liability, or is the association too remote? To determine causation "the court will apply a flexible test based on the principles of reasonableness, fairness and justice". They can also not be held liable for their inactivity if they genuinely were unaware that their/the action being witnessed was wrong. The courts, too, may also consider a person who is under severe emotional distress to not be liable for their actions.[1-4]

It becomes difficult to confer liability on a person who silently watches the wrongdoings of another practitioner, as no actual harm may yet (or ever) occur to the patients. Thus, the essential elements of delict will not be fulfilled. However, their inactivity is nonetheless unethical as they are aware of the wrongdoing but choose to not become involved in trying to stop it. This goes against the principles of non-maleficence. They could also be accused of negligence if their inactivity showed an inadequate standard of behaviour as expected by their profession.[4,6] Here their conduct would be judged against a predetermined standard. This considers if they were aware that there was a foreseeable risk of harm for patients, and whether they took reasonable steps or precautions to try to prevent this from happening.

1.5 Damage (harm or damage that ensues). These may be patrimonial which could include things such as medical fees, loss of income and the costs incurred by the patient to rectify the injury or impairment. The latter are termed special damages. Non-patrimonial damages include pain and suffering, disfigurement, loss of function and psychosocial injury – these are all referred to as general damages. It may also take the form of pure economic harm not connected to any actual physical hurt or injury. Nervous and psychiatric damages inflicted through a sensory input may not result in a visual physical injury, but rather a mental impact, and are still considered as damages. But for legal actions to be taken the damages need to be proven to have been "intentionally or negligently inflicted".[4] Once again, an objective reasonable person test may be used to determine: that "mental harm has arisen; it must not be a trivial emotional experience; there should have been some intention to shock (here a much stronger legal action will ensue) or it occurred from a negligent action; it must have been foreseeable; there must be some direct relationship between the injured party and the injurer, or the injurer had some special knowledge which could have affected their behaviour positively or negatively".[4,6]

Damages such as discomfort, pain and suffering, nervous of psychosocial injury, mental stress, inconvenience or sadness and depression are intangible, and subjectively experienced and assessed by an outsider. Their presence and extent of effect are difficult to assess and even more challenging to prove legally, and are seldom, if ever, compensated for in terms of financial settlements.[4] However, they can have a profound negative impact on the sufferer's life and wellbeing. While it may not be possible to prove that wilful blindness was intentional or negligent, the objective reasonable person test would shed light on the ethical acceptability of such inactivity.[6] The problem is that it is impossible to assess the degree of another person's mental anguish or emotional distress. A practitioner who consciously knows that there are imminent dangers for patients and does not intervene is wilfully malevolent and

could at the very least be charged with unprofessional and unethical behaviour.

2. The HPCSA Regulations

The HPCSA guidelines advocate that reporting misconduct by colleagues is an important aspect of maintaining professional standards and ensuring patient safety. To this end they provide guidelines of the processes to follow when reporting another practitioner. The first step is to familiarise oneself with the regulations to be sure that the practitioner is contravening set practices. The next would be to document the misconduct in as thorough a manner as possible, including any evidence to support the accusations. Thereafter the matter needs to be reported to the relevant authority within the council. The HPCSA does promise to provide appropriate protection for the reporting party to try to allay fears and encourage practitioners to not remain silent when they encounter illegal or unethical behaviour from colleagues.

Once the HPCSA receives a formal, written complaint they are mandated to investigate. Each case is dealt with on its own merits following a step-wise process as follows: (taken from the HPCSA Booklet no 2, Genetic Ethical Rules and Annexures).[7,8]

- Within seven (7) working days of receiving a complaint, the registrar forwards the complaint to the healthcare professional concerned and requests a written explanation from him/her;
- A letter of complaint, together with the healthcare professional's explanation (if submitted), is referred to the Professional Board concerned for consideration;
- Should the board decide that there are grounds for complaint, a Professional Conduct Committee will hold a professional conduct enquiry, during which oral evidence is presented, often including independent, expert witnesses. (Note: Professional conduct enquiries are open to the public and the media, unless closed at the discretion of the chairperson);
- If the professional conduct enquiry finds the healthcare professional guilty of misconduct, the committee's decision is final, unless either party lodges an appeal.

A healthcare professional found guilty of professional misconduct may be subject to the following penalties:

- A caution or a reprimand or both;
- A fine;
- Suspension for a specified period from practicing his/her profession;
- Removal of his/her name from the relevant register;
- A compulsory period of professional service or payment of the costs of the proceedings.[7,8]

3. Discussion

The common adage "there are none so blind as those who do not wish to see" springs to mind when confronted by colleagues in the dental fraternity who witness wrongdoing within their profession, yet choose to ignore it. While there are few legal obligations for a clinician who witnesses the wrongdoings of others in the profession to speak out, there are clearly a number of pertinent ethical and moral imperatives they need to consider. Silence due to apathy or indifference cannot be condoned. However, one needs to consider the risks associated with being a "whistle-blower". By exposing a colleague, they may put themselves at risk of being accused of defamation. This could open them up to costly and lengthy legal ramifications. Even the truth may be considered defamatory if it is divulged publicly. In addition, we are all aware that the dental fraternity in South Africa is a small community, and word could spread that the whistle-blower is a "malicious, self-appointed watchdog". It is generally far easier, less stressful and tempting to rather do nothing. However, based on the Freedom of Speech Act, a person "can opposed defamation with a right of opinion if it is sincere and based on facts". Thus, for the ethically-conscious observer who wishes to divulge a wrongdoing and the potential risks associated with this, there are a few guidelines that may help protect them legally. Fair comment is permissible if it is revealed upfront to be an opinion and based on an educated observation; predictions of adverse events must be justified by generally well-known or expected risk outcomes; the comments must be fair and revealed without malice; avoid revealing personal names or any form of identification publicly unless instructed to do so by a court of law; and disclosure should be in the patient's or public's best interest.

CONCLUSION

There is an unwritten (silent) understanding that "silence is consent". Thus practitioners who witness wrongdoing and yet turn a blind eye to it are in essence condoning, or at least allowing, the behaviour to continue. Ethical professionals should always strive to place the patient's best interest first and foremost and then be guided by the principles of beneficence, non-maleficence and justice. It helps also to remember the words of the Hippocrates and the Hippocratic Oath which all new graduates sign that states: "I will exercise my profession to the best of my knowledge and ability for the safety and welfare of all persons entrusted to my care and for the health and wellbeing of the community." In addition, we should "make a habit of two things: to help; or at least to do no harm". Hippocrates

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MAXILLOFACIAL RADIOLOGY

Hemifacial hyperplasia

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L Merbold[1], C Smit[2]

CASE

A 49-year-old male patient presented to the clinic with a main complaint of a painless swelling of the left mandible that had been present for more than 14 years. On radiological examination, the patient presented with enlargement of the mandibular ramus, angle and corpus on the left, with a normal appearing trabecular bone pattern. The midline deviated to the right, with superior displacement of teeth 43-38 with no associated macrodontia noted (Figures 1,2).

Figure 1: Panoramic radiographs of the patient 11 years ago (2012) at the age of 38 showing enlargement of the left ramus and corpus of the mandible.

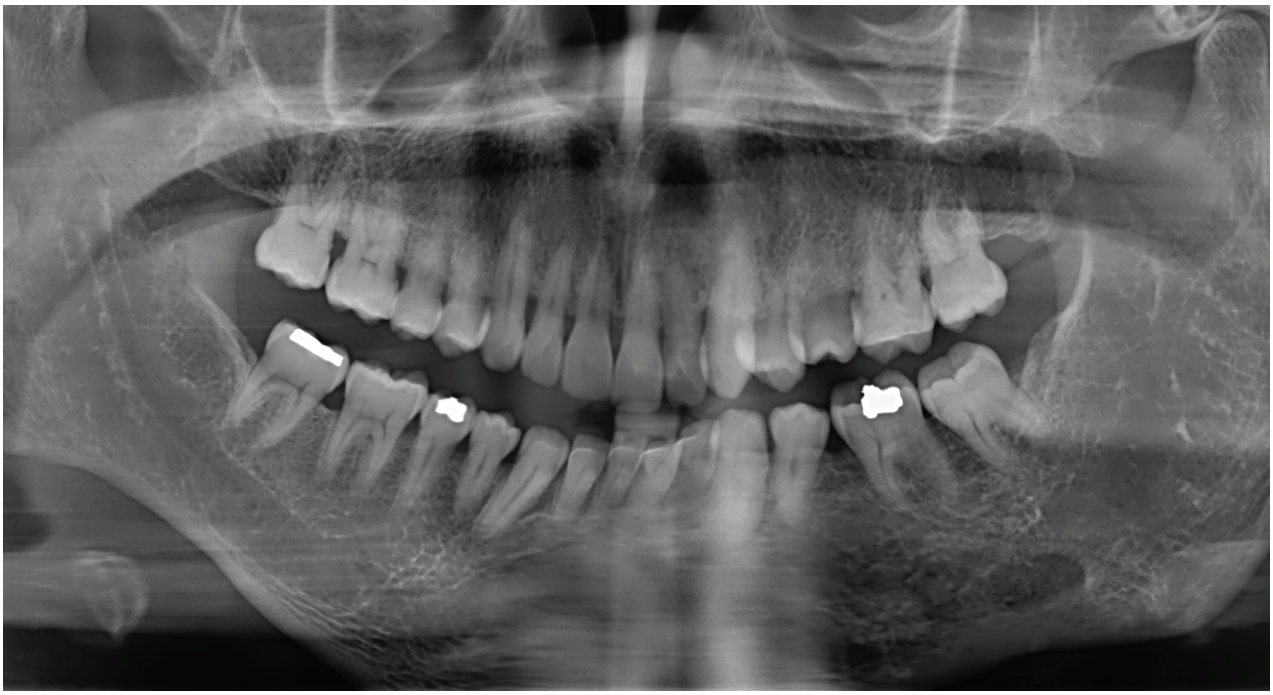

Figure 2: Panoramic radiograph of the same patient in 2023. No significant growth occurred between the two examination periods.

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The diagnosis of partial hemifacial hyperplasia was made based on the clinical and radiological findings, including localised involvement of the mandible, cessation of growth and no altered trabecular bony pattern. The patient is currently under continuous follow-up.

INTERPRETATION

Hemifacial hyperplasia (HFH), first described by Beck in 1836,[1] is a rare developmental condition characterised by unilateral overdevelopment of the hard and/or soft tissue of the affected side of the face.[2] The terms "hemifacial hyperplasia" and "hemifacial hypertrophy" have been used interchangeably, although the term "hyperplasia" is more appropriate as the tissues show an increase in cellular number rather than an increase in cellular size.[3]

HFH may be a part of hemihyperplasia of the whole body.[4] Asymmetry in HFH may be present at birth, but is only accentuated after puberty.[1] The growth is proportional during this period up until cessation at adulthood.[5] The prevalence of HFH is 1:86,000 with a male predominance.[6] The aetiology of HFH is still unknown with endocrine dysfunction, central nervous system disorders, lymphatic or vascular malformations, somatic mutations and chromosomal abnormalities included among possible theories.[6]

The affected side grows faster than the non-affected side, leading to asymmetry of the face.[1] HFH can affect the facial bones, soft tissue, teeth and/or any associated structures.[7] Unilateral enlargement of the fungiform papillae of the tongue is a common finding when the soft tissue is affected.[3] Additional facial characteristics on the affected side include wrinkling of the skin, smaller nasal vestibule, nasal deviation, chin deviation and inferior displacement of the auricle.[8]

Rowe classified hemihyperplasia as follows:
- Simple hemihyperplasia (involving a single limb)
- Complex hemihyperplasia (involving half of the body on the same side)
- Hemifacial hyperplasia (involving half of the face) subclassified into:
  - true hemifacial hyperplasia (enlargement of all tissues)
  - partial hemifacial hyperplasia (not all structures are enlarged to the same degree or not all).[8,9]

The differential diagnosis to consider for HFH is CLOVES, and Kippel Trenaunay syndrome associated with fibrous dysplasia (FD) and capillary lymphatic-venous deformation. In the case of FD, an altered trabecular bony pattern is seen. Other overgrowth syndromes can also be included.[6]

The initial radiographic method used for assessment is a panoramic radiograph. Other supporting techniques that can be used include posterior-anterior images as well as CBCT (Cone Beam Computed Tomography).[10] The diagnosis can be made from clinical and radiographic information, given practitioners understand the differentiating criteria.[8]

The treatment of HFH is usually for cosmetic rather than functional considerations and is based on individual assessment.[3] Treatment includes facial contouring after growth has ceased. In paediatric cases, surgical intervention can be considered if the patient is suffering from psychosocial issues. Some cases of HFH present with progressive growth, thus long-term follow-up is required.[3] The prognosis of HFH is good, with no reported cases showing malignant transformation.[3] The current case highlights the importance of adequate history as well as clinical and radiological examinations in diagnosing HFH.

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AUTHORS' DECLARATION

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The authors declare that they have no conflict of interest.

Ethics approval
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CPD questionnaire

Root and canal morphology of the mandibular first molar: a micro-computed tomography-focused observation of literature with illustrative cases: Part 2: Internal root morphology

1. **Choose the CORRECT answer. According to authors, the middle-mesial (MM) canal in mandibular first molars have a prevalence ranging between:**
   A. 5% - 35%
   B. 0% - 25%
   C. 7% - 28%
   D. 0% - 59%

2. **What is the CORRECT range. According to authors and various studies, the middle-distal (MD) canal in mandibular first molars have a prevalence ranging between:**
   A. 1% - 5%
   B. 0% - 11%
   C. 2% - 3%
   D. 0% - 4%

3. **Select the CORRECT answer. The highest number of canals that has been identified and treated in a mandibular molar was:**
   A. 10
   B. 9
   C. 8
   D. 11

4. **Choose the CORRECT option. According to Ahmed et al. mentioned in this paper, an apical delta is an apical root canal network at or near the apex where the main canal divides into:**
   A. Two accessory canals
   B. Three accessory canals
   C. More than two
   D. More than three

Perception of Dental Students' Education Environment: A systematic review and meta-analysis

5. **Select the CORRECT answer. Existence of publication bias is measured and described by the following:**
   A. Egger's test score ≥ 5%
   B. Begg's test score ≥ 5%
   C. Symmetry of the funnel plot
   D. All of the above
   E. None of the above

6. **Which of the following is CORRECT. Heterogeneity is assessed using the following statistics**
   A. Cochran's Q statistic,
   B. I2 index,
   C. $\tau 2$
   D. All of the above
   E. None of the above

7. **Choose the CORRECT answer. Measure the probability of the true mean effect sizes in comparable populations or similar populations in future.**
   A. Effect size using the random effect model
   B. Effect size using the fixed effect model
   C. 95% confidence interval (95% CI)
   D. Predictive intervals (PI)

8. **Select the CORRECT option. The mean score for the total DREEM of 117.52 (95% CI = 112.52 to 122.52) means**
   A. Perception of teaching is viewed negatively
   B. There are many issues that need changing
   C. Learning environment is more positive than -negative
   D. All of the above
   E. None of the above

9. **Which of the following is CORRECT. The maximum score of the following domain is 44 points**
   A. Students' Perception of Learning (SPL)
   B. Students' Perception of Teaching (SPT)
   C. Students' Academic Self Perception (SASP)
   D. Students' Perception of Atmosphere (SPA)
   E. Students' Social Self Perception (SSSP)

Sodium hypochlorite as an endodontic irrigant and its effect on dentine: a review of literature

10. **Which of the following is CORRECT. By increasing the temperature of sodium hypochlorite, the following effect is observed:**
    A. Long-term stability of sodium hypochlorite
    B. Positive smear layer accumulation.
    C. Improved tissue dissolving capacity
    D. All of the above

11. **Which of the following is CORRECT. The ideal properties of root canal irrigant should:**
    A. Decrease bacterial growth
    B. Have an increased toxicity level
    C. Decrease penetration of infection site
    D. Activate the endotoxin
    E. All of the above

12. **Select the CORRECT answer. The tissue dissolving ability of sodium hypochlorite depends on:**
    A. Concentration
    B. Volume
    C. Contact time
    D. Surface area of exposed tissue
    E. All of the above

Radiology corner: Hemifacila Hyperplasia

13. **Select the CORRECT answer. Hyperplasia is:**
    A. An increase in cellular number
    B. An increase in cellular size
    C. A decrease in cellular size
    D. A decrease in cellular number

14. **Which of the following is CORRECT. Complex hemihyperplasia**
    A. involves a single limb
    B. involves half of the body on the same side
    C. causes enlargement of all tissues
    D. causes not all structures to enlarge

15. **Select the CORRECT option. Hemifacial hyperplasia shows which type of growth?**
    A. Progressive
    B. Regressive
    C. Constant
    D. Intermitted

16. **Select the CORRECT answer. An accurate diagnosis for hemifacial hypertrophy can be made by:**
    A. Radiographic examination
    B. Clinical examination
    C. A combination of clinical and radiographic information
    D. By a practitioner that does not understand the diagnosing criteria

Evidence-Based Dentistry

17. **Select the CORRECT statement. In a double- blind multicentre trial, which of the following statement best describes the trial process:-**
    A. The patient and the investigator are blind to the treatment and the trial patients are recruited from one centre
    B. The patient is aware of the treatment but the assessor is blind and the patients are recruited from many treatment centres
    C. The patient and the investigator are blind to the treatment and the trial patients are recruited from more than one centre
    D. The patient and investigator are aware of the treatment and patients are recruited from multiple centres

18. **Which of the following is CORRECT. In the Wang et al trial, the percentage of lesion area reduction in WSLs at 12 months in the resin infiltration group was:-**
    A. 29.75%
    B. 26.57%,
    C. 28.64%,
    D. 46.62%

19. **Select the CORRECT answer. In the wang et al trial, the intervention that showed the most treatment effect/ gain was**
    A. CPP-APP tooth mouse
    B. Toothpaste
    C. Resin Infiltration
    D. Fluoride Varnish

20. **Which of the following is CORRECT. In the Hemmi et al trial, the loss to follow up was**
    A. 2 patients
    B. 3 patients
    C. 4 patients
    D. 5 patients

Ethics: Wilful Blindness.

21. **Select the CORRECT statement. For conduct to be wrongful in terms of the law:**
    A. the person must have committed an offense
    B. the action must have caused some form of harm
    C. he person may have omitted to carry out some form of action
    D. all of the above
    E. only A. and C. above

22. **Which of the following is CORRECT. Harm may include:**
    A. physical impairment
    B. psychosocial injury
    C. loss of income
    D. all of the above
    E. only A. and B. above

23. **Choose the CORRECT answer. By failing to act in order to prevent a possible harm from occurring, a practitioner may be guilty of:**
    A. negligence
    B. malpractice
    C. fraud
    D. collusion

24. **Select the CORRECT statement. The degree of wrongfulness:**
    A. may be measured using the “reasonable person rule”
    B. is often determined by social policy
    C. may be based on a value judgement
    D. all of the above
    E. only A. and B. above

25. **Choose the CORRECT statement. With regards to defamation of character:**
    A. only false comments are considered defamatory
    B. comments must be fair and revealed without malice
    C. it may be opposed based on the based on the Freedom of Speech Act,
    D. all of the above
    E. only B. and C. above

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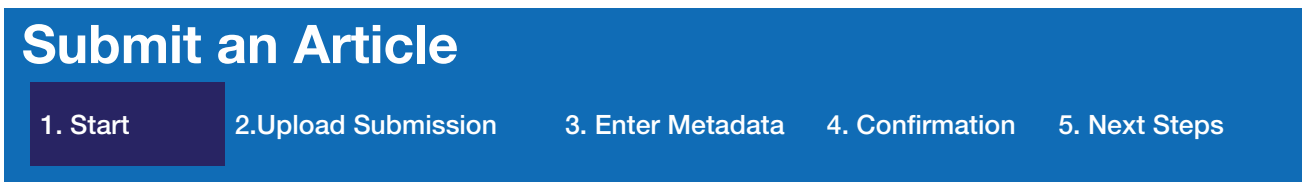

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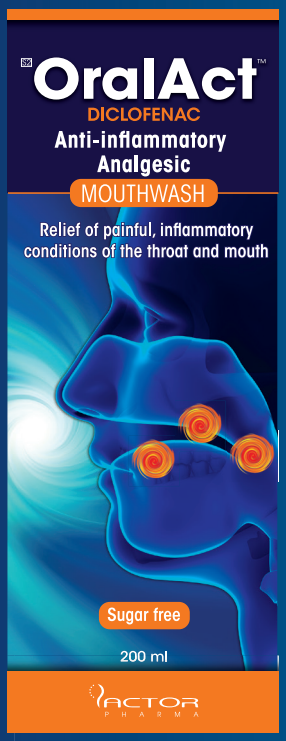

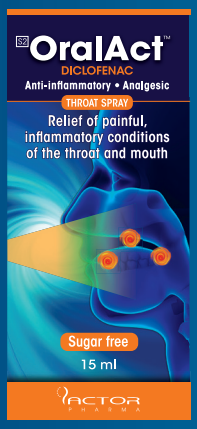

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