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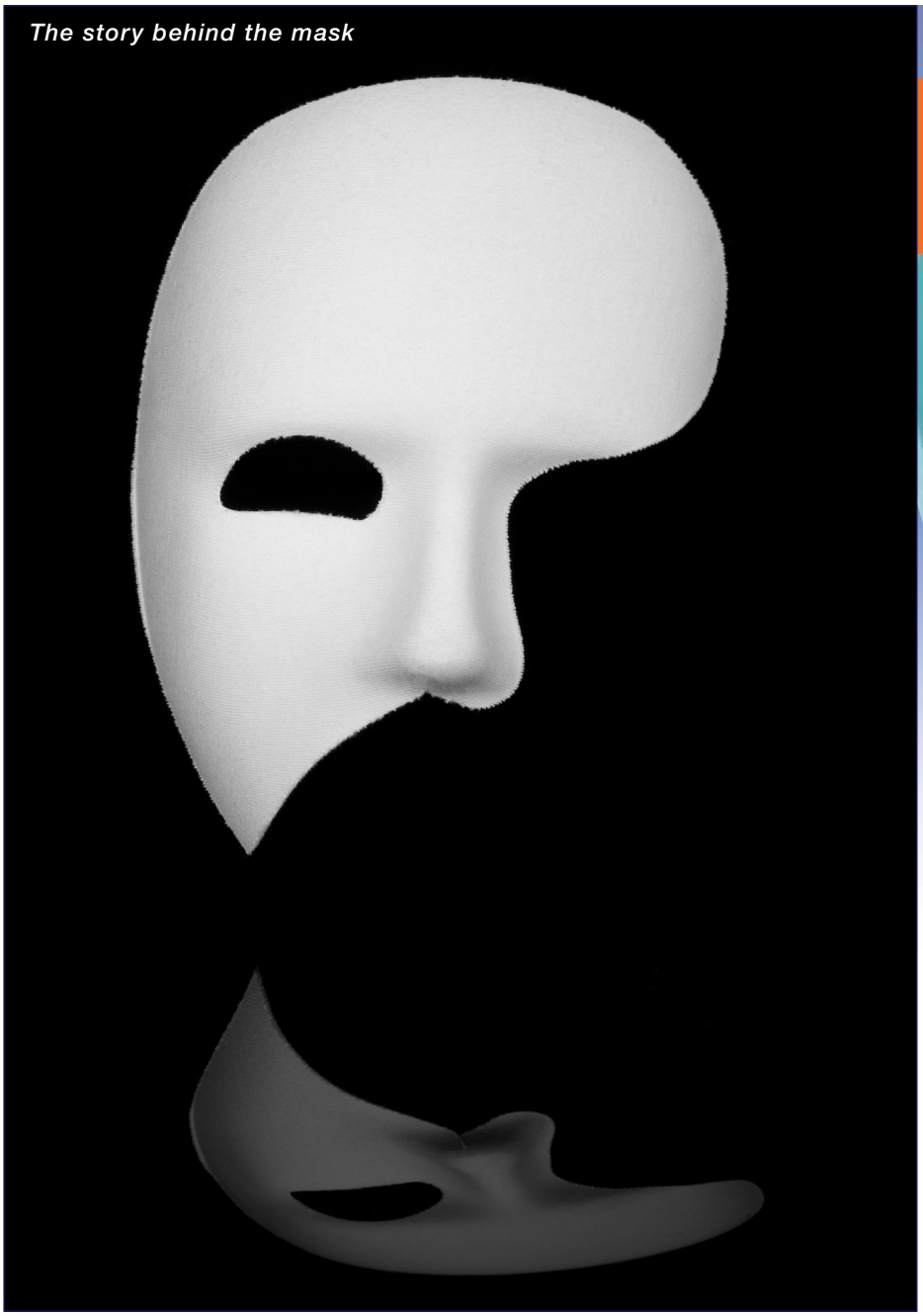

The story behind the mask

The Phantom of the Opera is based on the novel written by French author Gaston Leroux. The story revolves around a character whose face is ravaged by grotesque disfigurements. He becomes known as "phantom of the opera" because he uses a mask to hide his defects from cruel onlookers. The mask symbolizes his vulnerability and the injustice he suffers from, as he is forced to hide his face because it causes too much horror in other people. When he finally removes his mask he reveals his own vulnerability. The plight of the phantom is something that we as health care practitioners need to be aware when treating facially disfigured patients. This topic is explored more in the paper titled "Looking beyond the physical management of patients with head and neck cancer". Perhaps a good take home message is to consider the suggestion that *"Since "healthiness" stems from "wholenesss", "to heal" really means "to make whole" - Unknown.*

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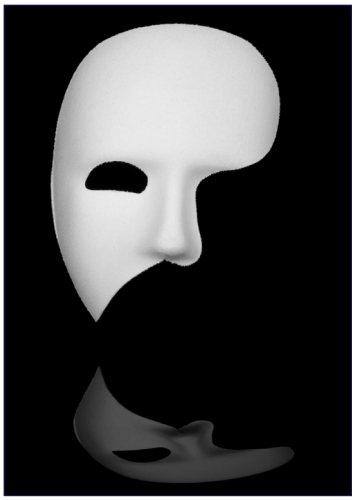
Our Front Cover for this Issue...

The theme for the Front Cover of the South African Dental Journal this year showcases various types of masks. Masks have been admired and worn throughout the world for centuries and play an integral part of many activities including customary rituals, cultural events, battles, entertainment, and for protection. The cover for July explores the story behind the mask used in the *The Phantom of the Opera*.



The story behind the mask

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Isolate in unison, wear your mask in unity

SADJ July 2021, Vol. 76 No. 6 p305

LM Sykes

In keeping with the cover theme of masks, it seems that the dreaded Corona virus (SARS-CoV-2) has made many people weary and even rebellious towards wearing protective facemasks. This brought back memories of a patient who had been treated at one of the government hospitals many years before airborne epidemics made mask-wearing in public an observable occurrence. His story will be related in the hopes that its childlike innocence will be a reminder to us all that if we unselfishly unite in our struggles against this, and any of life's adversities, we WILL all win in the end.

Fransie* was a painfully shy and frail 7-year-old boy who was born with HIV/AIDS (Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome) virus. He had been abandoned by his mother and lived with his granny in the village. Unfortunately due to his poor immunity and general state of health, he contracted a cancrum oris infection. It ravaged his small body "eating away" parts of his face, including his upper lip and nose. He was taken to hospital for treatment and spent the rest of his life as a "hospital orphan". Following the initial consultation, the treating dentist thought of a way that may help with the upcoming procedures as well as assist in finding Fransie a friend. He was taken back to the children's ward and told that he could have the honour of "picking his new nose". He was tasked to spend the next few days looking at the noses of his "co-inmates" and to then choose the shape of one that he would like for himself. If the chosen child agreed, then a replica of their nose would be used to fabricate his prosthesis.

The following appointment saw Fransie standing timidly at the entrance to the surgery, wearing the surgical mask that he had taken to use as a way of covering his missing nose and lip. He was clutching the hand of his new playmate, Jackson*, a young boy who had been admitted to hospital with severe burns to his limbs as a result of a shack fire. Jackson was going to be the model for Fransie's new nose. The boys were giggling nervously and whispering secrets to each other while they waited their turn. Although both boys were no older than 7 years, their long stay in hospital had made them very independent. They arrived for their appointment unaccompanied, and each carrying their own big, brown envelopes which contained all their hospital records, radiographs, and documentation.

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These may well have been the only personal possessions the boys owned. They looked like little ragamuffins in their oversized, stripy green-and-white, hospital-issue pyjamas. The picture of these two little waifs, battling to hook their bulging envelopes under one arm, while trying to hold hands, and hoist up loose pyjama pants with their other arm was made even more heart-wrenching because Jackson, the new best friend, was now also wearing a surgical mask, in unity with his buddy!

The assisting dental technician Frans* was a "big man" with an even bigger heart, who was also the generous donor of sweets and chips at previous visits. The boys stood against the wall giggling, and Fransie was pointing toward his namesake as Frans entered the cubicle. They were no doubt hoping for similar treats that day. Frans had anticipated this session and true to his nature, been shopping. He was carrying two large boxes, one for each boy. It was difficult to tell who was more excited with the gifts, Frans or the boys as he handed them over. Both kiddies dropped envelopes (and PJ pants), tore open the boxes, and discovered two brand new, remote-controlled, motorcars. Even under their surgical masks, one could see the size of their grins as their eyes sparkled with delight. That appointment must have felt like an eternity to these two small boys who were clearly anxious to go play and with their new cars.

Late that afternoon, as the staff headed for their own cars, if one looked hard into the fast-fading light of the early evening you would have caught a glimpse of two little dark figures in stripy green pyjamas scrambling across the adjoining veld, and disappearing into the laundry entrance at the back of the hospital. If you looked even closer into the dry sand of the parking area where they had been playing you would have seen stretches of miniature tyre tracks, worn into the earth from the hours and hours they had spent driving their cars. The hardships of life had thrown these two little boys together, and now thanks to the generosity of one kind heart, they had formed a unique friendship. A friendship that had allowed them to drop their guard and reveal themselves to each other, imperfections and all, without fear of ridicule or rejection. How do I know this? Because, there alongside the tyre tracks lay their two crumpled up surgical face masks, no longer needed for either of them to hide behind.

If we could all empathise with one another the way these boys and their clinicians did, isolate and wear our masks in unison and unity with one another, then we most surely will all be able to face a mask-free future together. United we can and will all WIN.

*Pseudonyms

Compulsory vaccinations in the workplace

SADJ July 2021, Vol. 76 No. 6 p306 - p307

SADA Head Office

With our country's vaccine rollout underway, there are many concerns that are being raised. We will seek to address some of them in this communique in order to encourage more people to get vaccinated.

The impact of COVID-19 vaccines on the pandemic will depend on several factors. These include factors such as the effectiveness of the vaccines; how quickly they are approved, manufactured, and delivered; and how many people get vaccinated. Most scientists anticipate that, like most other vaccines, COVID-19 vaccines will not be 100 per cent effective.

The WHO is working to help ensure that any approved vaccines are as effective as possible, so they can have the greatest impact on the pandemic. The Department of Health is working with the South African Health Products Regulatory Authority (SAHPRA) to ensure that whichever vaccine being recommended or made available through the COVAX Facility has met all the regulatory requires of safety, efficacy, and quality.

Compulsory vaccinations in the workplace

The Minister of Employment and Labour has issued an amended COVID-19 Direction on Occupational Health and Safety Measures in Certain Workplaces (Amended OHS Direction), which was gazetted on 11 June 2021 and is now in force. The Amended OHS Direction replaces the Direction that was published on 1 October 2020.

While most of the required health and safety protocols in workplaces remain unchanged, the Amended OHS Direction now deals with the much anticipated and somewhat controversial issue of workplace vaccinations.

The updated guidelines now contain in “Annexure C - Guidelines if an Employer makes Vaccination Mandatory”

Risk assessments and plans for protective measures

In addition to the (now standard) risk assessment and Workplace Plan outlining the protective measures in place at the workplace, the Amended OHS Direction now requires an additional risk assessment to be conducted by all employers to determine:

i). whether it intends to make vaccination mandatory and if, so

ii). those employees who by virtue of the risk of transmission through their work or their risk for severe COVID-19 disease or death due to their age or comorbidities, must be vaccinated.

The assessment must be conducted taking into account the operational requirements of the workplace.

This risk assessment must be performed by all employers within 21 days of the coming into operation of the Amended OHS Direction, i.e., by 2 July 2021.

Guidelines if an employer makes vaccination mandatory

Annexure C of the Amended OHS Direction contains guidelines that are intended to guide relevant parties (including employers and courts) in determining the fairness of a mandatory vaccination policy and its implementation. The guidelines do not prescribe binding rules and deviations may be justified in appropriate circumstances.

The Guidelines emphasize that three key issues be kept in mind, namely public health imperatives, the constitutional rights of employees, and the efficient operation of the employer’s business.

In terms of the Guidelines, where an employer’s plan requires identified employees to be vaccinated, that plan should provide the following:

For every employee identified for vaccination to be notified of

i). the obligation to be vaccinated as and when a vaccine becomes available for that employee;

ii). the right to refuse to be vaccinated on constitutional or medical grounds; and

iii). the opportunity to consult a health and safety representative or a worker or trade union official, upon request;

If reasonably practicable, for transport to be made available to and from the allocated vaccination site; and for paid time off to be granted to employees who suffer side effects as a result of the vaccination where their sick leave entitlement in terms of BCEA has been exhausted, or for a claim for compensation to be lodged in terms of the Compensation for Occupational Injuries and Diseases Act, 1993.

Employees who refuse to be vaccinated on any constitutional or medical ground should be counselled, referred for further medical evaluation should there be a medical contraindication

for vaccination and, if necessary, steps should be taken to reasonably accommodate the employee (e.g. by allowing the employee to work off-site or at home, providing the employee with her/his own isolated office, requiring her/him to wear an N95 mask, modifying her/his working hours, or moving the employee into a position that does not require the employee to be vaccinated).

Administrative support and paid time off for vaccination

All employers are now required to give administrative support to assist employees to register on the Electronic Vaccine Data System Registration Portal for COVID-19 (available).Employers are also required to give their employees paid time off to be vaccinated, provided that the employee provides proof of the vaccination that has occurred or is to occur during hours that the employee ordinarily works.

Symptoms arising from vaccination

Since permitting workers back into the workplace, employers have been required to take measures to screen employees for typical COVID-19 virus symptoms and not permit any employees displaying such symptoms to come to work. The Amended OHS Direction now appreciates that these symptoms may arise after an employee has been vaccinated. Workers who present with symptoms between one to three days after having a COVID-19 vaccination may be permitted into the workplace, and the requirement to refuse entry to them will accordingly not apply.

Should an employee suffer side effects as a result of a COVID -19 vaccination and is unable to attend work following vaccination, the employer must place that employee on paid sick leave. In such case, an employer may accept a COVID-19 vaccination certificate issued by an official vaccination site in lieu of a medical certificate. The BCEA requires that employees produce a medical certificate as proof of illness if they've been absent from work for more than two consecutive days or on more than two occasions during an eight-week period.

Employers with 10 employees or less must bear in mind that more limited obligations still apply to them (as per Direction 12) and many of the additional measures explained above will not be applicable.

The key question and take-aways

With the above amendments in mind, the key question that employers are probably asking is whether they can now go ahead and implement a mandatory vaccination policy at the workplace. The Guidelines and the provisions in the Amended OHS Direction have certainly now confirmed that there may be circumstances in which a mandatory vaccination policy may be fair and justified.

However, employers are still advised to tread carefully when putting in place their vaccination plans, as what is also clear is that there are a number of competing rights and interests that need to be balanced. Ultimately, the lawfulness of a mandatory vaccination policy will depend on, interalia, the nature of the employer's workplace and the type of work performed and the intended consequences for employees who refuse to be vaccinated.

By way of example, in a dental practice with clinical staff and dental assistants work in close proximity with each other and patients, in this case it may well be reasonable to require the employees to be vaccinated, and to deal with objections on the basis of religious beliefs or underlying medical conditions on a case-by-case basis.

Employees who refuse to be vaccinated

At the National Economic Development and Labour Council (Nedlac), government and the private sector agreed that workers' refusal to take the Covid-19 vaccine should not justify a dismissal. However, Business for South Africa (B4SA) told businesses that the revised guidance does not bar employers from firing workers who reject the vaccine. "There is nothing contained in the Revised Occupational Health and Safety Direction which prohibits an employer from dismissing an employee who has been identified as high risk and who has refused to be vaccinated (and cannot be reasonably accommodated)," B4SA told its constituents.

Before considering a dismal, employers must have first conduct a risk assessment of their workplace to determine the category of employees which it requires to be vaccinated on a mandatory basis. There may be two main reasons you could get fired for refusing to be vaccinated if you are a high-risk employee and cannot be accommodated in the workplace.

After considering the employee's reasons for refusal, such as medical, religious, constitutional, and cultural, the employer is mandated to assess whether it is necessary for the employee in question to be inoculated and whether they fall under a high-risk category where vaccinations are required.

Dealing with dismissals on a case-by-case basis will determine the fairness of the termination and the employee's role, work environment, the alternatives they have or have not been provided, and their reasons for objection should be taken to account. Workers can be dismissed based on the operational re quirements of the employer which would lead to standard retrenchment. This could mean employees no longer fit into the organogram because you refuse to be vaccinated where all the employees in this category are required to be vaccinated. The practice may also argue that a particular Covid-19 high-risk category, because of the vaccination requirement, has had to undergo a restructuring and disqualifies workers who refuse the vaccine.

Where an employee is identified to be vaccinated due to their job role, the vaccine is available to be administered and there is a refusal, and you require somebody in that position, then the employer would have to the operational requirement route. Workers can also be dismissed for incapacity where an employee can simply no longer perform the tasks required of them, or because of medical reasons. Again, the employee will have to be taken through the incapacity process which is complicated.

Seek specific advice from a labour consultant in this case. Where you have employees, for example who don't really require the vaccine because of the nature of their job; they're not interacting with the public, they're not even interacting perhaps with other employees, because they sit in an office and they can self-isolate, there's simply no need, in relation to that employee, to make vaccinations mandatory. In a dental practice case, this may not be possible.

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Perceptions of academic staff about mentoring in a Faculty of Dentistry in a public university in South Africa

SADJ July 2021, Vol. 76 No. 6 p309 - p314

SL Amosun[1], GAVM Geerts[2], R Basson[3]

ABSTRACT

Introduction
Mentoring programs contribute to the development and retention of academics in dental education.

Objectives
To describe the perceptions of academic staff of the Faculty of Dentistry, University of the Western Cape, South Africa, about a funded pilot mentoring process.

Design
Cross-sectional, purposive sampling qualitative design.

Methods
Twenty mentees who had engaged in the funded mentoring process were targeted for semi-structured interviews, to describe their perceptions about the ongoing mentorship process, experiences in other mentoring processes, and expectations about future formal mentoring in the faculty. Quantitative data was analysed descriptively, while content analysis of the qualitative data was performed to identify themes.

Findings and conclusions
Perceptions of eight mentees, aged 37 to 59 years and spent between 3 and over 20 years in the faculty, were categorized into two themes - 'A welcome initiative' and 'Mentorship seen as a holistic experience'. The program provided the much-needed space where mentees felt they could seek guidance for their development.

Expectations from a future formal program included assistance in meeting institutional and personal demands. Participants' expectations were broader than what the pilot program offered, though the benefits reported were similar to earlier studies.

Keywords
Mentoring, academic staff, faculty development, oral health, dental faculty.

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1. **Seyi L Amosun:** Conceptualisation, reviewed analysed data, preparation of initial and final draft of manuscript - 35%
2. **Greta AVM Geerts:** Conceptualisation, resourced grant for project, reviewed analysed data, contributed to and reviewed final draft of manuscript - 35%
3. **Reneda Basson:** Project administration, reviewed analysed data, contributed to and reviewed final draft of manuscript - 30%

INTRODUCTION

More than twenty-five years in the post-apartheid era, the government of the Republic of South Africa (RSA) continues to seek ways to reverse the past inequities in higher education by introducing the National Development Plan (NDP) as part of the transformation process.[1,2] The Department of Higher Education and Training (DHET) was mandated to achieve the following goals, among others, by 2030 - increase the (i) percentage of PhD qualified academic staff from current 46% to over 75%; (ii) number of doctoral graduates per million from current 46 to 100; and (iii) publication count, which increased from approximately 5500 in 1995 to 15 542 in 2014.[3]

The University of the Western Cape (UWC) is one of the 26 universities that benefited from the University Capacity Development Grant (UCDG), funded by the DHET to assist with capacity development of academic staff.[4] In 2018, the DHET introduced the University Capacity Development Program (UCDP) for the development of students, staff, and academic programs.[5]

A portion of the UCDG was allocated to the Existing Academic Staff Capacity Enhancement Program (EASCEP) to support the completion of postgraduate studies (MSc, PhD, post-doctoral)[6] and increase publication count. The Deputy Vice Chancellor (Research and Innovation) manages the process at UWC, and in 2019 mentors were appointed on a part-time basis for each of the seven faculties. The Deputy Dean Research and Postgraduate Programs supervises the processes in the Faculty of Dentistry.

Though labelled a previously disadvantaged university which operated under severe financial and social constraints, UWC has contributed towards democracy and transformation by providing access to students from previously disadvantaged communities.[7,8] By widening access, the university experienced exponential growth resulting in large classes with underprepared students and often inadequate facilities.[9] These factors contributed to the challenges in attracting and keeping competent academics who could mentor junior academic staff to succeed in the areas of teaching, research, and academic administration, among others.[10]

While the first dental education program in the country was established in 1925,[11] there were concerns that the dental needs of a heterogeneous community were not being fully met.[12] The dental faculty at UWC was established in 1974[13] to broaden access into the profession[12,14] and address the shortage of oral health professionals.[15] The breakdown of dentists registered with the Health Professions Council of South Africa (HPCSA) for 2015, according to age, gender and race, showed that younger dentists were predominantly female and Black while older dentists were mainly White and male.[14]

To empower the academic staff with the necessary pedagogical skills,[9] the recommendation of the American Dental Education Association about mentoring[16-20] becomes relevant to the RSA. Descriptions about mentorship "encompass a synergistic relationship between a mentor with accumulated expertise and a mentee with novice-like inexperience, who engage in the sharing of knowledge and personal experiences to facilitate career development and guidance towards a path of promotion, fulfilment and overall success ...a lack of mentorship may result in failure to retain junior faculty at an institution or within academia altogether." [p2][18]

In 2019, there were approximately 100 academics within the faculty, required to teach and provide dental care services in hospitals and communities.[21] The profile of the academics reflected the general profile of those reistered with the HPCSA.[14] Fifty-eight of the academics were in permanent full-time positions, eleven at professorial levels, and only 15 possessed PhD qualifications in addition to their professional qualifications. Within the first year of the mentor's (SLA) appointment, less than one third of 20 mentees consulted on issues about post-graduate studies and writing papers for publication. Others sought "guidance on coping with faculty demands".

OBJECTIVES

The absence of guidelines for effective mentoring programs in the faculty prompted the exploration of the perceptions of academics below professorial rank about the pilot mentoring program. The objectives were to evaluate the experiences of academics who engaged in (a) the EASCEP and (b) any other mentoring process after joining the faculty; and (c) the perceptions of academics about what a faculty mentoring program should focus on. To prevent a potential bias, a research assistant (RB) was appointed to independently manage the study process, at the end of which the analysed data was then checked and debated by the authors.

METHOD

Procedure

After obtaining ethics approval (BM19/9/15) and sourcing for funding from the Research Office of the university, a self-administered adapted questionnaire[16,22] was pilot tested for face and content validity with five academics in the faculty. Using a cross-sectional, descriptive research design, RB later distributed the survey instrument via email and hard copies, among academics below professorial ranks (n=89). The four-part survey instrument (**Appendix 1**) sought biographical information (9 items), perceptions about the EASCEP (4 items), experiences in any other mentoring processes after joining the faculty (12 items), and expectations of a future faculty mentoring program (24 items).

A cover letter accompanied the survey instrument, explaining the study procedures and the voluntary basis of participation. Unfortunately, the response was poor. Such development is not necessarily an unwillingness of academics in dental schools in the RSA to participate in research, but their responsibilities in teaching and service delivery are often obstacles.[21] A purposive sampling, qualitative research design[18,23-25] was then adopted to address the same aims. The twenty mentees who engaged in the EASCEP were targeted, but only eight consented. The amended four-part survey instrument (**Appendix 2**) was also administered by RB via individual, semi-structured interviews via Skype which took place in March 2020 during the COVID-19 pandemic. Part A of the survey instrument sought biographical information, while the remaining three parts sought participants' (i) perceptions about the EASCEP, (ii) experiences in other mentoring processes since joining the faculty, and (c) expectations about mentoring in the faculty.

Table 1. Profile of participants (n=8).

Participant	Age (years)	Highest qualification achieved	Position in faculty	Years in faculty
A1	37	Masters	Senior lecturer	3
A2	52	PhD	Senior Lecturer	18
A3	55	PhD	Senior lecturer/Assoc. Professor	17
A4	47	PhD	Assoc. Professor	20
A6	45	PhD	Senior Lecturer	+/- 20
A7	59	Masters	Biostatistician	3
A9	59	Masters	Senior Lecturer	26
A10	42	Masters	Senior Lecturer	8

The survey instrument was sent in advance to the eight participants so they could answer the closed-ended questions and have time to ponder on their responses to the open-ended statements. Unfortunately, only five of the participants (A2, A4, A6, A7, A9) were able to keep the interview appointments, while the remaining three (A1, A3, A10) completed and submitted the survey instrument (Appendix 2).

The demographics of the non-respondents were similar to those of the respondents presented in Table 1. The interviews were audio-recorded and transcribed. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Analyses

Quantitative data was analysed descriptively, while content analysis of the qualitative data was performed by two independent academics with expertise in qualitative research to identify themes which were then discussed to reach consensus.[23] To check and establish credibility in the findings, data were triangulated through (i) giving the participants access to the transcriptions for verification; (ii) comparing interview data alongside relevant academic literature; and (iii) agreement of the interpretations of the data by the researchers.

FINDINGS

Table 1 describes the profile of the participants. Two participants (A2, A3) had only brief interactions with the mentor and were unable to comment on the value of the mentorship program but presented their expectations about a future formal mentorship program in the faculty. Though A2 and A4 were not engaged in other mentoring processes since appointment, there was consensus among the participants about the purpose of mentoring as described by A9:

Understanding the mentee, providing a safe space for the mentees to share their plans, aspirations and challenges; assisting the mentee to reflect objectively on their challenges and aspirations, …guiding the mentee to reach goals… to reflect [but] not creating dependence on the mentor.

Participants also differentiated a mentor from a supervisor:

…The supervisor… can guide you in the methodological process and has deep insight into your [research] topic… The mentor is [a] person I will [go to] if I need something my supervisor cannot give me, such as, someone to share my research experiences with…, when I need additional emotional support …when I begin to chart unknown territory, when I need to bounce off ideas… when I need my morale as a researcher lifted, when my supervisor cannot provide me with all the skills I require, like writing support, selecting a journal …a supervisor helps only with research related issues whilst a mentor can help with other factors such as promotion… or publication of an article. [A2]

Two themes emerged from the survey:

'A Welcome Initiative'

The mentoring program was perceived as necessary and a welcome initiative. A response that resonated with many of the participants was having 'a very positive experience' during consultations.

I think it is a very positive effect. It is nice to know there is someone there that you can bounce ideas off if you are not too sure. Especially if you are new with supervising PhD students. [A4]

… the entire process has been very positive …I developed a lot of confidence. [A6]

On what worked well in the mentorship program, mentees described their experiences:

I think it was having somebody who was accessible. [A6]

The mentor listened and tried to understand where I was academically … my work situation … where my work fitted into my life situation. Also, that he followed up, that he wasn't very demanding, that he wasn't really in any way judgmental. He tried to help me make sense of where I was. [A9]

What I enjoyed was the open communication. We were able to bounce ideas off each other; could bounce ideas off someone else and see whether we are on the right track… [A4]

Having a sounding board, somebody to talk to you whenever I felt like I was stuck and needed advice that I wouldn't normally get from anybody else, to listen to me at that time because everybody is always at meetings or they have got to be… their primary focus is something else, rather than being there to help academically, or just to help staff when they have questions. It is always nice to have a bouncing board … I always felt if I didn't know the answer that I would be guided to finding the right person or the right direction. [A7]

The mentor helped me to define and conceptualize my research idea. I feel guilty at times that I had not utilized the mentor to the fullest. [A10]

One on one sessions and meetings; step by step counselling [A1]

As to what did not work well, the experiences of two respondents related to time:

Due to my clinical and postgraduate engagements it was difficult to meet every time and complete tasks. [A1]

I still struggled to execute, and I suppose that time management is a problem for me that was not addressed. [A10]

The professional background of the mentor was a concern to one participant while two others perceived this was beneficial:

The mentor wasn't a dentist; so, context was always a

problem and the mentor didn't have experience within the faculty. So, you always have to put context into it because things work differently at the dental faculty. [A7]

For me, I find it is often nice to have somebody from a different discipline to give you different insights because they see things differently and I think when you are in the same faculty it can be a little bit awkward. I think that really helped me a lot. In my experience I have found it very helpful to get somebody from the outside, from another discipline to see how they view things because we do things that are similar, but we have different approaches to it and different understandings. It is refreshing to learn different techniques to do the same thing. [A6] It is also good to speak with somebody that's not working with you directly and you know doesn't have any other expectations of you and simply sees you for what you are doing at that point. [A9]

Participants A1 and A10 also expressed similar views on what to improve in the mentoring process:

Allow employees to clear their undergraduate and postgraduate schedule for one day or a half a day to receive mentoring. [A1]

I think that respective mentees need to be identified and mentored to develop their career paths, including research, to ensure a sufficient number of suitably qualified personnel for succession planning; …the process must be individualized and help to direct focus and use strengths and support areas of weakness … some clear steps are to be jointly determined by the mentee and mentor, with clear short- and long-term deliverables. [A10]

Those involved in other mentorship networks, mostly initiated on their own accord, shared different experiences - I had a mentor to assist with career pathing, the mentor was too busy to really assist me and we never worked on a jointly agreed upon plan of action, it was good to engage with someone from a different faculty, but little value in mentorship had been gained. Perhaps we were mismatched. [A10]

I think that there are many unofficial mentors [like] supervisor of my PhD …I regarded him as a mentor in that I could always go to him outside of the PhD and he would always have an open door. I think there is an almost unofficial system that is very healthy but sometimes not that healthy because you can end up being in a group where you have negative experiences and that drag you into a negative space. Therefore, a mentor that is almost outside of that, that can take you away from that is very good. In that way, I think, the current person has the potential to really support staff in different ways. [A9]

I had experience outside of the faculty for many years with one of the professors … If there was anything I would need, guidance as to how to apply for the current position I have, or if I have any issue. I have two mentors inside the faculty besides the funded mentor. It has been a very positive and uplifting experience. I feel that I have gained a lot from all these people. [A7]

I think previously, during my PhD I was part of a program which was for PhD students. We weren't assigned mentors formally but within the group we mentored each other through the whole process of doing the PhD. So that was very helpful. For me it was a lonely process because at the time, within the faculty, there were very few people doing PhDs and none of my peers was doing a PhD. [A6]

'Mentorship seen as a holistic experience – A career friend'

The participants strongly expressed the need for a formal mentorship program within the faculty, which should be holistic in nature for optimum use and success. As for their expectations from a future formal faculty mentorship program, one participant explained it clearly:

There is a lack at the faculty, in terms of support; there is a lack in terms of work and how you are supported in coping with the many roles you have. [A9]

Participants expressed their expectations from a future formal mentorship program:

I will tell you why, up until now I am still struggling to get an article out of my PhD program, simply because I don't have mentorship. Doing a PhD is very different from writing a journal article, I am up and running with my writing again, but I still feel that I am lacking in mentoring for that process. I never had that, and I am learning from scratch and unfortunately it has taken the life out of me because I become so frustrated and dejected at times. A mentorship program is needed. Not only for the PhD [and] Masters process but also for the process after that, what happens afterwards. [A2]

The mentor should be actively involved in teaching us new skills and knowledge. …should be able to listen and give constructive feedback. [A1]

Someone to guide you to improve your position within the faculty…. impacts on your development, someone who improves your knowledge about faculty related issues. [A3]

The mentor can basically just guide you to make sure that you make use of the opportunities that are available to you. We often get emails about opportunities. I think… if you are starting out in a lecturer position it is very helpful to have that type of guidance that is formal, because I think then we are capacitating staff a lot easier and the staff development can be more structured and more meaningful rather than just doing odd ad hoc things. [A6]

It's just teaching you things that people expect you to just know, a role of a mentor. It is not just academic, its social and its psychological. It is not easy. Being in the dental faculty is not easy, being in academia is not easy but being in [this] dental faculty is exceptionally not easy … you still feel it. Just somebody who can be your sort of career friend… so it's not just about furthering my career in a hard way but in soft skills as well. [A7]

Whatever, it might be good if that person has an idea to say this is the expectations of this institution of you and how can I help you, or support you to develop your own

career plan, or your plan that you actually meet these requirements…. there must be some space where the person knows the expectations and can guide you to say, maybe you need to speak to the faculty about these other things that is making it difficult for you. [A9]

Just talking to someone sometimes triggers other ideas, like I could have done it that way, that's not a bad idea. I could maybe try something else. So just getting a different perspective might trigger other ideas or other ways of doing things. That's also good. Just talking about it helps, so that is very valuable when it comes to the mentorship… [A4]

Define short- and long-term goals and purpose for the mentorship. Determine deliverables to meet those goals at reasonable intervals. An analysis is required of each mentee to determine what the real need of support may be to identify stumbling blocks to execution and impart skills to overcome those to ensure delivery of goals, both short and long term. [A10]

Different ways of developing the mentorship program were suggested:

I recommend a panel of mentors ... spearheaded by [a] Professor… the panel can actually sit in on maybe the research committee that sits twice a month… so that panel should actually feed into the research committee. It is something we are really, really lacking in the faculty. [A2]

I actually think that it would be helpful for somebody coming … into academics for the first time … assign them a mentor as part of their probation period … it would be very helpful because often we don't really have a plan when you start out as a lecturer. [A6]

For maximum reach to a wider range of staff members, it was suggested that the mentorship program be introduced to the staff in a different manner:

To be honest with you, it needs to be advertised. You need to widely tell the staff and the students this is what is available. I will be honest, I heard about it but it was not spelt out to us in no uncertain terms this is what is available to us. I didn't even know until this interview process that this is the kind of mentoring capacity we have in the faculty. I was astounded, and I quickly wrote an email to Prof and said I need help … So, as you can see, I think it needs to be spelt out with clear terms of reference. [A2]

I think [the] faculty should have introduced the mentor differently… I think it was very much left to staff by word of mouth, to say "have you met with the mentor because he is really helpful". So, if I [did not hear this] I probably wouldn't have bothered, and I think I would have lost a good opportunity. I think where it can improve is to get the faculty board to actually introduce the mentor to staff and maybe the mentor do a presentation of, this is who I am, this is the work I have done, this is what I can offer so that it is out there to the staff. I don't think it worked that well putting an email out because I think it depended very much on word of mouth. I think more people could have been reached. [A9]

DISCUSSION

This study set out to evaluate the experiences of academics in the Faculty of Dentistry at UWC who engaged in the EASCEP, as well as their expectations from a future formal program. The change in methodology due to the poor response in the first survey did not compromise the integrity of this study as similar methodologies have been utilized in previous studies.[18,23-25] However, the poor participation of academics in research[21] may be a reflection of their inability to satisfactorily share their time in meeting the demands in teaching, research, clinical service and administration.

The participants also acknowledged that it was essential to allocate time to participate in the mentorship process. Upon entering a career in dental education, the academic is expected to successfully navigate an often-unfamiliar environment of teaching, scholarly activity and research, as well as perform administrative tasks and participate in both university and community service.[18] Academics may also need assistance to manage the time to meet these demands. With little or no previous experience and coming from diverse backgrounds, the new academic may become overwhelmed, unsupported, and discouraged.

Currently, there is little documented evidence of specific formal activities relating to mentorship of academic staff in Dental faculties in RSA. Though the pilot program targeted academics yet to obtain a doctoral degree or below professorial rank, it was accessible to all academic staff. So, it is worth noting that two participants who had not engaged in any mentorship process had been in the faculty for 18 and 20 years respectively. Such occurrence acknowledges the need for a formal mentorship process to help new lecturers in their transition into their new positions,[18] especially in a faculty where the demographic profile of the lecturers is still similar to the profile of those registered with the HPCSA in 2015.[14]

Overall, the EASCEP was perceived as a necessary and welcome initiative as in other studies.[16-20] On what worked well in the mentorship program, mentees perceived the consultation provided the much-needed space, where they felt they were heard and understood to seek the required support and guidance in respect to academic development. Participants appreciated the accessibility of the mentor and the individual attention they received. However, it should be noted that there were no discipline-specific issues raised with the mentor, though it is uncertain if this was due to the mentor not having a background in dentistry.

Participants were clear in what they expected from a formal mentorship program stemming from what seemed to be lacking within the faculty. The expectations were broader than what was being addressed in the EASCEP and included seeking assistance to meet faculty and institutional demands. As the unique context of each institution and the diverse needs of each academic will

impact on how the capacity development of academics is managed, an ideal mentorship program should address both the professional and the personal development of academics.[10] To enhance the accessibility of the mentorship program, the mentees in the EASCEP recommended ways to improve the advertisement of such a program. Thomas et al. recommended that administrators of mentorship programs might consider publicising the programs in advance of the academic year in which the programs are offered.[25] The recruitment materials should also be explicit regarding what is expected of the participants, as well as what benefits they may expect. In addition, due consideration should be given to train potential mentors.

CONCLUSIONS

There is evidence that the UCDG mentorship program has been beneficial to those individuals who participated in the process. There is also the expectation that a formal mentorship program within the Dental Faculty at UWC is critical in the career development of the academic staff.

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Declaration of interest statement

The authors do not have any potential conflict of interest.

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Evaluation of preparation times of WaveOne Gold reciprocating instruments compared to two analogous counterparts

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ABSTRACT

Manufacturers are constantly developing new products to optimise endodontic treatment. These newer file systems are often associated with increasing expenditure of instrumentation and can affect the cost effectiveness of root canal treatment. Recently, companies have emerged that claim to have successfully reproduced many of the more established endodontic file systems manufactured by Dentsply Sirona (Ballaigues, Switzerland).

EdgeEndo (Albuquerque, New Mexico, USA) and Pac-Dent (Brea, CA, USA), which manufacture files similar in design to that of Dentsply Sirona, claim that they are similar and sell them at a lower price. A performance comparison of the replica file systems to their original is of clinical importance.

The aim of this *ex vivo* study was to compare the total glide path and canal preparation times of WaveOne Gold Glider (Dentsply Sirona) combined with the Primary WaveOne Gold (Dentsply Sirona), Edge GlidePath (Edge Endo, Albuquerque, New Mexico, USA) followed by the Primary EdgeOne Fire (EdgeEndo); and One File G Glide Path (Pac-Dent, Brea, CA, USA) file combined with the Primary One File G (Pac-Dent) Shaping file.

Sixty curved untreated canals of extracted, human, mandibular molars were randomly divided into three groups of 20 canals each for mechanical glide path enlargement and root canal shaping. Group 1 (WaveOne Gold Glider + Primary WaveOne Gold); Group 2 (Edge GlidePath + Primary EdgeOne Fire); and Group 3 (One File G Reciprocating Glide Path File + Primary One File G Reciprocating shaping file).

The total time taken to prepare a glide path and to complete the root canal preparation of each canal was recorded (in seconds) by means of an iPhone stopwatch (Apple Inc., Cupertino, California). The time taken to change files was not recorded. Throughout the instrumentation process, RC Prep was used as a lubricant, and 5 mL 3% sodium hypochlorite was used as irrigation solution.

Mean and standard deviations were determined for each group, and analysis of variance was used to statistically compare the mean glide path preparation times for the three groups.

The fastest final canal preparation time was achieved by WOGG/PWOG (41.78 ± 10.58 s), followed by OFGP/POFS (42.02 ± 12.16 s) and then EGP/PEOF (42.49 ± 10.44 s). There were no statistically significant differences between the canal preparation times of the three combination groups ($p>0.05$).

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INTRODUCTION

Thermomechanical processes have resulted in the development of nickel-titanium (NiTi) endodontic glide path and shaping files with increased flexibility and fatigue resistance compared to their predecessors. Companies

are now developing analogous instrumentation systems that are similar in form and function to their competitors' but are constructed from differing proprietary heat-treated NiTi.

The preparation of a glide path prior to the introduction of rotary NiTi instruments is a standard adjunct to ensure more safety during root canal instrumentation.[1] A glide path can be defined as a smooth, radicular tunnel from the canal orifice to the physiologic terminus of the root canal.[2] Varela-Patiño et al.[3] found that fewer instrument fractures occurred when a wide and smooth-walled glide path was created and the canal was pre-flared before canal preparation with rotary files.[3]

Glide path preparation allows for an understanding and appreciation of the original canal anatomy, renders the canal patent to receive rotary files, and permits a more effective and safer action during root canal shaping.[4,5] Once established, successful glide path preparation can reduce torsional stresses and increase the life span of a rotary instrument by up to 6 times.[5]

A study by Patiño et al.,[3] showed that the incidence of instrument separation was significantly reduced in canals in which preparation was preceded by proper glide path preparation. A separate study showed a higher incidence of distortion and separation of NiTi files in the absence of initial glide path preparation.[6]

NiTi rotary PathFiles (Dentsply Sirona, Ballaigues, Switzerland) were introduced in 2009 to facilitate glide path preparation. A study by Cantatore et al.,[7] showed that PathFiles can prepare a glide path with fewer irregularities and better conservation of original canal anatomy, even after canal preparation by inexperienced users. In recent years, single-file rotary and reciprocating glide path preparation systems have been introduced.

The use of NiTi shaping files in a reciprocating motion is a recent innovation, with manufacturers claiming increased resistance to instrument separation compared to rotary instrumentation, and to adequately shape and preserve the anatomy of root canal systems.[8]

Although some studies indicate more debris accumulation with the reciprocating technique,[9] compared to multiple consecutive rotary files, overall cleaning effectiveness has been shown to be equal or comparable[10,11] and, in some, better[12] than traditional rotary systems.

Several studies have also shown that the reduction of the bacterial load was found to be similar in both reciprocating and rotary systems.[13-15]

In a review article by Plotino et al.,[8] they conclude that reciprocating files have a lower incidence of dentinal defects and cracks. However, a study by Deus et al.,[16] observed no association between these cracks and shaping with single-file reciprocating or multi-file rotary systems.

The aim of this *ex vivo* study was to compare the total glide path and canal preparation times of WaveOne Gold Glider (Dentsply Sirona) combined with the Primary WaveOne Gold (Dentsply Sirona), Edge GlidePath (EdgeEndo, Albuquerque, New Mexico, USA) followed by the Primary EdgeOne Fire (EdgeEndo); and One File G Glide Path (PacDent, Brea, CA, USA) file combined with the Primary One File G (Pac-Dent) Shaping file. The null hypothesis tested was that there are no differences in canal preparation times between the three groups. Currently, there are no published studies comparing the total canal preparation times of these analogous shaping systems in curved canals of mandibular molars.

MATERIALS AND METHODS

Specimen preparation

Extracted mandibular first molar teeth with curved mesial roots containing two separate canals and mesial apical foramina were collected for this study. Radiographs (Carestream Health Inc., NY State, USA) were used to select a total of 60 previously untreated mesiobuccal canals with closed apices and curvatures of 25° to 35° according to the Schneider method.[17] The 60 specimens were engraved from 1 to 60 and then randomly divided into three experimental instrumentation groups of 20 each using an online randomiser tool (Research Randomizer version 4.0) (Urbaniak & Pious 2011).[18]

All specimens were mounted in an FKG vice (FKG Dentaire, La Chaux-de-Fonds, Switzerland) designed for endo training, to simulate clinical situations and standardise preparation conditions. After access cavity preparation, working length (WL) was determined by deducting 0.5 mm from the length of the canal measured to the major apical terminus under 10 times magnification using a surgical microscope (Zumax Medical Co. Ltd, Suzhou, China).

The mesio-buccal canals were located and explored with a size 08 Senseus K-Flexofile (Dentsply Sirona) and canals were negotiated to patency. An initial manually reproducible micro-glide path was prepared by negotiating a size 08 Senseus K-Flexofile to WL with increasing amplitudes of 1-3 mm. This process was repeated using a pre-curved size 10 Senseus K-Flexofile (Dentsply Sirona). Reproducibility was checked by the ability to place the Senseus K-Flexofile 3-4 mm short of working length and pushing it to full working length without any obstruction by means of light finger pressure.

Glide path preparation and root canal shaping

Glide path preparation and root canal shaping were carried out by the same operator and new files were used for each tooth. RC Prep (Premier, Pennsylvania, USA) was used as a lubricating agent during the glide path enlargement and 3.5% sodium hypochlorite was used for canal irrigation after the use of each file. Patency was maintained throughout the glide path and root canal preparations with an ISO size 08 Senseus K-Flexofile.

Group WOGG/PWOG (n=20)

The X-Smart IQ endodontic motor (Dentsply Sirona) was used in reciprocation mode for both glide path preparation with the Wave One Gold Glider (WOGG), and shaping with the Primary Wave One Gold (PWOG). This was done on the WaveOne Gold setting according to the manufacturer's instructions.

Group OFGP/POFG (n=20)
The X-Smart IQ endodontic motor (Dentsply Sirona) was used in reciprocation mode for both glide path preparation with the One File G Glide Path file (OFGP), and shaping with the Primary One File G Shaping file (POFS). This was done on the WaveOne Gold setting according to the manufacturer's instructions.

Group EGP/PEOF (n=20)
The X-Smart IQ endodontic motor (Dentsply Sirona) was used in rotary mode (300rpm, 3Ncm - ProGlider settings) for glide path preparation with the Edge GlidePath (EGP), and shaping with the Primary Edge One Fire (PEOF) in reciprocation. This was done on the WaveOne Gold setting according to the manufacturer's instructions.

Data collection

Each glide path or root canal preparation file was only used to prepare one canal before being discarded. The total time taken to prepare a glide path and to complete the root canal preparation of each canal was recorded (in seconds) by means of an iPhone stopwatch (Apple Inc., Cupertino, California). The time taken to change files was not recorded. Throughout the instrumentation process, RC Prep was used as a lubricant, and 5 ml 3% sodium hypochlorite was used as irrigation solution.

Statistical analysis

Mean and standard deviations were determined for each group, and analysis of variance was used to statistically compare the mean glide path preparation times for the three groups. Statistical procedures were performed on SAS Release 9.3 (SAS Institute Inc, Cary, NC) running under Microsoft Windows (Micro- soft Corp, Redmond, WA) for a personal computer.

RESULTS

The mean and standard deviation values for the glide path preparation and final canal shaping times for the three different groups are presented in Table 1. The fastest final canal preparation time was achieved by WOGG/PWOG (41.78±10.58s), followed by OFGP/POFS (42.02±12.16s) and then EGP/PEOF (42.49±10.44s). There were no statistically significant differences between the canal preparation times of the three combination groups ($p>0.05$).

DISCUSSION

The total canal preparation time for three glide path preparation instruments and their associated shaping systems were investigated in mesio-buccal root canals of mandibular molars with moderate canal curvatures of between 25° and 35°.

Each instrument was used in a reciprocating motion except for the EGP, which was used in continuous rotation before final shaping with the Primary EOF. Recently EdgeEndo launched its reciprocating glide path file, EdgeOne Fire GlidePath, which was not available at the time this research was undertaken.

The WaveOne Gold Glider (Dentsply Sirona) is a single glide path file with an ISO 15 tip size, variable taper from 2% at D0 to 6% at D16, a parallelogram-shaped cross-section, and a semi-active tip. WaveOne Gold (Dentsply Sirona) is a shaping system characterized by an alternating offset parallelogram-shaped cross-section design with two 85° cutting edges. Both these systems are manufactured from Gold-Wire and are used in reciprocation.

The Edge GlidePath file (EdgeEndo) is a variable tapered single rotary glide path file with an ISO 19 tip size, a triangular cross-section, non-cutting tip, and a progressive taper with a 15mm cutting length. EdgeOne Fire (EdgeEndo) is a reciprocating shaping system similar to WaveOne Gold. Both the EdgeOne Fire and Edge GlidePath systems are manufactured from a new proprietary heat-treated NiTi referred to as "FireWire".[19] The One File G Reciprocating File System (Pac-Dent) consists of a single glide path file and four shaping files.

The One File G Glide Path file (Pac-Dent) has an ISO 15 tip, 2% taper, and a parallelogram-shaped cross-section. One File G Shaping files (Pac-Dent) each have a parallelogram-shaped cross-section, constant helical angle of 24° along the active length of the instrument and two 80° cutting edges and are used with the same handpiece settings as WaveOne Gold. The One File G Glide Path- and Shaping files are made using proprietary heat-treated NiTi wire and have roundly tapered guide tips without any cutting edges.

In the present study the total time taken to prepare a glide path and shape each canal was recorded (in seconds). There were no statistically significant differences in preparation times between the three combination groups in this study.

Several studies have compared single and multiple instruments in curved canals and have concluded that single file systems are significantly faster.[12,20,21] In a study by Vorster et al.,[22] glide path preparation times of WOGG in a reciprocation motion were compared to that of K-Files and PathFiles in a rotary motion. WOGG showed statistically significantly faster glide path preparation times compared with both the K-file and the PathFile preparation groups. The authors attributed the results to the multiple instrument use in each of the other two groups compared to the WOGG group, which consisted of a single instrument.

Table 1. Descriptive statistics: Mean final canal preparation time (in sec) of the three groups (n=20).

Value of K	Strength of agreement	Value of K	Strength of agreement	Value of K
WOGG/PWOG	41.78[a]	10.58	25.32	64.66
EGP/PEOF	42.49[a]	10.44	25.70	57.49
OFGRG/POFGR	42.02[a]	12.16	23.71	68.68

Mean values with the same superscript letters were not statistically different at $p>0.05$ using the Kruskal Wallis test.

Some of the studies examining preparation times favour reciprocation,[23] while others claim that single files used in rotation are faster.[24] A study examined the shaping ability and preparation times of different single-file NiTi systems in rotation and reciprocation.[25] In this study by Hwang et al.,[25] single Mtwo (VDW, Munich, Germany) and Reciproc (VDW) shaping files were used after glide path preparation with a size 15 K-File and no differences in preparation times were found between the shaping groups. A separate study examined the shaping ability of different NiTi systems in simulated S-shaped canals with and without glide path preparation, and concluded that glide path preparation exerted no significant effect on preparation times of these canals.[26]

In a study by D'Amario et al.,[27] they compared the canal preparation time of One Shape (MicroMega, Besancon, France), Reciproc and WaveOne preparation systems after glide path preparation with a size 10 K-File. They found no clinically relevant differences in preparation times between the three single file systems. Their recorded times were much higher than that of the current study. This could be attributed to the curvature of their tested specimens or the fact that the present study incorporated glide path files, which decreased the total shaping times.

In this study, preparation times were similar for all three combination groups. These single-file glide path and shaping systems are appealing for use in the clinical setting because of their reduced overall canal shaping time, potential low cost, prevention of cross-contamination, and easy clinical application.

CONCLUSION

Within the limitations of this study, it can be concluded that all three groups presented with similar preparation times, and no statistically significant differences were noted ($p > 0.05$).

The limited information on EdgeEndo and One File G systems in the literature made it impossible to compare the results obtained in this study with other studies. To date, no paper has been published on the preparation times of these file combinations. It is however recommended that further studies are needed to evaluate these endodontic glide path and shaping systems clinically.

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Do the CPD questionnaire on page 383

The Continuous 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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Oral health knowledge, attitudes, and practices of undergraduate students at a South African University of Technology

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ABSTRACT

Background
Awareness of oral health is essential for developing healthy habits, and a correlation between improved knowledge and better oral health has been shown to exist. Health-related behaviours are more likely to be followed if a person has greater control over their health with a better understanding of diseases and their aetiology.

Objectives
To determine the knowledge, attitudes, and practices regarding oral health care among undergraduate students in the Life Sciences Department at a University of Technology, Free State.

Methods
This descriptive study gives insights into the oral hygiene knowledge, attitudes, and practices of undergraduate students in the Faculty of Health and Environmental Sciences, Department of Life Sciences at a University of Technology. Data were collected using an online questionnaire eliciting quantitative and qualitative data.

Results
The results revealed that most of the participants, 80% (n=178) understood that oral health is essential to their overall wellbeing. Overall, in this research, the findings of oral health education were found not to be covered. However, we found that variations in the source of dental information were correlated with university students' oral health behaviour.

Conclusion
The study, therefore, concludes that oral health care knowledge, attitudes and practices are affected by education and show that advocacy for the promotion of oral health is significant for the students.

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1. **Feziwe Flora Mbele-Kokela:** Study conception and design, data collection, data analysis, data interpretation and drafting of the manuscript - 50%
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INTRODUCTION

Oral health is a primary predictor of health, nutrition, and overall quality of life.[1] Furthermore, one should be free from oral cancer and infection, periodontal diseases, tooth decay, tooth loss, and any facial disorders that impair a person's ability to bite and chew.[2] However, in South Africa, oral disease is still a health problem and a considerable burden, which often leads to pain and more significant loss of the tooth.

This disease affects appearance, quality of life, consumption of nutrients, and thus growth and development.[3] The 2020 mid-year population estimates from Statistics South Africa (Stats SA) were estimated at 59.62 million. Around 51,1% (about 30.5 million) of the population is female.

The ages of the participants in this study ranged from 18 to 24 years, with the majority being females, in line with South Africa's gender demographics. Stats SA also provides data that suggests that participation in post-school institutions has increased over the past two decades, primarily due to the rise in government support for the sector. However, the nation is still struggling to meet the increasing educational needs of young people and demand skills from the market.

According to the Higher Education and Skills in South Africa 2017 report, in 2016, the life science and physical sciences intake in Universities was 3.3% of females and 2.8% males while a majority of 51% of those that did not attend university stated that they did not have money to pay the fees.

The development and preservation of good general and oral health is a priority and a key factor in enabling adults to achieve overall wellbeing and enhanced quality of life. Therefore, it is essential to determine how people rate their oral health status, their perceived dental needs, and the actual use of available dental services.[4] Ghaffari et al. (2018) suggested research that supports that better oral

care practices are presented through proper oral health awareness.[5] In addition to this, a positive attitude toward oral health practices facilitates improved oral health habits.[5]

The literature suggests that integrated dental services should be part of every educational institution where oral health education and oral health screening are provided. Students can access dental services through funding, i.e. simple dental payment systems, including scaling and polishing, restorations, fissure sealants, and relief of sepsis, making things easy and accessible for all students.[6,7]

Of concern among students is alcohol consumption, smoking, and sugary intake, which peaks between 18 and 25. University students in this age group are at particular risk because of increased alcohol consumption than non-enrolled individuals.[8] Ramphoma (2016) noted that even though oral health has an impact on general health, in South Africa, it is still one of the most overlooked aspects of health.[9]

This is the first study evaluating oral health that was conducted at a University of Technology. Even though research suggests that structures such as school health-based and community-based programmes are in place to promote behaviour practices in oral health, it is crucial to remember how the knowledge, attitudes and practices (KAP) are applied, as investigated in this study.

BACKGROUND

Oral health is now an essential component of general health, and oral health awareness is growing worldwide.[8] The Global Oral Health Program of the World Health Organization has done much in the past five years to raise awareness.[8] Furthermore, 3.5 billion people worldwide suffer from oral diseases, with the most prevalent non-communicable diseases of untreated dental caries, with an established oral and general health relationship.

For example, diabetes mellitus is associated with the development and progression of periodontitis. In addition to the previous statement, there is a causal correlation between high intakes of sugar and non-communicable disorders such as cardiovascular disease and diabetes.[8,10]

Literature suggests that adults' periodontal health impacts their smiling patterns and their quality of life-related to smiles. Furthermore, poor periodontal health also prevents positive emotions from being expressed by adults, which can, in turn, affect their self-conception and social interactions.[11] Evidence supports that problems with oral health can, in several ways, affect the quality of life. Poor oral health can stop students from expressing positive emotions that can affect their social interactions and how they feel about themselves.[11]

According to Sheiham (2005), some of the risk factors causing oral health disorders worldwide are poor oral hygiene, diet and smoking.[12] Additionally, poverty remains the primary determinant of oral health disorders in Africa, predisposing people to a lack of information and poor lifestyle choices.[13] In South Africa, there is a high dental caries rate despite public and private services being available. While access is a problem, the knowledge of preventative measures is also very low.[14,15]

The outcomes of a study done about oral health-related knowledge, attitudes and practices of adult patients in Mangaung Metropolitan Municipality could be used to enlighten the planning of integrated oral health promotion plans, in Mangaung and the Free State Province of South Africa.[15] A similar study done in KwaZulu-Natal among undergraduates about knowledge and attitudes in oral self-care practices showed that although oral diseases cannot be avoided, they can be prevented through simple tooth brushing measures twice a day with a fluoride toothpaste but that alone is also not enough.[16]

With an increased awareness of health and self-care in schools, this study aimed to establish the students' general knowledge, attitudes, and practices concerning oral health care.

OBJECTIVES OF THE STUDY

The objectives were to determine the students' knowledge regarding oral health care, explore the students' attitudes towards dental care, and establish the students' practices regarding oral health and hygiene using an online questionnaire.

METHODS

The study was conducted among undergraduate students at a University of Technology. This University of Technology is in Bloemfontein in the Free State province of South Africa. Ethical approval was obtained from the Humanities and Social Sciences Research Ethics Committee from UKZN (HSSREC/00001570/2020) and thereafter from the Life Sciences Department.

All principles and policies of the UKZN HSSREC were adhered to throughout the study. An online information sheet was uploaded on QuestionPro for all participants in the study to access easily. Informed consent was obtained from the participants online. Participants could withdraw from the study at any stage.

All 260 participants in the Department of Life Sciences were invited to participate during October 2020. A pilot study was conducted on ten students to determine if the students will understand the questionnaire. Thereafter minor changes were made to the research tool.

This was a cross-sectional descriptive study design that used both quantitative and qualitative methods. Data were collected from an online survey questionnaire during October 2020 using QuestionPro. An email contact list was acquired through the programme coordinators, and the link to the study was sent to participants via email. Students were also sent the link via their WhatsApp groups. The questionnaire consisted of five sections: demographics, habits, knowledge, attitudes, and practices. A curriculum checklist was used to review the modules offered in the first year for both two programmes.

Both quantitative and qualitative methods were used for this. Quantitative data in response to each question was entered into an Excel spreadsheet and analysed with SPSS version 26.0. The results present the descriptive statistics in graphs, cross-tabulations, and other figures

for the collected quantitative data. Inferential techniques included the use of correlations and chi-square test values, which were interpreted using the p-values. The traditional approach to reporting a result requires a statement of statistical significance. A p-value was generated from a test statistic. A significant result is indicated with "p<0.05".[17]

The qualitative analysis included an analysis of the targeted curriculum review and thematic analysis of long answer questions. The results from the groups were added to an excel spreadsheet and compared. A curriculum checklist was used. The method used to analyse qualitative data was content analysis by following the steps defined by Braun and Clarke (2006), using a thematic process.[18]

RESULTS

Demographic data

Overall, the ratio of males to females was approximately 1:2.3 28.4% (n=62): 70.2% (n=153) with 1.4% (n=3) classifying themselves as other (p<0.001). Within the age category of 22 to 24 years, 28.2% (n=60) were male.

The age distributions are not similar as there are more respondents (90%; n=189) younger than 24 years (p< 0.01). This study reported that many respondents lived at home 44.5% (n=97) and private residences 39.9% (n=87), while a smaller number lived on campus 15.6% (n=34) (p<0.001).

Habits

Participants were asked about their habits of drinking alcohol and smoking. Nearly 72% (n=160) had never smoked while 26.6% (n=58) smoked. In this category, it was noted that more males smoke than females.

An overwhelming 99.1% (n=218) of participants (n=220) have had an alcoholic drink. Over 60% (n=132) drink over seven alcoholic drinks per week. Habits were also structured around the participant's sugar intake, and in our study, over 80%; (n=187) of the participants agreed that they love sugar.

Figure 1 provides data on habits about toothbrushing which show significantly different patterns (p<0.001) where more than 63% (n=138) confirmed to brushing their teeth twice a day while only 31% (n=68) brushed once a day.

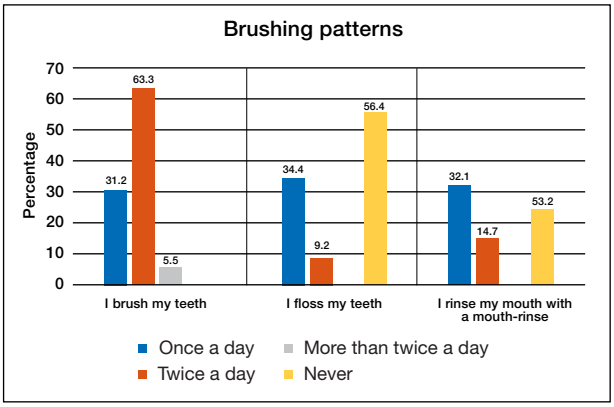

Figure 1. Brushing patterns.

Table 1. Demographic profile of participants.

Age (years)		Gender			Total
		Male	Female	Other	
16 - 18	Count	5	13	0	18
	% within Age	27.8%	72.2%	0.0%	100.0%
	% within Gender	8.1%	8.5%	0.0%	8.3%
	% of Total	2.3%	6.0%	0.0%	8.3%
19 - 21	Count	25	81	1	107
	% within Age	23.4%	75.7%	0.9%	100.0%
	% within Gender	40.3%	52.9%	33.3%	49.1%
	% of Total	11.5%	37.2%	0.5%	49.1%
22 - 24	Count	20	49	2	71
	% within Age	28.2%	69.0%	2.8%	100.0%
	% within Gender	32.3%	32.0%	66.7%	32.6%
	% of Total	9.2%	22.5%	0.9%	32.6%
>24	Count	12	10	0	22
	% within Age	54.5%	45.5%	0.0%	100.0%
	% within Gender	19.4%	6.5%	0.0%	10.1%
	% of Total	5.5%	4.6%	0.0%	10.1%
Total	Count	62	153	3	218
	% within Age	28.4%	70.2%	1.4%	100.0%
	% within Gender	100.0%	100.0%	100.0%	100.0%
	% of Total	28.4%	70.2%	1.4%	100.0%

Table 2. Participant's oral health care habits.

		Strongly agree	Agree	Unsure	Disagree	Strongly disagree	Chi-Square p-value
I have bad breath	B15	10 (4.6%)	20 (9,2%)	44 (20.2%)	89 (40.8%)	55 (25.3%)	<0.001
I have missing teeth	B16	15 (6.9%)	54 (24.8%)	18 (8.3%)	72 (33.0%)	59 (27.1%)	<0.001
I have bleeding gums	B17	11 (5.0%)	43 (19.7%)	43 (19.7%)	75 (34.4%)	46 (21.1%)	<0.001

In this study, 56.4% (n=123) of the participants confirmed that they had never flossed before, while 53.2% (n=116) stated they had never used a mouth-rinse before. Nearly, 68.8% (n=150) of the participants provided information that suggested that they brush their teeth twice a day, in the morning and before going to bed, whilst a smaller number, 5% (n=12) brushed three times a day.

The significance of the differences in habits was noted in the participants. The higher levels of disagreement imply that respondents consider their breath, teeth, and gums healthy or acceptable. A small number 13.8% (n=30) indicated that they had bad breath, and 31.7% (n=69) indicated missing teeth. A further 24.7% (n=54) indicated that they had bleeding gums.

Knowledge

Participants provided significantly higher levels of agreement regarding their knowledge of oral health. Over 51% (n=112) agreed that smoking could affect their gums, while 64,2% (n=159) believed that dental caries is caused by a combination of sugar, bacteria, and poor oral hygiene. However, a significant 86,7% (n=189) supported the statement that supports brushing twice a day to keep their teeth clean and healthy.

Attitudes

The participant's responses towards their oral health care attitudes indicated that out of the participants (n=220), over 94% (n=206) agreed that taking care of their oral hygiene was important, and about 67% (n=146) visited the dentist twice a year. Only a few with a response of 8,4% (n=18) indicated that taking care of their oral hygiene was not important in the present time of Covid-19 with everyone wearing a mask. Few of the participants, 29,4% (n=64), believed that one could get heart diseases from bad oral health.

Practices

About 65% (n=141) of participants believed they should brush their teeth for two minutes, while 29,3% (n=63) suggested there is no need to visit a dentist if they have no problems orally. Oral hygiene techniques such as brushing twice daily (36.9%) and flossing (7.5%) were recorded and identified by many dental assisting students. Interestingly, most participants, 64,9% (n=141) agreed that they had been taught about oral health in school, but their habits prove otherwise, as discussed above.

All open-ended questions are reported in the tables below. Participants were asked to reflect on their oral health care while exploring their knowledge, attitudes, and practices. The responses were summarised from QuestionPro and supported with quotes, and these were analysed thematically. In our study, out of n=220 participants, 34% (n=75) were from Dental Assisting (DA) and 65.9% (n=145) from Environmental Health (EH).

It must be noted that the participants could give multiple responses. The participants were asked, "what is plaque?" Out of (n=220), more than 41% (n=91) stated it was a layer of bacteria in the teeth. A few participants, 14%; (n=38) stated it was dirt on the teeth, while a 6.3% (n=14) believed that it was a calcified deposit on teeth. However, the rest 37.9% (n=77) of the participants stated they did not know what plaque was. Themes and frequencies are shown in Table 3 below.

Table 3. Knowledge of dental plaque.

Theme	Frequency (n=220)	Supporting evidence or quotes
Bacterial layer on teeth	**41% (n=91)**	Respondent 334: "Bacteria that forms on the teeth due to lack of oral health care." Respondent 366: "An accumulation of bacteria on teeth from food and liquids when teeth aren't brushed efficiently."
Did not know	**37.9% (n=77)**	Respondent 398: "Have no idea."
"Dirt" layer on teeth	**14.0% (n=38)**	Respondent 345: "Dirt on teeth which has bacteria." Respondent 380: "Build-up of dirt on teeth."
Hard layer on teeth	**6.3% (n=14)**	Respondent 397: "Hard substance on my tooth." Respondent 444: "Stone substance on teeth."

Table 4. Prevention of tooth decay.

Themes	Frequency (n=220)	Supporting evidence or quotes
Brushing of teeth	**90.2% (n=199)**	Respondent 479: "Brush teeth at least twice a day after meals. Avoid eating sugary stuff. Do not smoke. Floss at least once a day."
Avoiding sugars	**13.1% (n=29)**	Respondent 469: "Avoiding over-consumptions of sugary drinks and food, brushing teeth regularly twice a day, flossing at least once at the end of the day." Respondent 524: "Brush teeth and eat less sugar."
The use of fluoride	**9.0% (n=20)**	Respondent 471: "Brush teeth using fluoride toothpaste. Drink water regularly. Eat tooth-healthy food."
Flossing daily	**5.4% (n=12)**	Respondent 491: "Brush your teeth at least twice a day with a fluoride-containing toothpaste. Clean between your teeth with a floss."
Rinsing after meals	**1.3% (n=3)**	Respondent 486: "Brush with fluoride toothpaste after eating or drinking. Rinse your mouth. Visit your dentist regularly Consider dental sealants. Drink some tap water. Consider fluoride treatment". Respondent 510: "Brushing twice a day with fluoride toothpaste Rinse your mouth after eating. Visit your dentist twice a year."
Did not know	**1.3% (n=3)**	Respondent 1137: "Don't know."
Eating healthy foods	**0.9% (n=2)**	Respondent 471: "Eat tooth-healthy food."

Table 5. Poor oral hygiene knowledge.

Themes	Frequency (n=220)	Supporting evidence or quotes
Bacterial build up	62.0% (n=140)	Respondent 808: "bacteria cause tooth decay."
Halitosis	10.9% (n=24)	Respondent 622: "A person may experience halitosis which is an offensive bad breath, this may also lead to tooth decay or even worse oral diseases such as gingivitis and periodontal disease."
Bleeding gums, gum disease	3.6% (n=8)	Respondent 750: "You might have bad breath and bleeding gums."
I don't know	2.2% (n=5)	Respondent 734: "Unsure."
Tooth decay	1.8% (n=4)	Respondent 711: "Rotten teeth."
Accumulation of plaque and calculus	0.9% (n=2)	Respondent 706: "Plaque and tartar will grow on teeth, demineralising teeth and weakening the gingival structure. (Decay, gingivitis etc.)."

Table 6. Oral health care practitioner visit.

Themes	Frequency (n=220)	Supporting evidence or quotes
For dental extraction	36.0% (n=78)	Respondent 1037: "To remove a tooth that had causes abscess in my mouth." Respondent 914: "Extraction of a rotten tooth."
For scale and polish	11.3% (n=25)	Respondent 1033: "To clean my teeth."
For a dental check-up	9.0% (n=20)	Respondent 1026: "Teeth check-up and washing of teeth." Respondent 1016: "One of the reasons why I visited them was because I was going on a Church mission in Madagascar and a dental check-up was a must-do for me."
Lack of time	3.1% (n=7)	Respondent 892: "Because I don't have time to visit the dentist."
For Orthodontic procedures	2.2% (n=5)	Respondent 959: "I had to put on braces."
For restorative care	1.8% (n=4)	Respondent 992: "For cleaning and a filling."
Experienced pain	1.3% (n=3)	Respondent 1018: "Painful teeth."
Gold teeth	0.9% (n=2)	Respondent 902: "Cleaning my teeth and putting on a gold tooth". Respondent 903: "Cleaning my teeth, tooth extraction, insertion of gold and silver teeth."

Table 7. Reason for not visiting.

Themes	Frequency (n=220)	Supporting evidence or quotes
Affordability	15.0% (n=34)	Respondent 942: "I cannot afford to pay." Respondent 990: "Money is the problem."
No reason to visit	10.4% (n=23)	Respondent 1001: "No need for me."
Healthy mouths	2.2% (n=5)	Respondent 944: "I care for my teeth and never had problems with my teeth and so didn't see any need to see a dental practitioner."
Fear of dental practitioner	0.3% (n=1)	Respondent 987: "I'm scared of dentists."

Table 8. General health.

Themes	Frequency (n=220)	Supporting evidence or quotes
Don't know	32.0% (n=72)	Respondent 1157: "I have no idea."
Periodontal diseases	5.9% (n=13)	Respondent 1120: "I was told that oral decay, halitosis, periodontitis and other problems can cause heart problem, can cause stroke, premature for pregnant women."
Diabetes	5.0% (n=11)	Respondent 1136: "Diseases such as diabetes can lower the body resistance to infection, making oral health problems more severe." Respondent 1172: "If you have chronic condition like sugar diabetes."
Lowering resistance	2.7% (n=6)	Respondent 1133: "Can lower the body's resistance to infection, making oral health problems more severe."
Concern about appearance	1.8% (n=4)	Respondent 1174: "If you have unhealthy teeth, they might affect your general appearance."
HIV	0.9% (n=2)	Respondent 1141: "Gum disease play a role in some diseases such as diabetes and HIV/Aids can lower the body's resistance to infection, making oral health problem more severe."

Table 9. Methods of cleaning teeth.

Themes	Frequency (n=220)	Supporting evidence or quotes
Toothbrush and toothpaste	99.0% (n=218)	Respondent 1469: "I use a soft toothbrush brush and a fluoridated toothpaste, and I brush for two minutes, and I visit a dentist twice a year."
Mouth-rinse	5.9% (n=13)	Respondent 564: "By mouth wash and using a healthy dental diet."
Salt and water	1.8% (n=4)	Respondent 1513: "Toothpaste and toothbrush, water and sometimes salt and water solution."
Don't know	1.0% (n=3)	Respondent 1451: "don't know."

Participants reflection on the prevention of tooth decay

Participants were asked: "How can you prevent tooth decay?" 90.2% (n=199) responded, "by brushing twice a day". While there were multiple responses, only a few did not know how 1.3% (n=3). Themes and frequencies are shown in Table 4 below.

Participants reflection on the sequelae of poor oral hygiene

Participants were asked: "What happens if you do not clean your mouth?" The responses indicated that they were aware that tooth decay is caused by bacteria and plaque build-up from not brushing regularly. Below are themes and frequencies (Table 5).

Reason for visiting a dentist

Respondents were asked if they had ever been to a dentist, dental therapist, or an oral hygienist. Overall, 58% (n=129) stated yes and 31.3% (n=69) had not been to either one. Out of the 58% (n=129) that stated they have been to one and the majority, 36% (n=78) indicated that it was mainly for extraction (Table 6). A slightly lower number, 15% (n=34), stated that they did not have money to go to a dentist/therapist or a hygienist. Themes are reflected in Table 7.

Table 8 reports that about 32% (n=72) of the participants did not understand how the state of one's oral health can affect their general health. They indicated that they did not know the relationship between the two. In comparison, only 44.5% (n=98) had an idea. Table 9 reports on the methods of cleaning teeth, its themes, statements, and frequencies. The respondents were asked what methods they used to clean their teeth. The majority 99% (n=218) stated they brushed with toothpaste and a toothbrush.

DISCUSSION

In this study population, we found that variations in the source of dental information were correlated with oral health behaviour; both positive and negative associations were observed between the sources and oral health behaviour.

The ages of the participants in this study ranged from 18 to 24 years, with the majority being females, in line with South Africa's gender demographics. Overall, the ratio of males to females is approximately 1:2.3; 28.4% (n=62): 70.2% (n=153). Participants reported to be living at home were 45% (n=97) which might influence their oral hygiene methods. This statement is supported by a study conducted in Mangaung, Free State, South Africa where oral health care knowledge, attitudes, and practices among adult patients was researched..[15]

Modikoe et al. (2019) suggest that living at home could influence oral hygiene methods in a good or bad way to fight dental caries.[15] However, the correlation between students staying at home and toothbrushing in our study revealed no degree of association or significance - between the number of household individuals and toothbrushing habits of the participants. Our research noted that significantly more males 26.6% (n=58) smoked than females. Interesting enough, over 51% (n=114) in our study, agreed that smoking could influence their gums.[6,19] Formicola (2017) and Park et al. (2011) found that tobacco use may influence students' oral hygiene methods.[6,19] An analysis of smoking and bleeding gums was done, and no significant difference was found in our study.

Almost all the participants, 99.1% (n=218) have had an alcoholic drink, and of the 99%, over 60% (n=132) drink over seven alcoholic drinks per week. These findings might influence the participants' oral hygiene as seen in a study conducted by Afshin et al. (2019).[8] It was observed that the overall trend of alcohol use increased among students. Furthermore, the systematic analysis for the Global Burden of Disease Study done in 2017 suggested that alcohol intake influenced students in all educational institutions regarding their lifestyle.[8]

This study's habits were also structured around the participant's sugar intake as reported in a study conducted by Modikoe et al., (2019), whose findings indicated a low intake of vegetables and more sugary products in adults. In our study, over 80%; (n=187) of the participants agreed that they love sugar and only 14%; (n=32) do not like sugar.[15] Over 22%; (n=50) stated that they take sugar more than three times a day.

Their intake of sugar is to be noted, as it is significantly high. There was a strong and significant positive correlation between high sugar levels, bad breath and missing teeth using the Pearson Chi-Squared Test (p=0.01). This finding is also to be noted as 72.2% (n=159) participants believed that a combination of sugar, bacteria causes dental caries and poor oral hygiene, but the results of their drinking and smoking habits prove otherwise.

Oral health knowledge

More than 63% (n=138) participants confirmed brushing their teeth twice a day, and 31% (n=68) brushed once a day. Taniguchi-Tabata et al. (2017) cited that oral health education successfully modified students' oral health behaviour.[26] However, this research study's findings further suggested that participants did not use oral hygiene strategies such as dental floss (56.4%; n=123), or have ever used a mouth-rinse (53.2%; n=116). The findings in our study are close to that of a research carried out by Ghaffari et al. (2018), where it was concluded that oral health problems have a considerable effect on the quality of life of individuals.[5]

Similar patterns were observed in another study conducted by Taniguchi- Tabata et al., (2017) among Japanese university students on dental knowledge. It was indicated that school is important as a source of dental awareness for oral health education.[26] In addition, dental awareness from dental clinics may effectively improve oral health behaviour, as Taniguchi-Tabata et al. (2017) stated.[26] In our study, majority of the participants 62% (n=140) indicated that they are aware that tooth decay is caused by bacteria and plaque build-up from not brushing regularly; however, the findings of oral health education were found not to be covered.

Oral health attitudes

In our research, an area of concern was when the participants were asked about why they had to visit a dentist, dental therapist, or an oral hygienist. Nearly 58% (n=129) stated yes and 31.3% (n=69) had not been to either one. Out of the 58% (n=129) that stated they have been to one, the majority 36% (n=78) indicated that it was mainly for extraction. The research explored by Silva and Oliveira (2018) suggested that the outcomes for primary care oral health services have shown that areas with lower coverage for dental services are more prone to oral health problems.[27]

In our study, fifteen percent (n=36) indicated that they did not have money to go to a dentist/therapist or a hygienist. Pain and sepsis could hinder students from going about their daily life, as defined, and supported through research by (Glick et al., 2016) through the FDI World Dental Federation's definition of oral health.[2]

Research further notes the mouth as multifaceted that involves the voice, smile, smell, taste, touch, and chew. Additionally, it is used to swallow and communicate a spectrum of emotions through confident and painless facial expressions of the craniofacial complex.[2] Furthermore, poor oral health care could compromise the functioning of the oral cavity needed for mastication.[20]

University students are aware of their oral health and appearance, pain and cavities could affect their confidence levels and progress. If students have bypassed school and are now at the university level with oral hygiene issues, oral health education needs to be reviewed at school level.

Peltzer and Pengpid (2014) conducted a study in developing countries, including SA. The results suggested that oral hygiene education in our country was associated with weak oral health habits.[21] These findings suggest that oral hygiene may not have been adequately incorporated into the secondary education system.[21] Notably, there was strength in toothbrushing rates from the participants in our study.

Dental care is expensive even in high-income environments, averaging five percent of overall health spending and 20% of out-of-pocket health expenditure.[9,22] Sarpkaya et al. (2018) suggested that the Universal Health Coverage should support activities that would help frame policy dialogue and resolve weak primary oral health programs. Furthermore, to resolve high out-of-pocket oral health care costs in SA, a simple dental payment system would assist the students, as cited in a study considering students' cost of dental education by Formicola (2017). This study's outcomes suggest that oral health care campaigns would benefit the students, and free oral health screening and discounted dental services could be offered to students.

Oral health practices

This study's findings suggest that the majority, 86,7% (n=191), brushes twice a day to keep their teeth clean and healthy. This is supported by Al-Hussaini et al.'s (2003) research on dental health knowledge among students at Kuwait University that suggests what university students know about oral health care.[23]

The literature further supports the results of our study. Azodo et al. (2010) researched students in Nigeria and concluded that most students were aware that oral health is an aspect of general health and affected everyday life.[4]

However, 32% (n=72) did not know the correlation between oral and general health. Thus, the study advocated maintaining proper oral health which relies on implementing habits, such as dental check-ups, frequency of toothbrushing, food and sugar intake, dental floss, and other interproximal cleaning techniques. In the prevention of dental caries and periodontal disease, these practices play an important role as adequate oral hygiene habits and the frequent use of dental services have shown efficacy in reducing the prevalence of these diseases as well as in preventing them.[24]

Our study noted a marked difference between Dental Assisting (DA) and Environmental Health (EH) students in the reported oral health knowledge and practices. Oral hygiene techniques such as brushing twice day were recorded (36.9%), and flossing (7.5%) were identified from (DA) students. The dental assisting group knew there was a correlation between oral health and general health. Nearly 29,4% (n=64) DA believed that one could get heart diseases from bad oral health while a small number from DA and the Environmental Health (EH) had no idea 70% (n=156).

The study further reveals that higher levels of disagreement from DA students imply that respondents consider their breath, teeth, and gums healthy or more acceptable than the EH group. These findings could potentially be attributed to the structure of the curriculum for both groups. No module covers oral and general health for EH students, whereas for DA students; oral and general health is covered in pharmacology, oral pathology, dental assisting theory and practical. This was verified by a curriculum checklist that was done for both programmes.

Lastly, in this study, we explored whether there is a course that focuses on students' self-care and general health. A study conducted in oral and oral health knowledge and the attitude among nursing students revealed that because oral health was not part of the curriculum, students had no interest or knowledge about oral health.[25] This study's findings suggested that both programmes did not feature a module that teaches them about self-care. This was verified through a curriculum checklist. Even though the DA might have a bit of knowledge about oral health in this research, further research and a more thorough review of this learning process must unpack the dynamic realities of understanding health and oral disease systems.[16]

Despite the impact that oral health has on general health and the quality of life, in most developing countries including South Africa, it is still one of the most neglected aspects of health.[9]

Clinical relevance

This is the first research study to evaluate oral health awareness and oral health behaviours among students in a University of Technology. The dental clinic in the university will be presented with the results of this study, and this will provide the basis to modify the current teaching module to improve the outcomes and treatment services offered to students.

Noting that there is a shortage of oral health research at the university, this study's results can be a catalyst for more oral health research. Although research recognises that knowledge does not always translate into action, the disparities found in this study may be primarily resolved using community and individual-based oral health education, promotion and prevention strategies and services. These can be integrated into the National Health Insurance planning for university students in South Africa.

Limitations of the study

The study participants were drawn from a single place, and therefore, the results cannot be generalised to other departments. This study, with its limitations, can provide insight into students' oral health care knowledge. Further research about oral health care knowledge still needs to be explored in all the university departments. In our study, the DMFT index could not be performed due to the Covid-19 pandemic.

CONCLUSION

The study aimed at exploring the students' oral health care methods and thereafter make them aware of measures such as the use of fluoridated toothpaste and application of topical fluoride. Curative measures are available, but the achievement of lower dental caries rates in SA could be through community campaigns and oral health programs. Although these are already in place, the coverage needs to be increased and include tertiary institutions. Oral health promotion should be community-based and must also be included in the course designed for University students.

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Disclaimer

The views expressed in the submitted article are the authors own and not an official position of the institution.

Competing interests

The author(s) declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Ethical consideration and consent to participate

This is contained in the manuscript.

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Availability of data and materials

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The induction of bone formation: From bone morphogenetic proteins to the transforming growth factor-β_3 protein - Redundancy, pleiotropy and the induction of cementogenesis

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ABSTRACT

This review proposes to translate organogenesis and the induction of bone formation by the recombinant human transforming growth factor-β_3 (hTGF-β_3) in the Chacma baboon *Papio ursinus* to periodontal tissue induction and regeneration.

Naturally derived highly purified osteogenic proteins of the transforming growth factor-β (TGF-β) supergene family were implanted in Class II furcation defects of the first and second mandibular molars. Additional defects in *P. ursinus* were treated with recombinant human osteogenic protein-1 (hOP-1, also known as bone morphogenetic protein-7, hBMP-7) and hBMP-2, singly or in binary applications. In different studies defects were also implanted with hTGF-β_3 singly or in binary application with hOP-1. Harvested specimens on day 60 and 180 were processed for undecalcified histology using tungsten-carbide knives mounted on Polycut sledge' micro-tomes or the Exakt precision cutting and grinding system.

Highly purified osteogenic proteins showed the induction of Sharpey's fibres into newly formed cementoid with foci of mineralization. hOP-1 induced substantial cementogenesis whilst hBMP-2 preferentially induced alveolar bone. Intramuscular implantation of hTGF-β_3 absorbed onto coral-derived macroporous bioreactors engineered large heterotopic multicellular bone organoids.

Gene expression pathways by quantitative Reverse Transcription Polymerases Chain Reaction (qRT-PCR) show that the induction of bone is *via* several profiled BMPs and TGF-βs expressed upon implantation of hTGF-β_3 recapitulating the synergistic induction of bone as shown by binary applications of low doses of hTGF-β_1 and hTGF-β_3 with hOP-1.

The rapid induction of bone by hTGF-β_3 provides the framework for a paradigmatic shift from recombinant hBMPs to hTGF-β_3 in clinical contexts, provocatively operational in periodontal tissue regeneration with substantial induction of cementogenesis in angiogenesis.

Keywords
Bone morphogenetic proteins' gene expression, qRT-PCR, TGF-β_3 master gene, noggin, molecular redundancy, pleiotropy, cementogenesis in angiogenesis, primates.

INTRODUCTION

Across the Century, systematic studies in the Chacma baboon *Papio ursinus* have reported the induction of cementogenesis with *de novo* nucleation of Sharpey's fibres inserted directly into mineralized dentine or newly forming cementoid matrix together with angiogenesis and capillary sprouting within the newly formed periodontal ligament space.[1]

Our first paper describing the induction of cementogenesis and of alveolar bone regeneration by highly purified naturally derived bone morphogenetic proteins (BMPs) in Class II furcation defects of *Papio ursinus* showed the substantial induction of periodontal tissue regeneration.[2] We also showed that BMPs initiate cementogenesis, regulating the assembly of "a functionally orientated periodontal ligament" space.[2] These preliminary observations in the non-human primate *P. ursinus* indicated that the presence of "multiple forms of BMPs may reflect a biological significance, locally regulating the regeneration of other tissues including the periodontal ligament and cementum".[2] This has suggested that the published material "may lay the foundations for systematic structure-activity relationships by recombinant hBMPs".[2]

These and other challenges were raised in a review that stated that the biological significance of redundancy of BMPs was a critical area of research ahead raising the question: "Does the presence of multiple forms of BMPs have a therapeutic significance?".[3] It was also stated that the "future direction will depend on an optimal combination and/or developing a structure-activity profile amongst the members of the BMP family".[2,3]

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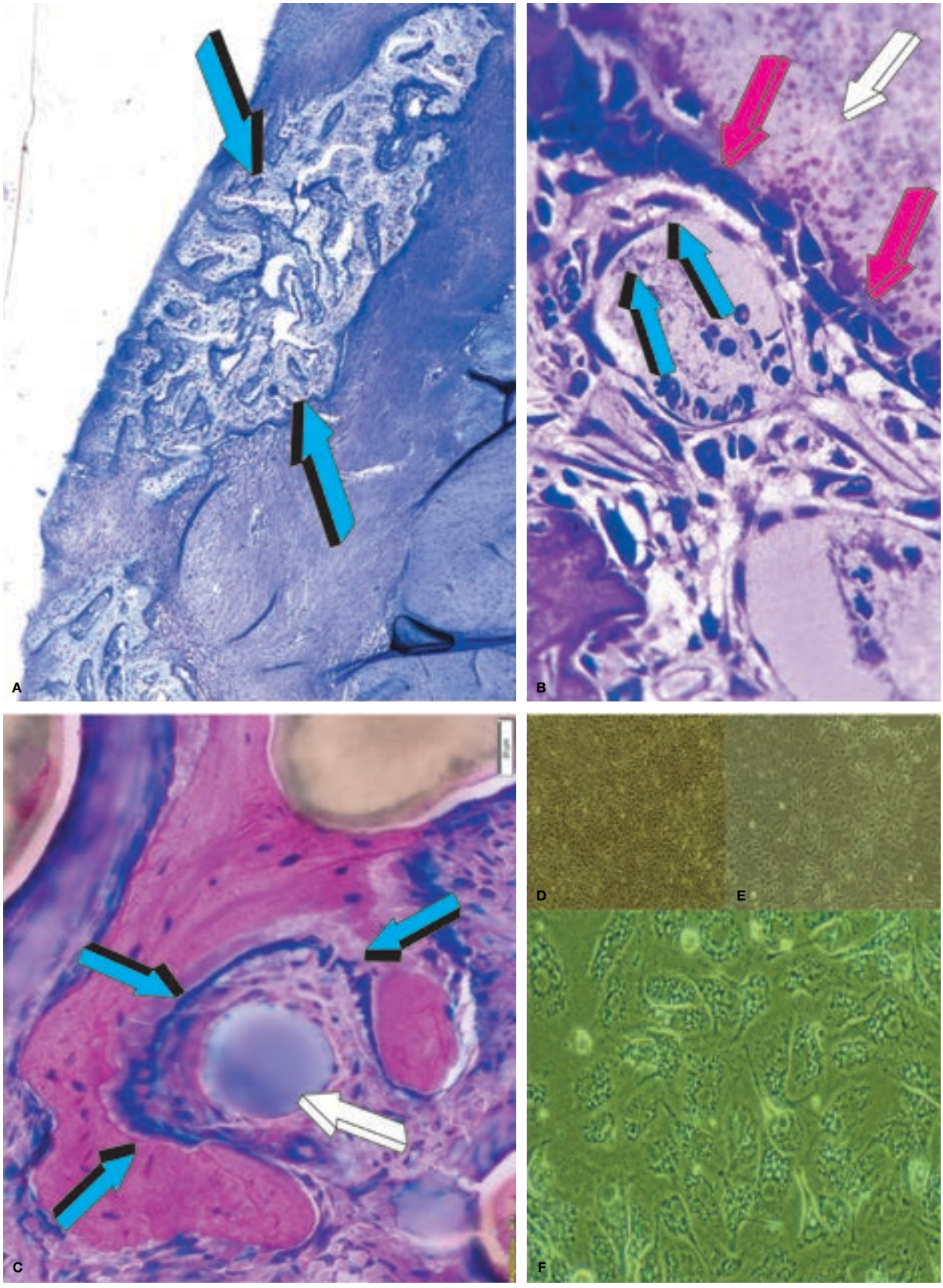
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Figure 1. Pleiotropic activity of morphogenetic soluble signals, inductive non-mineralized extra cellular matrices controlling uroepithelial osteogenesis[32,33] and osteogenesis in angiogenesis[27,28,45] with osteogenetic and morphogenetic vessels.
A. Experimental induction of uroepithelial osteogenesis (light blue arrows) after transplantation of the *rectus abdominis* fascia to surgically prepared full thickness defects in the dome of the bladder: induction of uroepithelial osteogenesis in the Chacma baboon *Papio ursinus*.
B. "Osteogenesis in angiogenesis":[27,28,45] capillary sprouting and invasion between rat insoluble collagenous bone matrix (white arrow) reconstituted with highly purified osteogenic fractions from baboon bone matrices.[27,45] Large nucleated endothelial cells (light blue arrows) moving from the vascular compartment (top right light blue arrow) towards the osteoblastic compartment (magenta arrows).
C. The role of the vessels in osteogenesis: morphogenetic and osteogenetic action of the central vessel (white arrow) surrounded by the prehensile plasticity movement of the newly formed bone populated by contiguous osteoblasts (light blue arrows). The central capillary morphogenizes the shape of the newly formed bone around the vessel, the "morphogenetic vessels" of Aristotle' definition.[31,34,36,37]
D-F. Phenotypic modulation of human aortic endothelial cells (E8) *in vitro* by highly purified naturally derived osteogenic fractions.[51]
D. E8 endothelial cells to confluence with cobblestone morphology.
E. E8 endothelial cells 48h after the addition of BMPs fractions at a concentration of 6 µg of protein per 300µl of medium showing a fibroblast-like phenotype.[51]
F. Rounding up, detachment and the acquisition of a spindle-like cell phenotype seen at 72h regardless of the protein concentration added.[51]

The above challenges were addressed in a series of systematic experiments in *P. ursinus* aimed to reveal whether there is a structure-activity profile amongst BMPs family members, and whether the presence of multiple isoforms may have a therapeutic significance.[4-19]

The aim of this review is to convey a perspective on the rapid induction of bone formation by the mammalian transforming growth factor-β_3 (TGF-β_3) isoform in *Papio ursinus*. As a prelude to the induction of periodontal tissue regeneration, the review begins by examining a number of classic experiments that, in our opinion, facilitated our current understanding of "Tissue induction"[20] and of "Bone: formation by autoinduction".[21] These seminal experiments helped to study the vast phenomena of tissue induction, morphogenesis, differentiation and de-differentiation, pleiotropy and redundancy. The multifaceted biological pathways highlighting the induction of bone formation are outlined below.

The review further translates the "operational reconsti tution" of the bone matrix[22-24] and the "Bone induction principle"[25] to periodontal tissue induction by the osteogenic proteins of the TGF-β supergene family.[26,27] Lastly, the manuscript reviews the molecular/morphological correlation of tissue induction and cementogenesis by the third mammalian TGF-β isoform presenting novel data on vascular canals embedded into regenerated cementoid by the hTGF-β isoform.

All the described experiments with the reported undecalcified histology sections were performed in the Chacma baboon *Papio ursinus*. Animals were housed in the Wits Research Animal Facility (WRAF), Faculty of Health Sciences, University of the Witwatersrand, Johannesburg.

Selection criteria, housing conditions and diet were as described.[2,4,9,28] For each different experiment, research protocols were approved by the Animal Ethics Screening Committee of the University. Experiments were conducted according to the Guidelines for the care and use of Experimental Animals prepared by the University complying with the Public Service Department National Code for Animal Use in Research, Education and Diagnosis in South Africa. Experiments were performed in consideration of the ARRIVE Guidelines.[29]

"Bone: formation by autoinduction"

"Bone: formation by autoinduction"[21] epitomizes the development of regenerative medicine's dreams and paradigms. It was first invoked by postulating the presence of "morphogenetic factors", defined by Turing as "forms generating substances".[30]

Molecular and morphological observations have generated the high expectation of a regenerative scenario of "molecularly generated tissues and organs in assembling human tissue factories".[31] Developmental molecular biologists, together with experimental surgeons and tissue biologists alike, are still dreaming of such "regenerative tissue and organ factories" to benefit the ageing human population, affected by debilitating disorders of tissue and organ failure together with all spectra of degenerative pathologies.[31]

Early research experiments pointed to the capacity of several extracellular matrices, including the uroepithelium (**Fig. 1A**),[32,33] to initiate inductive phenomena, paradigmatically set by the induction of bone formation.[27] These experiments highlighted the induction of bone together with angiogenesis and capillary sprouting (**Fig. 1B**), to the extent that authors speculated the presence and release of putative morphogens, or morphogenetic signals, endowed with the striking capacity to initiate the heterotopic induction of bone formation.[20-25]

Trueta stated,[34] "Angiogenesis is a prerequisite for osteogenesis" and highlighted the "role of the vessels in osteogenesis" (**Fig. 1B**). In 1763, von Haller indicated that the "vascular system is responsible for osteogenesis", further stating that endothelial cells are osteoblasts' precursors.[35] Much earlier, Aristotle associated sprouting blood vessels with a patterning function during organogenesis.[36,37] The patterning scenario envisioned by Aristotle's "morphogenetic vessels" highlights the vessels' capacity to act as a framework or "model" to shape the body structure (**Fig. 1C**). Recent work has expanded Aristotle's vision, providing evidence that endothelial cells are signalling centres secreting molecular signals in an angiocrine fashion to induce tissue morphogenesis.[38]

Senn[39] in 1889, used "decalcified bone, rendered not only completely aseptic, but thoroughly antiseptic by keeping it immersed for a considerable length of time in sublimate alcohol"[39] to repair trephined defects in canine calvariae. Senn observed postnatal bone regeneration in treated defects upon implantation of decalcified bone matrices.

New bone developed via embryonic tissue induction, i.e. new bone formed recapitulating embryonic development.[39] This recapitulation of embryonic development is pivotal to postnatal tissue induction, as we know it today: molecules exploited in embryonic development are re-exploited and re-deployed post-natally to initiate tissue induction and morphogenesis.[26,27,40]

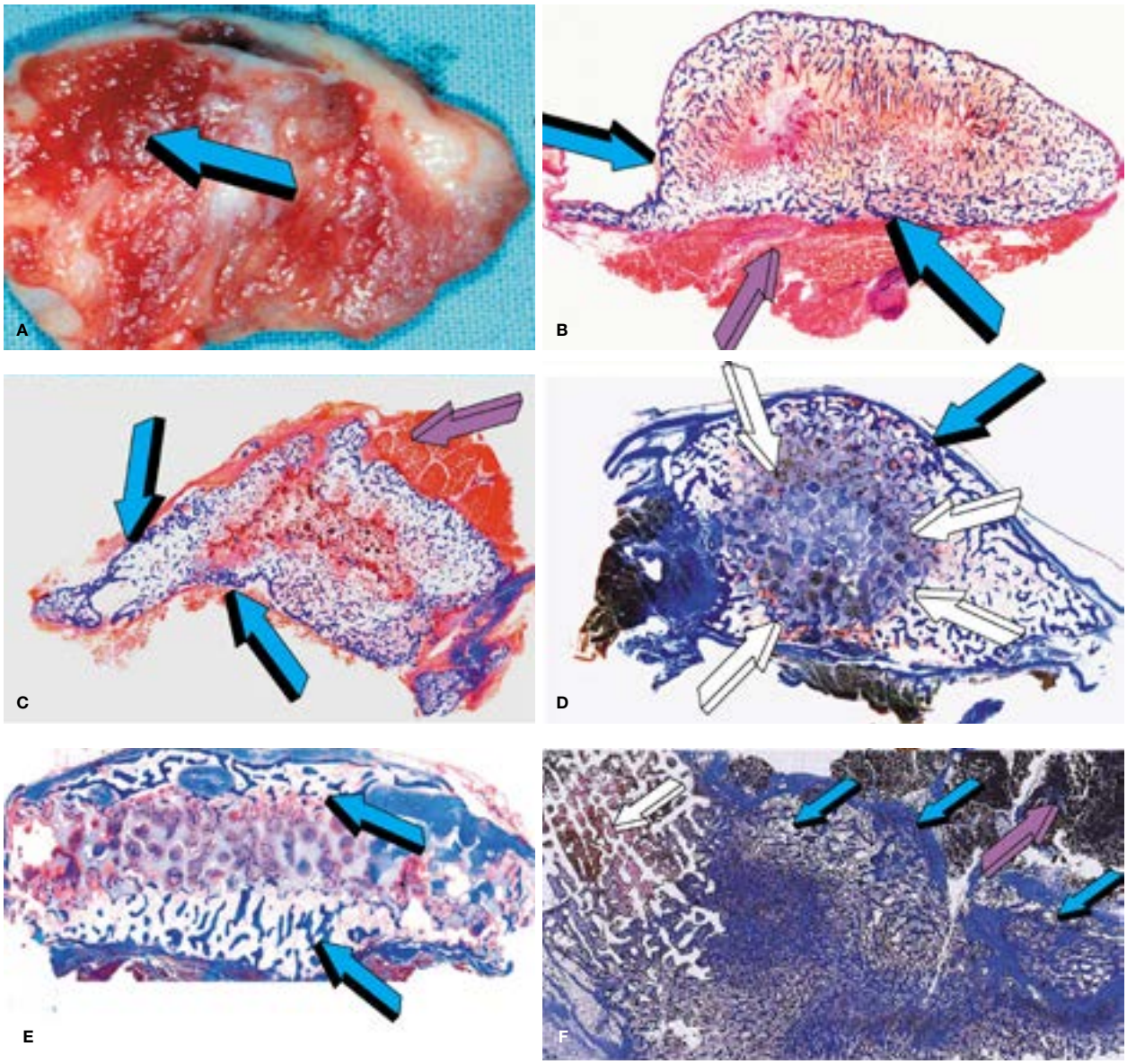
In a number of reviews on the induction of bone formation,[26-28,45] we have always credited the experiments and conclusions of several authors, particularly highlighting the innovative work of Levander and his School in Köping.[20,41,42] With a series of heterotopic experiments in lagomorphs, Levander shows an understanding of the basic mechanisms of the "bone induction principle",[25] showing that, upon implantation of devitalized alcohol extracted bone matrices, bone forms directly from the mesenchymal tissue surrounding the graft.[41,42]

Levander states that "this specifically bone forming substance is liberated from the bone tissue and is carried by the tissue lymph to the surrounding areas where it is able to activate the mesenchymal tissue in such a way that this becomes differentiated into bone tissue, either directly or by means of the embryonic pre-existing stage of bone and cartilaginous tissue".[41,42]

In 1958, Moss described how an osteogenic inductor was extracted from bone.[43] In his experiments, Gelfoam sponges incubated with bovine bone paste were implanted intracerebrally under parietal bone flaps in Long-Evans rats. Processed tissues showed extensive osteogenesis two weeks after implantation.[43] Moss hypothesised that the intracerebral osteogenic activity was because of "stimulation of pre-existent osteoblasts in calvarial implantation sites by some factor extracted from the bone paste".[43]

The concept of "putative factors, substances and/or morphogens", firstly described by Turing.[30] appears in the middle of last century epitomized by the innovative work of Levander and his team on alcohol-soluble osteogenic substance from bone.[41,42] Indeed long before Urist' paper in Science,[21] Levander postulated the presence of inductive substances within the solubilized matrix of bone.[41,42] This was crystallized in his 1945 Nature' paper "Tissue induction".[20]

The hypothesis of putative substances and/or morphogens that initiate tissue induction is a fundamental step ahead from several experimentalists poised to finally dissect the rules of tissue induction and morphogenesis. Amongst the firsts, Senn,[39] Sacerdotti and Frattin,[32] Huggins,[33] Levander,[20,41] Moss,[43] Urist,[21] and Reddi,[44] persevered to identify, purify and characterize the putative "osteogenic



activity" present within several extracellular matrices yet endowed with the striking prerogative of *de novo* initiating "Bone: formation by autoinduction".[21] The fascinating search for selected morphogens initiating the induction of bone formation allowed the discovery of an entirely new family of proteins initiators belonging to the transforming growth factor-β (TGF-β) supergene family.[26,27,40]

Vessels and capillary sprouting are morphogenetic (Fig. 1C) but, after the fundamental studies of Trueta,[34] are also "osteogenetic", i.e. capillaries that molecularly and morphologically regulate the induction of bone formation (Fig. 1B, C). The induction of bone formation is supported by an unlimited supply of responding perivascular pericytic and/or endothelial cells (Fig. 1B). Such "osteogenetic vessels" express alkaline phosphatase activity and their basement membrane components bind angiogenic and morphogenetic proteins to provide the conceptual framework for the supramolecular assembly of the induction of bone formation defined as "osteogenesis in angiogenesis".[26,27,45]

Levander describes heterotopic bone induction as being rich in capillaries with multiple cells clustering around the invading vessels.[20,41,42] In his experiments, Senn noted the importance of vascularised tissue in canine calvarial experiments and in clinical contexts.[39] He described postnatal tissue induction as a recapitulation of embryonic development, preceding by almost 50 years the statements of Levander that "Post-natal tissue induction recapitulates embryonic development" and "the same substances deployed in embryonic development are re-deployed in post-natal tissue induction".[20,41]

Figure 2. Rapid and substantial induction of bone formation by human recombinant transforming growth factor-β_3 (hTGF-β3) in the rectus abdominis muscle of the Chacma baboon *Papio ursinus*.
A-C. Induction of large heterotopic *rectus abdominis* corticalized ossicles on day 30 by 125μg hTGF-β3 delivered by insoluble collagenous bone matrix.
D, E. Generated constructs by 25μg hTGF-β_3 pre-combined with rods (D) and disks of biphasic hydroxyapatite/β-tricalcium phosphate (HA/β-TCP).
F. Prominent and substantial induction of bone formation by coral-derived macroporous constructs super activated by 250μg hTGF-β_3 and harvested 60 days after heterotopic *rectus abdominis* implantation[58,62].
B, C. Engineered ossicles display a maturational gradient of tissue induction, with corticalized mineralized areas enveloping trabeculae of mineralized bone covered by osteoid seams with scattered remnants of the collagenous matrix carrier.
D. HA/β-TCP construct super-activated by the hTGF-β_3 isoform displays substantial induction of bone formation away from the implanted construct (white arrows).
B, D. The genetic control of tissue induction and morphogenesis as initiated and maintained by the hTGF-β_3 isoform when delivered by substantially different carrier matrices results in the induction of replicable geometric ossicles within the *rectus abdominis* muscle.
E. Substantial induction of bone formation at the periphery of a HA/β-TCP macroporous disc super-activated by 25μg hTGF-β_3.[61,62]
F. Prominent induction of bone formation by 250μg hTGF-β_3 preloaded onto coral-derived macroporous bioreactors with lack of bone differentiation within the macroporous construct (white arrow) on day 60.[58,62] Explosive amounts of bone (light blue arrows) formed centimeters away from the implanted super-activated bioreactor (white arrow). hTGF-β_3 transduces a series of inductive and transforming molecular signals that are able to activate responding cells several millimeters away, surrounding the implanted bioreactor and transfiguring the enveloping *rectus abdominis* muscle (light blue arrows).
B, C. Undecalcified sections embedded in KPlast resin cut at 5μm stained free-floating with a modified Goldner's trichrome stain.
D, E. Exakt undecalcified sections cut, ground and polished between 27 and 37 μm using the Exakt AW 110 diamond cutting and grinding equipment stained with methylene blue basic fuchsin.
F. Decalcified paraffin embedded section cut at 6μm.

Vukicevic et al. reported the *in vitro* development of long inter-connecting processes that resemble the osteocyte's canalicular network seen in bone when osteoblast-like cells were cultured on basement membrane components, namely type IV collagen, laminin, entactin and nidogen in a reconstituted Matrigel® Matrix.[46] The authors further proposed that the osteocyte, a developmental stage of the osteoprogenitor-osteoblast lineage, retains a developmental 'memory' of the interaction between the osteoblast and components of the extracellular matrix of the invading capillaries, namely laminin and type IV collagen.[46]

This memory results in a ripple-like cascade of cell differentiation and the induction of bone formation.[46] Reddi's incisive work[46] has suggested that this "developmental memory" is re-activated by osteoprogenitors/osteoblastic cells reading laminin amino acid motifs across the basement' membrane components of the invading osteogenetic vessels[46] of Trueta' definition.[34] The invading capillaries provide a framework for the newly forming bone made from mesenchymal condensations around each patterning capillary (Fig. 1C), and provide the foundation for the differentiation of osteoblastic cells.[27,28,45]

The multiple differentiating capacities of the endothelium, with its associated perivascular or pericytic cells, highlight the pleiotropic capacities of endothelial cells. A recent communication revitalizes the "osteogenetic vessels" of Trueta' definition,[34] describing structurally distinct subsets of capillaries whose endothelial cells show specific expression profiles suggestive of specialised functional properties.[47] The capillary endothelial subset, termed H endothelial cells, mediate localised growth of the vasculature providing niche signals for perivascular osteoprogenitors.[47]

How endothelial and osteoblastic cells communicate still remains little understood.[47] The endothelial cell retains the plasticity of growth and differentiation with the capacity to de-differentiate into osteoprogenitors as well as a stem cell-like status for later rapid differentiation into both angiogenic and osteogenic phenotypes.[38,47-49] Notch signaling promotes endothelial cell proliferation, establishing angiocrine signals, which couple angiogenesis to osteogenesis with a further release of Noggin from endothelial cells, the former a selected antagonist of bone morphogenetic proteins' signaling.[50]

Two experiments seemingly very different yet both highlighting the plasticity of the endothelium to differentiate and de-differentiate[51,52] highlight such endothelial pleiotropic plasticity. Aortic endothelial (E8) cells, treated *in vitro* with highly purified naturally-derived BMPs fractions[51] showed prominent changes in the morphology of E8 cells (Figs. 1D, E, F). Identical concentration of BMPs fractions did not alter the cellular morphology of rat vascular smooth muscle cells (RVSMCs) over 24, 48 and 72 hours.[51]

E8 cells changed from a typical cobblestone appearance (Fig. 1D) to a spindle-shaped phenotype after 24 and 48 hours (Fig. 1E) with eventual rounding-up and detachment of cells by 72 hours (Figs. 1F). Reacquisition of the typical cobblestone appearance could be achieved by withdrawing BMPs fractions for more than 48 hours, provided the initial fractions did not exceed 6μg.[51]

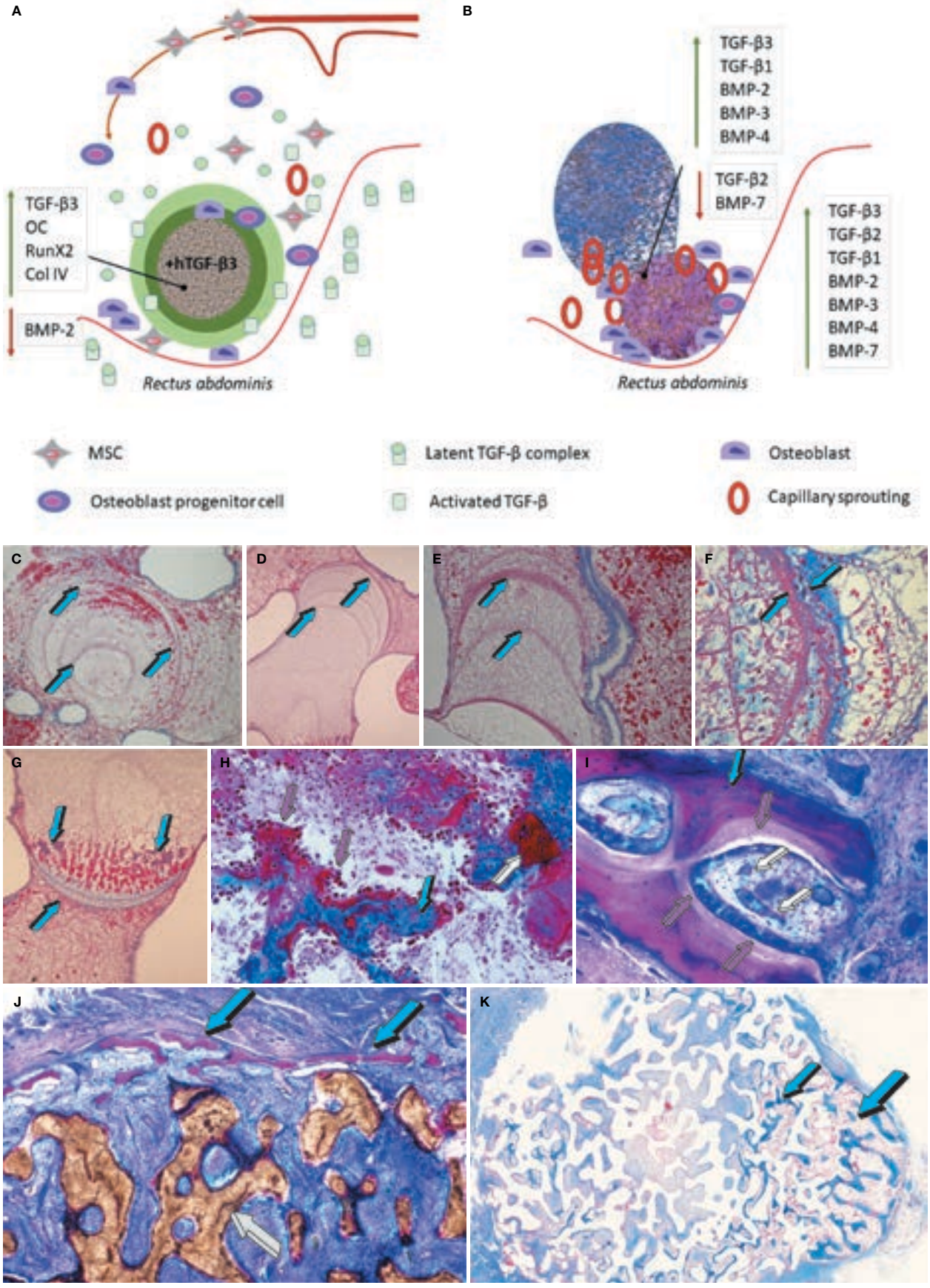

A
TGF-β3
OC
RunX2
Col IV
+hTGF-β3
BMP-2
Rectus abdominis
B
TGF-β3
TGF-β1
BMP-2
BMP-3
BMP-4
TGF-β2
BMP-7
TGF-β3
TGF-β2
TGF-β1
BMP-2
BMP-3
BMP-4
BMP-7
Rectus abdominis
MSC
Osteoblast progenitor cell
Latent TGF-β complex
Activated TGF-β
Osteoblast
Capillary sprouting
C
D
E
F
G
H
I
J
K

Figure 3. Molecular and morphological events of the induction of bone formation by coral-derived macroporous bioreactors combined with recombinant human transforming growth factor-β_3 (hTGF-β_3).
A. hTGF-β_3/treated coral derived macroporous bioreactors in the *rectus abdominis* muscle (red lines) of *Papio ursinus*. Heterotopic implantation of hTGF-β_3 causes a perturbation of the extracellular matrix (ECM) resulting in the activation of a pool of latent TGF-β. This, together with the exogenously implanted hTGF-β_3, recruits mesenchymal stem cells to the implantation site. Progenitor cells undergo osteoblastic differentiation and osteoblast synthesis and secretion. The responding micro environmental niche within the macroporous spaces becomes filled with an expanding network of fibrin/fibronectin.[58,61,62] The gene expression pattern at 15 days, reflected here, sees the prominent expression of type IV collagen, TGF-β_3 and the master transcriptional regulator RunX2.
B. After day 15, there is further recruitment of osteoblast progenitors and differentiation predominantly at the periphery of the implanted bioreactors. Extensive induction of bone is observed on days 30 (H), 60 (I, (J) and 90 (K), suggestive of the establishment of a gradient of TGF-β_3 activity extending into the responding micro environmental niche of the *rectus abdominis* striated muscle. (I, J) Preloading coral-derived macroporous constructs with 250µg hTGF-β_3 results in the rapid and substantial induction of bone formation by day 60.[61] Bone preferentially forms at the periphery of the macroporous bioreactors (J). Profiling of members of the TGF-β superfamily is indicated by upward green arrows (increased gene expression) and downward red arrows (decreased expression) relative to control devices and control muscle tissues.[58,61,63] The gene expression profiling shows the activation of BMPs family members in both the devices and surrounding muscle tissues. This indicates that the induction of bone formation by hTGF-β_3 occurs via the BMPs pathway.[55-58]
C-G. Differentiation and expansion of extracellular matrix fibrin-fibronectin rings[55,61-63].
F. Patterning with nesting of differentiating cells, de-differentiating somatic invading cells by the hTGF-β_3 preloaded onto coral-derived bioreactors harvested on day 15 after *rectus abdominis* implantation in the Chacma baboon *Papio ursinus*.[55,61-63]
C-G. Fibrinfibronectin rings expand within the macroporous spaces and, whilst expanding, provide the structural nests for the differentiation of entrapped cells within the matrix into osteo-blastic-like cells secreting early matrix against the established organized rings (light blue arrows F). The complex multifactorial image as shown in G (light blue arrows) is highly reminiscent of an embryonic growth plate, providing structural anchorage for transported somatic, and stem cells as osteoblastic precursors for rapid de-differentiation into highly secreting osteoblasts.[55,61-63]
H. Prominent hyper cellularity and osteoblastic activity with matrix synthesis on day 30 (H), 60 (I, J) (250µg hTGF-β_3), and 90 (K) after heterotopic implantation, with bone forming at the periphery of the implanted super-activated bioreactors (J, K). After removal of tissues for molecular analyses, harvested macroporous constructs on days 15, 30, 60 and 90 were processed for decalcified or undecalcified histology after fixation in 10% phosphate buffered formalin. Specimens were either decalcified in a Sakura TDE™ 30 decalcifying unit (Sakara Fintek, Torrance, USA) or later processed for paraffin wax embedding, or macroporous specimens were processed for methylmethacrylate embedding (Fluka, Sigma-Aldrich, Seelze, Germany). Undecalcified sections were processed by both heavy-duty microtomy with carbide-tungsten blades (SM-2500E Leica Microsystems, Bensheim, Germany) or cut by the Exakt diamond system (Exakt Advanced Technologies GmbH, Germany) cutting and grinding techniques.[55,61-63] Undecalcified sections were cut with carbide tungsten knives (H).
I, J. Exakt sections were cut, grounded and polished to 30µm using the Exakt 310 CP precision parallel cutting and AW 110 measuring control system.[55,64-66]
C-D, K. Decalcified sections cut at 4µm and stained by a modified Goldner's trichrome.[55,61,63]

The addition of highly purified osteogenic proteins fractions profoundly alters the endothelial phenotype (Fig. 1F), suggesting a critical role for bone matrix molecules in the phenotypic modulation of endothelial cells for the later induction of bone formation.[51] Leversha et al.[52] showed the capacity of glioblastoma (GBM) to generate stemness in tumour vasculature from putative cancer stem cells that comprise cell fractions capable of de-differentiation into endothelial progenitors.[52] This may explain mechanistically why GBMs are amongst the most aggressive of human cancers, able to induce stemness in malignant cells that subsequently de-differentiate into endothelial cells[52] providing nascent angiogenetic mechanisms for the survival and the rapid growth of the mother neoplasm.

The rapid induction of bone formation by htgf-β_3: morphological and molecular insights

Various delivery systems for soluble hTGF-β_3, applied singly or in binary synergistic application with osteogenic protein-1 (hOP-1/hBMP-7) were tested. These deliveries included allogeneic insoluble collagenous bone matrices (ICBM), calcium phosphate-based macroporous bioreactors, and Matrigel Matrix™.[9,11,16,19,53-58]

Histological analyses of hTGF-β_3 combined with insoluble collagenous bone matrix[11] showed rapid induction of heterotopically generated ossicles (Fig. 2A) with substantial corticalization of the newly formed mineralized bone (Figs. 2B, C). Newly formed cortices enveloped collagenous matrix remnants with limited, if any, vascular and cellular invasion, creating "tissue voids" within the central parts of the newly generated heterotopic constructs (Figs. 2B, C). Heterotopic ossicles are similar to the ossicles generated by synergistically combining hOP-1 with low doses of hTGF-β1[54] or hTGF-β_3.[16,53]

With the evolution of more complex multicellular organisms, comes the need to establish an intricate system for cellular communication and control via signaling pathways such as the transforming growth factor-β (TGF-β) supergene family.[24,26,27,59] Insights into the molecular mechanisms underlying TGF-β signaling have been garnered in organisms such as *Drosophila melanogaster*, *Xenopus laevis*[60] and *Papio ursinus*:[9-11,54-58] In the latter experiments, we studied how the TGF-β isoforms transduce signals in mammals and how they drive the induction of bone formation in primate species,[16,54,55,58,61,63] including the synergistic induction of bone formation when combining limited doses of either hTGF-β1 or hTGF-β3 with set doses of hOP-1/hBMP-7.[16,53-58]

Many TGF-β activators have been identified.[64-69] To transduce their signal, the TGF-β ligands activate two classes of receptors[64] such that the pleiotropic diversity in signaling by TGF-β is achieved by various combination of ligand-receptor and receptor type coupling.[64-69] Osteoblast differentiation by the TGF-β superfamily is dependent on both the classical Smad pathway and Smad independent pathways.[64-69] In Smad signaling, Smad complexes accumulate in the nucleus through the action of transcriptional regulators that direct coupling of the complexes to TGF-β responsive promoters.[67]

A variety of transcriptional factor partners have been identified, and the transcriptional repertoire is finely tuned by the recruitment of co-activator or co-repressor proteins.[67,70] Non-canonical Smad pathways include the ERK-MAP kinase (MAPK), JNK and p38 pathway.[67,69,71] The p38 and Smad pathways converge to control RunX2 expression and osteoblast progenitor cell differentiation.[70] TGF-βs act as pro-migratory factors to mobilize and recruit stem cells from the surrounding tissue, which may also include peripheral blood.[72] Multipotent mesenchymal stem cells (MSCs) are found in a variety of adult tissues, including muscle tissue and the periodontal ligament system.[73,74] TGF-β_1 stimulates MSCs proliferation through the Smad3 pathway causing the accumulation of β-catenin in the nucleus of responsive cells, thereby effecting gene expression profiles.[75]

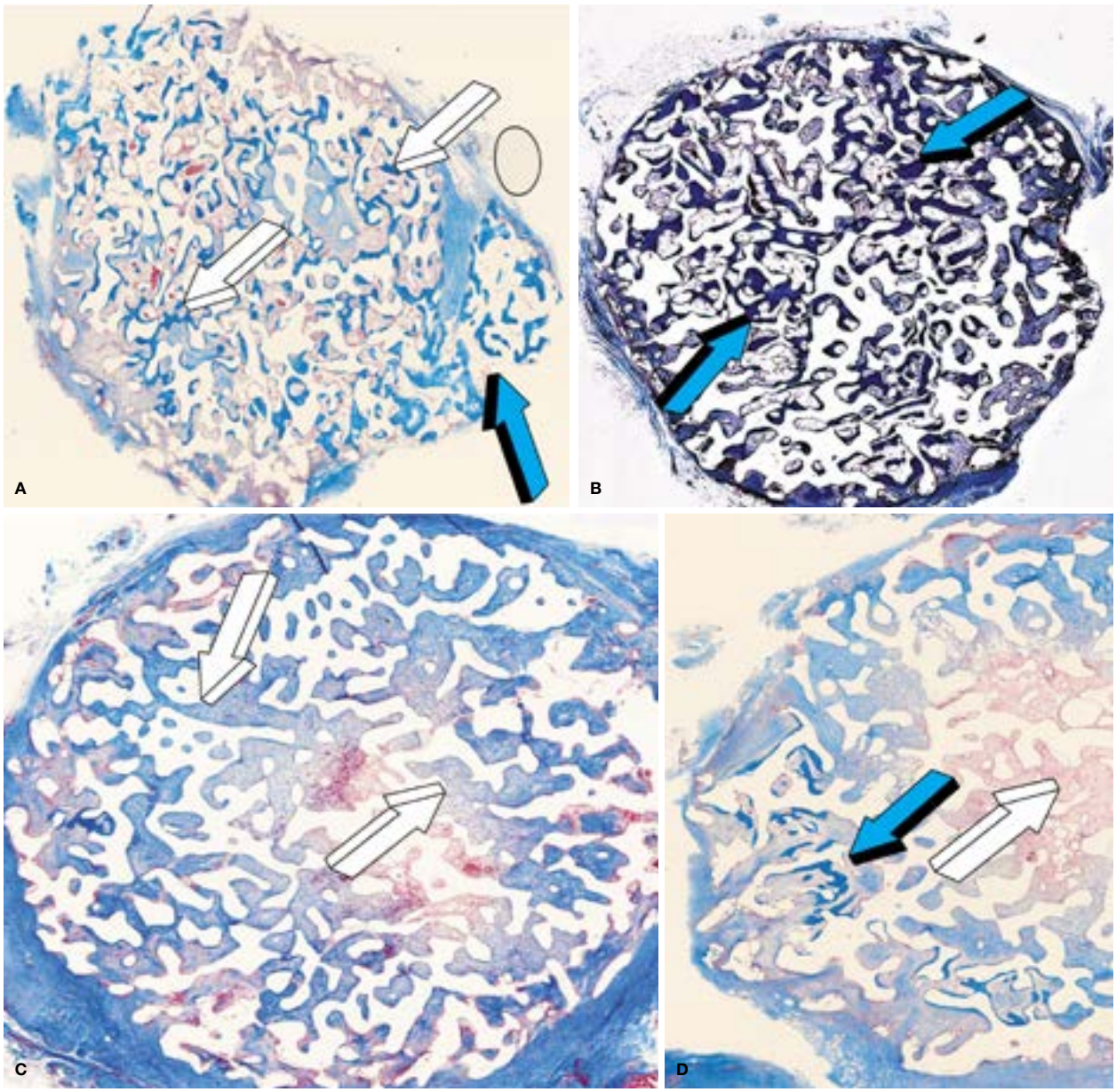


Figure 4. Mechanistic insights of the induction of bone formation by recombinant human transforming growth factor-β_3 (hTGF-β_3) when recombined with coral-derived macroporous bioreactors implanted in the *rectus abdominis* muscle of *Papio ursinus*.
A. Rapid induction of bone formation at the periphery of the 125µg hTGF-β_3 super-activated bioreactors (light blue arrow) harvested on day 90 with induction of bone across the macroporous surfaces (white arrows).
B. Substantial bone induction across the macroporous spaces (light blue arrow).
C, D. Lack of bone formation (white arrows) when acroporous bioreactors are preloaded with binary applications of 125 µg hTGF-β_3 and 125µg human Noggin. The lack of bone induction by coral-derived macroporous constructs highlights the critical role of BMPs in initiating the induction of bone formation.[55,58,61,63]
D. The spontaneous induction of bone formation by macro-porous coral-derived bioreactors[26,27] (light blue arrow) is abolished by 125µg hNoggin preloaded onto the macroporous construct (**D**), blocking the induction of bone formation (white arrows). **A, B, C** and **D**, Decalcified paraffin embedded section cut at 6 µm.

Incisive studies have shown the peri-vascular origin of mesenchymal stem cells (MSCs),[76] and reported that the MSCs found in several tissues and organs including the periodontal ligament system, are indeed pericytes.[76] The authors concluded that the vascular walls harbor progenitor stem cells representing the peri-vascular or pericytic origin of all MSCs.[76]

Wang et al.[77] showed that type IV collagens are important in establishing the Dpp dorsal-ventral gradient in Drosophila by supporting the assembly of Dpp complexes. This insight from Drosophila wing development patterning together with the observation of a marked increase in type IV collagen in generated ossicles by hTGF-β_3 in *Papio ursinus*[61] hints to the critical role that the extracellular matrix components play in establishing the pattern of activity required to induce bone by hTGF-β_3/treated macroporous bioreactors.

Until 1993, the prerogative of the induction of bone formation was assigned to the BMPs only.[78] Research in the fruit fly *Drosophila melanogaster* showed high levels of homology between Decapentaplegic (dpp) and 60A genes with BMP-2 and BMP-4, and BMP-5 and BMP-6, respectively.[27,78] This has suggested the primordial role of BMPs during the emergence and development of vertebrates.[27,40]

This common developmental role was shown by the capacity of recombinant dpp and 60A proteins to induce endochondral bone formation in heterotopic subcutaneous sites of the rat.[79] Thus, a phylogenetically ancient signaling pathway deployed for dorso-ventral patterning in Drosophila, is also operational for the induction of bone formation in mammals.

The most appealing knowledge one can gather from the above findings is that Nature relies on common yet limited molecular mechanisms to provide the emergence of specialized tissue and organs, demonstrating evolutionary conservation of related proteins from phylogenetically distant species. Nature has usurped genes of the fruit fly operational for more than 800 million years to generate, with minor modifications of the amino acid sequence motif of the carboxy-terminal domain, the bone morpho genetic proteins, the induction of bone formation, skeletogenesis and with it, the emergence of the vertebrates and of the Homo clade.[1]

Both 125µg and 250µg hTGF-β_3 induce large heterotopic ossicles with bone initiating at the periphery of the calcium phosphate-based macroporous bioreactors (**Figs. 2D, E, F; 3A; Figs. 4J, K**).[55,61-63] This occurs with the concomitant expression of members of the TGF-β superfamily, viz BMP-2, BMP-3, BMP-4, TGF-β_1, TGF-β_3 and BMP-7, with however down-regulation of TGF-β_2 (**Figs. 3A, B**).[55,61-63] A schematic of this proposed mechanism is shown in **Figure 3**.

The change in expression profile complements newly formed bone deposited by osteoblastic activity and osteoid synthesis (**Fig. 3H**). The newly formed bone shows prominent capillary sprouting and angiogenesis (**Figs. 3H, I**), the latter being marked by the increased expression of type IV collagen.[61-63] Type IV collagen shows a significantly increased relative expression 15 days post implantation of hTGF-β_3 treated coral-derived macroporous bioreactors (**Figs. 3A, B**).[55,61-63]

At the molecular level, hTGF-β_3 treated macroporous bioreactors induce bone by activating the BMPs pathway (**Figs. 3A, B**). Evidence of the BMPs expression pathway was shown in experiments where the inhibitory activity of the BMPs' antagonist Noggin was employed (**Fig. 4**).[55,61-63] Hydroxyapatite coral derived macroporous bioreactors were loaded with binary applications of human recombinant Noggin (125 or 150µg).[53,55,61-63] and 125µg hTGF-β_3, implanted into the *rectus abdominis* muscle of adult baboons and assayed for changes in gene expression patterns at 15, 60 and 90 days after implantation.[55,61,62] The data correlated with bone formation by induction. Macroporous bioreactors treated with binary application of hTGF -β_3 and hNoggin had limited bone formation (**Figs. 4C, D**) with down-regulation of BMP2 and TGF-β_3 genes.[55,61]

The use of recombinant human Noggin (hNoggin) preloaded onto coral-derived macroporous constructs was also instrumental to mechanistically resolve the "spontaneous and/or intrinsic" induction of bone formation by coral-derived macroporous constructs when implanted in heterotopic sites of the *rectus abdominis* muscle of *Papio ursinus*.[27,28,62] Preloading macroporous constructs with 125 or 150µg hNoggin blocks the induction of bone differentiation.[55,61] This has indicated that the spontaneous induction of bone formation by coral-derived macroporous constructs is via the BMPs pathway, since Noggin blocks the biological activity of the secreted and embedded proteins onto the substratum.[55,61-63]

Morphological analyses of tissues penetrating the macroporous spaces of TGF-β_3-treated devices 15 days after implantation, show a microenvironment enriched with progenitor cells embedded into fibrin/fibronectin rings expanding into the macroporous spaces organizing tissue patterning and morphogenesis (**Figs. 3C, D, F, G**).[55,61-63] The induction of fibrin-fibronectin rings is an early morphogenetic event signaling the differentiation of somatic invading cells into osteoblastic cell lines attached to and regulated by the developing extracellular matrix components.[55,61,62] Extracellular matrix rings serve to structurally reorganize invading, migrating and differentiating mesenchymal stem and somatic cells from the surrounding tissues to undergo differentiation and de-differentiation into osteoblasts,[55,61,62] highlighting the importance of the "micro-environmental niche" in defining cell fate.[53,58,63]

Expanding extracellular matrix rings serve as anchorage for hyperchromatic cells interpreted as differentiating osteoblasts re-programmed by hTGF-β_3 previously adsorbed onto the macroporous bioreactors from invading pericytic, perivascular myoblastic differentiated somatic cells (**Fig. 3F** blue arrows). RunX2 and Osteocalcin expression is significantly up regulated in hTGF-β_3 super-activated bioreactors on day 15 supporting the morphological observation of invading cells differentiating into the osteoblastic phenotype with hyper-cellular osteoblastic activity and extracellular matrix secretion (**Figs. 3H, I**).

The importance of the microenvironment was highlighted by profiling the expression of TGF-β superfamily genes in the *rectus abdominis* striated muscle surrounding and enveloping the implanted macroporous bioreactors. Relative gene expression changes in TGF-β_1, -β_2 and -β_3 and BMP-2, BMP-3, BMP-4, BMP-6 and BMP-7 were assessed by quantitative Real Time PCR (qRT-PCR).

Sixty days after heterotopic implantation of hTGF-β_3-treated bioreactors, there was increased relative expression of BMP-2, BMP-3 and BMP-4 with BMP-3 exhibiting the greatest change in expression, while BMP-6 expression was unchanged (**Fig. 4B**).[55,61] Of interest, was the effect of the hTGF-β_3 treatment in the surrounding muscle tissue, which showed an increase in BMP-3 and BMP-7 although BMP-7 expression was decreased in the device when compared to untreated devices and control tissues.[55,61]

Data from these experiments also revealed the differential expression of the TGF-β genes in response to implantation of hTGF-β_3 treated bioreactors. There was an increase in TGF-β_1 and -β_3 expression in both the device and muscle tissue relative to the control tissue and untreated control samples.[53,61-63] TGF-β_2 expression decreased however in the treated devices but increased in the surrounding muscle tissue (**Fig. 3B**).

Morphologically there was extensive induction of bone formation by the 250µg hTGF-β_3 treated devices with bone

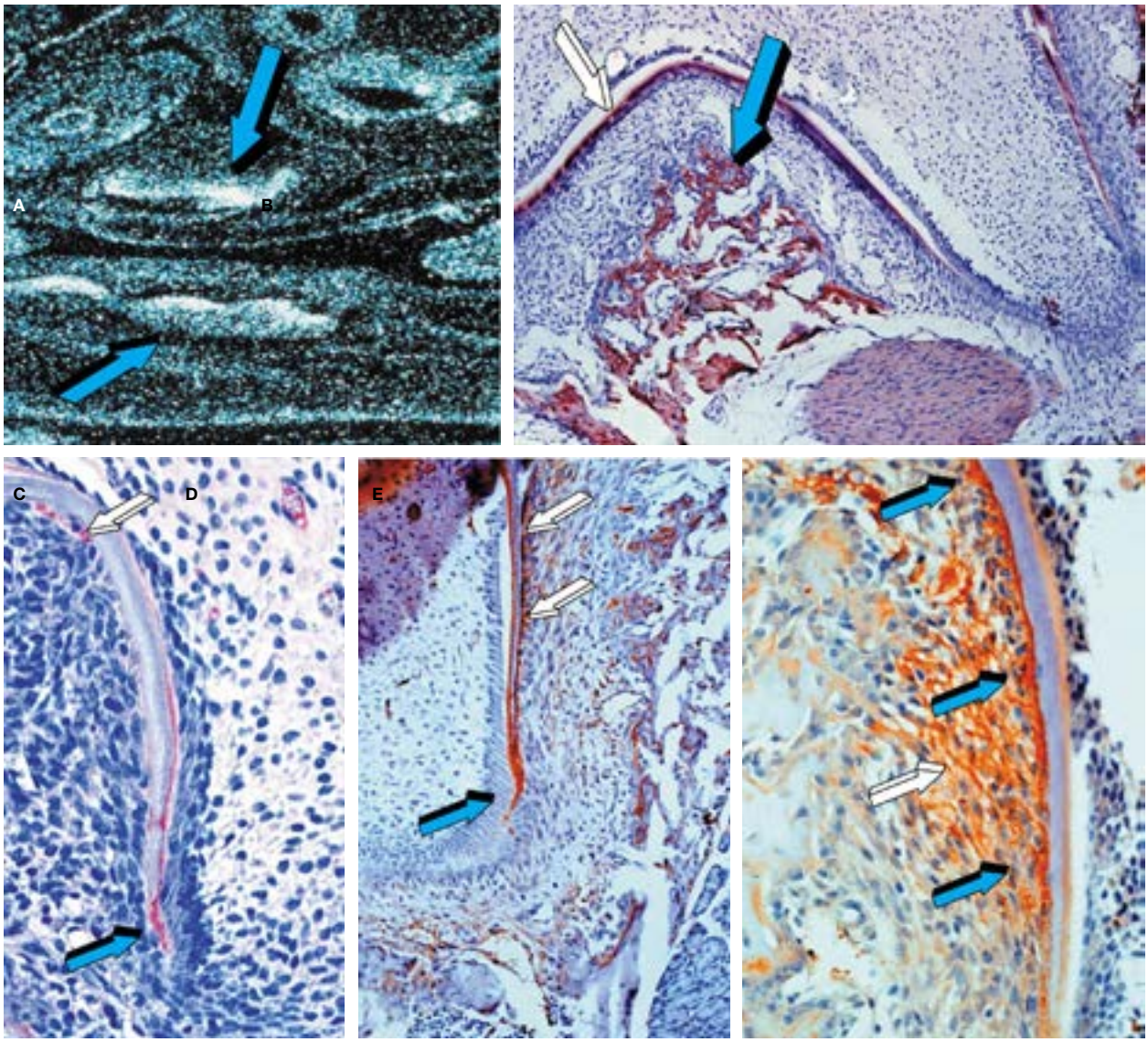


Figure 5. Pleiotropy and structure/activity profile of bone morphogenetic proteins during embryonic development as evidenced by *in situ* hybridization and immunolocalization studies during murine tooth morphogenesis. **A.** *In situ* hybridization of the murine cranio-mandibulo-facial complex with osteogenic protein-1 (OP-1, BMP-7) expression in the dental epithelium and dental mesenchyme of the developing murine molars (blue arrows). OP-1 appears first in dental epithelium in the cap stage and preodontoblasts and papilla cells in later stages of cell differentiation.[1,7,92] **B.** Immunolocalization of BMP-2: furcation area of mandibular molar tooth of a 16-d-old mouse pup. BMP-2 in alveolar bone (light blue arrow) and predentine (white arrow).[7] Lack of staining in cementum and periodontal ligament. **C.** developing furcation and maxillary molar root of 16-d-old mouse pup. OP-1 immunostaining in newly deposited cementum in the furcation (white arrow). OP-1 strong signal in predentine and mantle dentine (light blue arrow)[7]. **D.** Developing root of mandibular molar of a 16-d-old mouse pup: marked OP-1 immunolocalization in cementoblasts initiating cementogenesis (white arrows) along the developing rooth surface with strong signal in predentine and mantle dentine (light blue arrow).[7] **E.** Morphogenesis of the periodontal ligament system in a 8-d-old pup with expression of OP-1 during the assembly and tissue patterning of the periodontal ligament system (white arrow) with the induction of cementogenesis tightly attached to forming dentine (light blue arrows).[7]

forming at the periphery of the bioreactors only (Figs. 2D, E, F). Newly formed bone extendeding 3-4 cm from the profile of the implanted super activated macroporous bioreactors (Fig. 2F). Limited, if any, bone formed within the macroporous spaces of the implanted bioreactors (Figs. 2D,E,F).

The inductive capacities of the mammalian tgf-β isoforms in preclinical contexts

Morphological and molecular data have shown that in different animal models including rodents, lagomorphs, canines and pigs, heterotopic implantation of the three mammalian TGF-β isoforms does not result in bone differentiation by induction.[11,26,27,79] Klar et al.[55] suggested that the "molecular redundancy" associated with "different molecular functions in primate tissues represents fine tuning of speciation-related molecular evolution in anthropoid apes at the early Pliocene boundary which resulted in a more capable tuning of the bone induction cascade in primate species".[55]

Following identification of the first TGF-β_1 isoform in human platelets,[80] several reports proposed, but did not show, that the transforming growth factor-β proteins might possess inductive activities as well as bone forming capacities.[81-84] In an *in vivo* model in neonatal rats, injection of either hTGF-β_1 or -β_2 directly into the periostea of the parietal bones resulted in a 2-fold increase in bone thickness in a dose-dependent manner.[83] Further studies by

Sporn and colleagues proposed that the TGF-β was an "initiator" of chondrogenesis and osteogenesis in the rat femur.[84]

Initiators, or inducers, of bone formation are different from factors that may promote and/or maintain tissue induction cascades. An osteoinductive protein must be capable "of initiating endochondral bone formation in heterotopic extraskeletal sites of animal models".[11,21,22] Heterotopic sites avoid "the ambiguities of the orthotopic site where some degree of bone formation by conduction may occur from the viable bone interfaces".[21] Direct injection of morphogens isolated from naturally derived bone matrix or platelet extracts, interact with developed cellular populations and differentiating progenitors in the subperiosteal regions of either calvariae or long bones that are amenable to the rapid promotion of bone formation.[83,84]

The molecular cloning of the osteogenic proteins of the TGF-β supergene family[26] and the results of numerous preclinical studies in mammals including non-human primates have prematurely convinced molecular biologists, tissue engineers and skeletal reconstructionists alike to believe that a single recombinant hBMP would result in clinically acceptable tissue induction and morphogenesis in human patients. This theoretical potential has not been translated to acceptable results in clinical contexts.

Clinical trials in craniofacial and orthopedic applications such as mandibular reconstructions, sinus-lift operations and tibial non-union have indicated that supra-physiological doses of a single recombinant human protein are needed to induce often-unacceptable tissue regeneration whilst incurring significant costs without achieving equivalence to autogenous bone grafts.[27,28,45,62]

A recent study finally reported that supra-physiological doses of hBMP-2 were required to induce often clinically insufficient bone in clinical contexts, and recognized potential local and systemic adverse effects.[85] A proposed BMP/activin A chimera was formulated with superior activity to native BMPs, i.e. protein fractions extracted and purified from animal bone matrices,[85] in inducing bone in non-human primates with reduced doses compared to the BMP-2/absorbable collagen sponge previously approved for clinical use.[85] The recombinant chimera needs now to pass through clinical trials prior to seeking FDA approval.

A series of systematic studies in the non-human primate *Papio ursinus* showed that the hTGF-β_3 isoform is the most powerful soluble osteogenic molecular signal of the TGF-β supergene family so far tested in primates.[11,55,58,61,63] The robust induction of bone formation by hTGF-β_3 when pre-combined with inactive insoluble bone matrix[11] or coral-derived macroporous bioreactors[55,61] has required the re-evaluation of the induction of bone formation in primate models.[18,62]

The use of insoluble collagenous bone matrix as carrier results in the rapid induction of bone formation (**Fig. 2A**) with corticalization of newly formed ossicles as early as 30 and 90 days after heterotopic implantation with explosive growth at the periphery of the implanted specimens (**Figs. 2B,C**).[11] This explosive peripheral pattern is also seen when hTGF-β_3 is combined with macroporous calcium phosphate-based bioreactors (**Figs. 2D, E**), transfiguring the surrounding *rectus abdominis* muscle (**Fig. 2F**).[58]

The biological rationale for this explosive growth, supported by qRT-PCR data, is that the super-activated bioreactors rapidly transform progenitor cells of the *rectus abdominis* muscle via gradient activities enveloping the implanted bioreactors as initiated by the recombinant morphogen (**Figs. 2D, E, F, 3A, 4J, K**).[53-58]

Additional systematic experiments in the rectus abdominis heterotopic intramuscular sites of *Papio ursinus* have shown that the induction of bone by hTGF-β_3 applied singly is equal if not greater when compared to hetero topic ossicles generated by the synergistic induction of bone formation with binary applications of hOP-1/hBMP-7 with relatively low doses of hTGF-β_1 and -β_3.[16,53,54]

Because of the pleiotropic biological activity of the recombinant hTGF-β_3 in different orthotopic and heterotopic sites for craniofacial reconstruction,[58] experimentation to transfigure neoplastic carcinomatous masses was deemed a necessary experiment. This also followed the evidence of tissue transfiguration of the striated *rectus abdominis* muscle after heterotopic intramuscular implantation of 250 µg hTGF-β_3 combined with either collagenous matrices or coral-derived macroporous bioreactor.[58,62]

Bioptic material from harvested human squamous cell carcinomas (hSCCs) were transported in sterile medium to the laminar flow unit of the Central Animal Services (CAS) of the University Faculty of Health Sciences. Human and animal ethics clearances were obtained from the University (Human Research Ethics Committee Clearance certificate No. M150608). Fragments of 3 to 5mm in size were transplanted bilaterally under skin of the chest; bilateral pouches were created with sharp and blunt instruments to accommodate the transplanted hSCCs human biopsies' fragments.[86]

hSCCs grew within to three weeks to reasonable sizes. Tumors growth was palpated and when to sizeable sizes, nude mice under anesthesia were palpated in the thoracic area and approximately 300 to 500µl of Matrigel®Matrix with 250µg hTGF-β_3 were injected into the right neoplastic masses. In a number of mice, masses sustained multiple injections up to three injections of Matrigel®Matrix with 250µg hTGF-β_3 before euthanasia and tissue harvest.

Histological examination of resin-embedded sections of hTGF-β_3 injected hSCCs transplanted under the skin of the chest, showed a reproducible recurrent histological pattern of undifferentiated anaplastic growth at the periphery of the transplanted SCC biopsies vs. a different yet reproducible pattern of a highly differentiated oncotype in the center of the transplanted and harvested specimens.[86]

This oncotype and pattern' variations are of great significance. The morphological data show reproducible patterns of growth spatio/temporally distributed, i.e. poorly differentiated up to anaplastic SCCs at the periphery of the transplanted biopsies vs. more differentiated with keratinized oncotype in the center of the injected growing carcinomas, thus less malignant and more differentiated

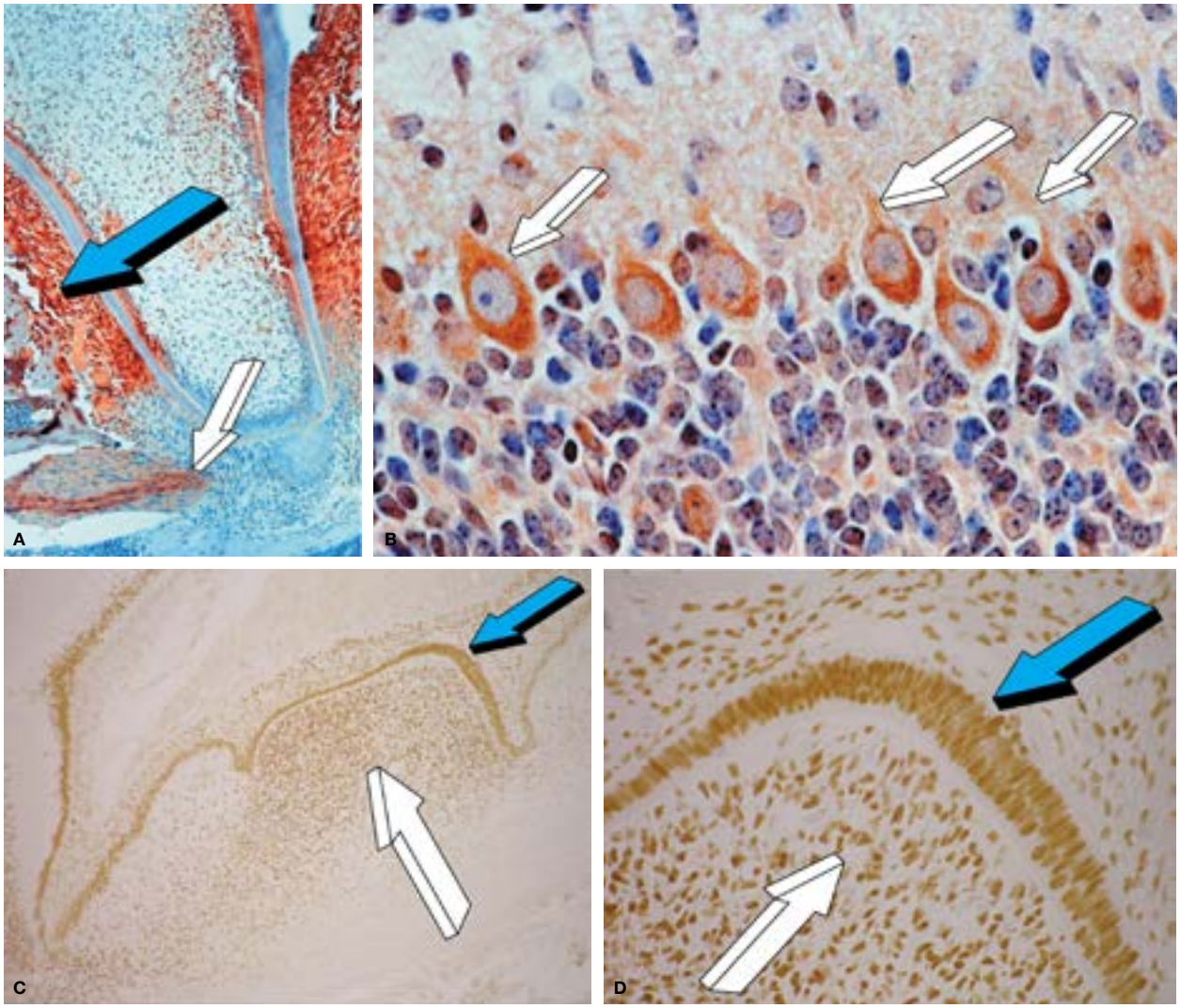


Figure 6. Apparent redundancy of molecular signals initiating the induction of bone formation and pleiotropic multifunctional activities of members of the transforming growth factor-β_3 beyond "Bone: formation by auto-induction".[21]
A. Immunolocalization of BMP-3 during tooth morphogenesis of a 13-d-old mouse pup with signals in alveolar bone, periodontal ligament, cementum (light blue arrows), predentine and the odontoblasts' layer. Strong signal in the inferior alveolar nerve (white arrow).[7]
B. BMP-3 immunolocalization in the cytoplasm of cerebellar Purkinjie cells also highlighting the neurite axons (white arrows).[7]
C. immunolocalization of transforming growth factor-β_3 (TGF-β_3) of the folding of the continuously erupting dental lamina of the dusky shark *Carcharinus obscurus*.[1]
D. TGF-β_3 immunolocalization along the folding of the selachians' dental lamina (light blue arrow) with immunolocalization of mesenchymal cells below the immunolocalized dental lamina (white arrows) highlighting me senchymal cells developing the papilla of the selachian's' endodontic space.[1]

oncotype in the center following injections of doses of hTGF-β_3 in the center of the neoplastic masses using the Matrigel®Matrix delivery system.[86]

Histological examination of transplanted and injected SCCs showed that hTGF-β_3 injections into hSCCs induced an oncotype characterized by a shift into highly differentiated oncotypes with multiple pearls of keratinization, with less neoplastic undifferentiated cells. Injected hTGF-β_3 vs. non-injected hSCCs showed a remarkable reproducible onco-type variation from poorly anaplastic undifferentiated to highly differentiated and keratinized oncotypes after hTGF-β_3 injections in Matrigel®Matrix.[86]

As a final mechanistic note, the powerful transfiguration patterns as seen within the center of the hTGF-β_3 injected hSCCs heterotopically growing and expanding subcutaneously in athymic nude mice show that the injected soluble molecular signal in Matrigel®Matrix activates the cellular memory of the transplanted carcinomas. Cancers survive by recapitulating mechanisms of the normal development. The injections of relatively high doses of hTGF-β_3 in Matrigel®Matrix re-introduced a memory of developmental events already known to the affected cells, bringing back affected cells to their initial non-neoplastic and keratinized status.[86] The transfiguration mechanism(s) by hTGF-β_3 in Matrigel®Matrix set into motion gene expression pathways bringing neoplastic cells back to their initial stage with keratinized pearls of a highly differentiated oncotype. Collectively, that available data show that hTGF-β_3 locally initiate tissue transfiguration *in vivo* yielding highly differentiated oncotypes.[86]

In studies using isolated transitional epithelial fetal baboon bladder cells cultured on Matrigel Matrix™, we reported the generation of three-dimensional constructs of transitional epithelial cells with branching morphogenesis and lobulation of replicating transitional epithelial cells, which

we defined as spheroidal organoids.[87] Organoids are three-dimensional constructs composed of multiple cell types that originate from stem cells by mean of self-organization capable of simulating the architecture and functionality of native organs.[88]

The induction of a three-dimensional *in vivo* culture system combining the morphogenetic soluble signal of the recombinant hTGF-β_3 with a coral-derived macroporous bioreactor, morphogenizes the rapid induction of *de novo* bone organoids within the *rectus abdominis* muscle of *Papio ursinus*.

These *in vivo* multicellular organoids of mineralized bone, with osteoid and rapidly expanding marrow cavities, show regional anatomical and molecular identities organized as discrete domains temporo-spatially separated by morphogenetic gradients.[58,61-63] Organoids form by recruiting peripheral stem and/or somatic cells and de-differentiating myoblastic, pericytic and perivascular somatic cells into newly differentiated osteoblasts that induce rapid bone formation.[61-63] Molecular gene expression analyses directly correlate with the anatomical morphological domains, showing a ripple-like cascade of changes in gene expression at the periphery of the intramuscularly implanted bioreactors (Fig. 3).[61-63] The implanted bioreactors per se, particularly at early time points, show limited cellular invasion within the macroporous spaces with minimal, if any, up regulation of morphogenetic genes.[58,61-63]

Whilst the paper of Alliston and Derynk[89] misses to report the evidence of the induction of bone formation by the mammalian TGF-β isoforms,[11,26,54,90] it shows that TGF-β "is a key regulator of the mechanical properties and composition of the bone matrix".[89] Our studies in the Chacmababoon *Papio ursinus* show the spatio/temporal distribution of gene expression pathways across boundaries of the *in vivo* generated organoids. Anatomical morphological boundaries are the muscular pouches and the linea alba of the *rectus abdominis* muscle, and particularly so, the macroporous configuration of the super activated bioreactors set by the exoskeleton of the coral-derived constructs. Our systematic studies have shown how TGF-β_3 controls the developmental cascade of the induction of bone formation in primates.[53-58,61-63]

The research work from laboratory' benches to pre-clinical studies in *Papio ursinus* has been translated to a long term follow-up of pediatric patients following reconstruction of massive mandibular defects with recombinant hTGF-β_3.[91] Ongoing experiments profiling additional pathways acting in concert with the master regulator TGF-β_3 will yield important information on the complexities underlying the induction of bone formation by hTGF-β_3 in the Chacma baboon *Papio ursinus* with relevance to man.

How can this wealth of knowledge be applied to periodontal tissue regeneration, and to the induction of cementogenesis with *de novo* insertion of Sharpey's fibers, the essential ingredients to engineer new attachment formation?

Cementogenesis by htgf-β_3 and homologous morphogens of the superfamily

The operational reconstitution of a soluble signal with an insoluble signal or substratum[22,23,27,28,40] enabled the identification of soluble osteogenic molecular signals within the bone matrix. It has resolved the biological background of the osteogenetic capacity of the bone matrix.[22-24]

The dissociative extraction and reconstitution of a soluble signal with an insoluble signal or substratum restored the biological activity of the chaotropically extracted de-mineralized bone matrix.[22-23] This operational reconstitution additionally defined the heterotopic bioassay,[22,23,26-28,40] and the bases for translational research of the "Bone induction principle"[25] to pre-clinical and clinical contexts.[27,28,40,45,91]

How the foreground review on the molecular and biological activity of the hTGF-β_3 isoform can be applied, modified and tuned to achieve the induction of cementogenesis, angiogenesis and capillary sprouting with *de novo* induction of Sharpey's fibers inserting into newly formed as yet to be mineralized cementum or cementoid?

The rational for linking "Bone: formation by autoinduction"[21] to periodontal tissue induction is based on the discovery of the pleiotropic activity of the osteogenic proteins of the TGF-β supergene family.[9,26,27] Such proteins "provides soluble osteogenic molecular signals endowed with the striking prerogative of initiating cementogenesis and the assembly of newly formed ligament fibers in primates".[1-3,9,14,15]

We further quote verbatim a critical statement of the induction of bone formation and regenerative medicine at large that has propelled forward the "Bone induction principle"[25] from preclinical to clinical contexts: "Obedient to the classic evo-devo' rule, developmental events that initiate in embryogenesis can be redeployed and recapitulated post-natally in tissue induction and thus regeneration".[1]

Several studies have shown that the embryological phases of craniofacial, periodontal and tooth morphogenesis display multiple mRNAs as well as secreted morphogenetic and osteogenetic proteins species predominantly of the TGF-β supergene family.[1,7,9] Such genes and secreted gene products, members of the TGF-β supergene family, singly, synergistically and synchronously initiate tissue induction and morphogenesis of the periodontal tissues and other craniofacial structures (Fig. 5).[1,7,9] The immunolocalization of distinct morphogenetic proteins within the periodontal ligament space of 12- to 18-day-old mouse heads showed that there is a site specific localization of immunolocalized BMPs molecularly highlighting the biological significance of redundancy as well as the structure/activity profile of each tested protein (Figs. 5, 6).[1,7,9,18]

Developmentally, *in situ* hybridization of murine craniofacial structures, including tooth morphogenesis, with osteogenic protein-1 (OP-1, BMP-7) shows expression of OP-1 in the dental epithelium and the dental mesenchyme of developing murine molars (Fig. 5A).[92,93] In context of the periodontal ligament space including cementum and alveolar bone, BMP-2 is primarily osteogenic with limited if any cementogenic inductive activity.[7-9] As such, immunolocalization of BMP-2 is strictly confined to the alveolar bone (Fig. 5B) with lack of immunolocalization within the cementum and the periodontal ligament space (Fig. 5B). The immunolocalization pattern of BMP-2 reflects the structure/

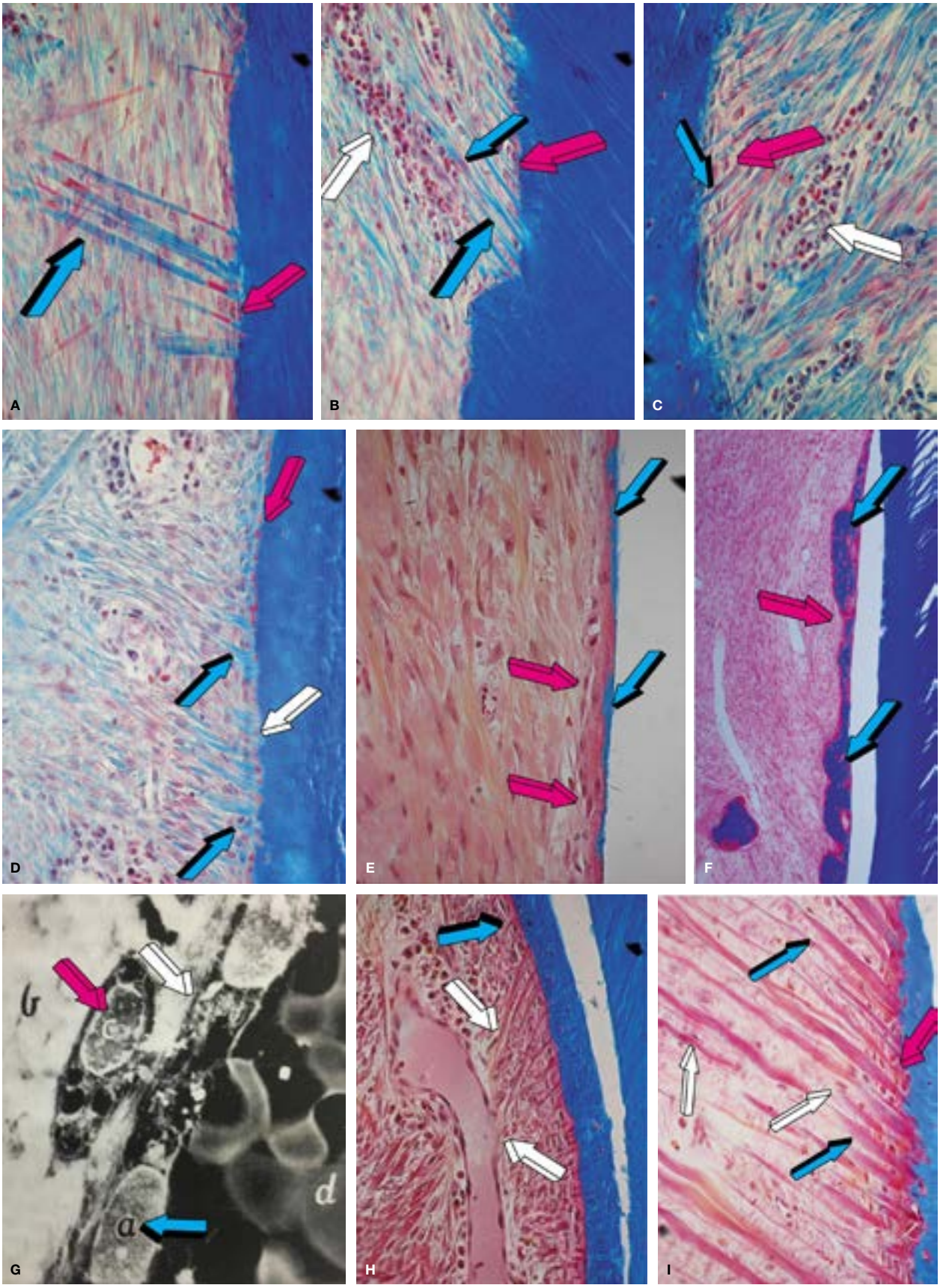

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Figure 7. *De-novo* induction of Sharpey's fibers, mineralized periodontal ligament fibers in continuity with dentinal tubules, staking cementoblasts along periodontal fibers, induction of cementogenesis with cementoid deposition, riding periodontal ligament fibers by cell progenitors, differentiation of riding cells by morphogenetic gradients, suspended capillaries providing angiogenic and cementogenic progenitors, foci of angioblastic activity within the regenerated periodontal ligament system, and induction of mineralized cementum with inserted bona fide generated Sharpey's fibers: the induction of periodontal tissue regeneration by naturally-derived highly purified osteogenic fractions, locally applied to mandibular molars' Class II furcation defects prepared in the Chacma baboon *Papio ursinus*. Harvested specimen blocks on day 60 were embedded undecalcified in K-Plast resins (Medim, Buseck, Germany). Undecalcified sections in K-Plast were cut at 3 - 6µm with carbide tungsten knives and stained, free-floating, with a modified Goldner's' trichrome stain.[2]

A-C. *De novo* induction of Sharpey's fibers (light blue arrow) directly into the dentinal substratum separated by cementoblasts (magenta arrow) stacked between fibers almost completely mineralized. The direct insertion of Sharpey's fibers within the dentinal substratum is evident in B,C, were fibers are seen to be in direct continuity with the collagenic material of the dentine substratum (light blue arrows).

B, C. Patterning of angioblastic cellular elements with condensed hyperchromatic chromatin (white arrows) indicating differentiating angioblasts and continuous induction of capillary sprouting and angiogenesis.[1] Plasticity of the regenerating periodontal ligament space showing cellular trafficking towards the cementoid/dentinal compartment with elongated mesenchymal cells riding the fibers towards the dentinal substratum across morphogenetic gradients set by TGF-β superfamily members in solution and bound to extracellular matrices from the periodontal ligament fibers to the cementoid inductive microenvironment.[1,13]

D. Induction of cementogenesis by differentiating cementoblasts along the planed dentinal surface (magenta arrow) with periodontal ligament fibers still providing anatomical and functional geometric cues for differentiating cementoblastic cells staked between fibers (light blue arrows). Cementoblasts form along the planed root surface possibly after minor dentinoclastogenesis (white arrow) during healing of the exposed and treated planed surfaces. Conceivably, identical mechanisms of decreased ph. might occur along the dentinal surfaces as compared to fracture healing where lower slightly acidic ph. surface demineralizes the bone at the fracture site exposing BMPs stored within the matrix now available to responding cells to initiate fracture repair. Demineralization of the bone matrix is the basic principle behind "Bone: formation by autoinduction"[21] and at the very basic mechanism of "The bone induction principle"[25] whereby bone matrices are demineralized to initiate the induction of bone formation.[21-25]

E, F. Induction of cementogenesis by highly purified naturally-derived osteogenic factions showing the induction of cementogenesis along the planed root surfaces with mineralized cementum (light blue arrows) surfaced by cementoid matrix as yet to be mineralized deposited by contiguous cementoblasts (magenta arrows).

G. "The role of the vessels in angiogenesis".[34] Original image of Trueta' paper[34] highlighting the exquisite relationship between osteoblastic cells (magenta arrow) and endothelial cells (light blue arrow a) separated only by the ultrathin basement membrane (white arrow) and its extracellular matrix components including laminin and type IV collagen.[27,45,87]

H. "The role of the vessels in angiogenesis"[34] is further shown by the digital image showing a suspended capillary within the periodontal ligament space with periodontal fibers connecting the cementoid and cementum deposition at the root interface (light blue arrow) to the angiogenic compartment (white arrows) of the central "osteogenetic vessel" of Trueta' definition.[34] Note how periodontal ligament fibers unite to the extracellular matrix of the suspended vessel, providing a reservoir of peri-vascular stem cells for a continuous flow to the cementogenic microenvironment.[9,13,14,17] (I) More organized periodontal ligament space with periodontal ligament fibers (light blue arrows) still staking differentiating cementoblasts (magenta arrow) providing spatio-temporal conduits for progenitors to ride across morphogenetic compartments (white arrow).[9,13,14,17]

A-F, H, I. Undecalcified sections embedded in KPlast resin cut at 3 to 6 µm with carbide-tungsten blades mounted on heavy-duty microtomes (SM2500E Leica Microsystems, Bensheim, Germany), stained free-floating with a modified Goldner's trichrome stain.[54,58]

activity profile of the isoform with the substantial induction of alveolar bone both in canine and non-human primates' models with limited if any cementogenic capacity.[7-9]

To the contrary, osteogenic protein-1 (OP-1), when applied to periodontal defects created in the Chacma baboon *Papio ursinus*, is preferentially cementogenic, with the induction of Sharpey's fibers within newly formed cementum along the planed root surfaces.[1,7-9,15,18] Once again the immunolocalization pattern of the OP-1 isoform defines the structure/activity profile of the protein (Figs. 5C, D, E). OP-1 was found to be expressed in newly secreted cementum and cementoblasts in 16-days-old mouse pups (Fig. 5C) with a strong signal in predentine and mantle dentine (Fig. 5D).[7]

OP-1 Immunolocalization of the periodontal ligaments space on 18-days-old mouse pups shows pronounced selected immunostaining of the newly formed cementum with a trabecular pattern of expression across the periodontal ligament fibers with minimal if any immunolocalization to the alveolar bone (Fig. 5E). The composite expression of molecularly different yet homologous morphogenetic proteins has suggested that optimal therapeutic regeneration may entail the combined use of homologous yet molecularly different proteins.[1,7-9,15,18]

Particularly enthralling are the expression patterns of BMP -3 gene and gene product in homogenized generated ossicles by the heterotopically implanted coral-derived macroporous bioreactors.[55,61-63] The pleiotropic activity of the BMP-3 gene and gene product is shown in Figure 6. The protein is immunolocalized throughout the periodontal ligament space including the alveolar bone and the cementum (Fig. 6A).[7] Of note, BMP-3 immunolocalizes along the inferior alveolar nerve (Fig. 6A white arrow).[7]

Surprisingly, as it may seems for a bone morphogenetic protein,[27,28] BMP-3 immunolocalizes in the cerebellar white matter of the cerebellar folia (Fig. 6B).[7] BMP-3 immunolocalizes in the cytoplasm of Purkinjie cells of 13-days-old mouse pup (Fig. 6B)[7] delineating the axonal neurite of the Purkinjie cells (Fig. 6B).[7]

These findings by Thomadakis et al.[7] are noteworthy, and indicate that BMP-3 is neurotrophic during development and maintenance of the mammalian nervous system. Potentially thus, BMP-3 immunolocalization in the cerebellar folia and in the cytoplasm of Purkinjie cells and neurite axons may simply control the cerebellar fine tuning of striated muscle activity (Bone Research Unit, unpublished data 1998).

Immunolocalization of BMP-3 in the periodontal ligament space, alveolar bone and cementum (Fig. 6A) has indicated that the isoform may recapitulate post-natally the induction of all the essential components of the periodontal ligament system, i.e., cementum, Sharpey's fibers, periodontal ligament fibers and the alveolar bone. This hypothesis was tested by implanting highly purified osteogenic proteins fractions, predominantly containing BMP-3 as shown by partial amino acid sequence information[2,27] into Class II furcation defects of adult Chacma baboons *Papio ursinus*.[2]

Defects were implanted with 150 mg of baboon insoluble collagenous matrix (ICBM) reconstituted with 250µg of highly purified osteogenic fractions after gel filtration chromatography on Sephacryl S-200. Fractions were purified greater than 50.00-fold with respect to initial crude extract.[2] This naturally derived highly purified preparation is predominantly composed of BMP-3 (osteo-genin)[2] and BMP-2, with no detectable TGF-β_1 or TGF-β_2 (NS Cunningham and AH Reddi, unpublished data).

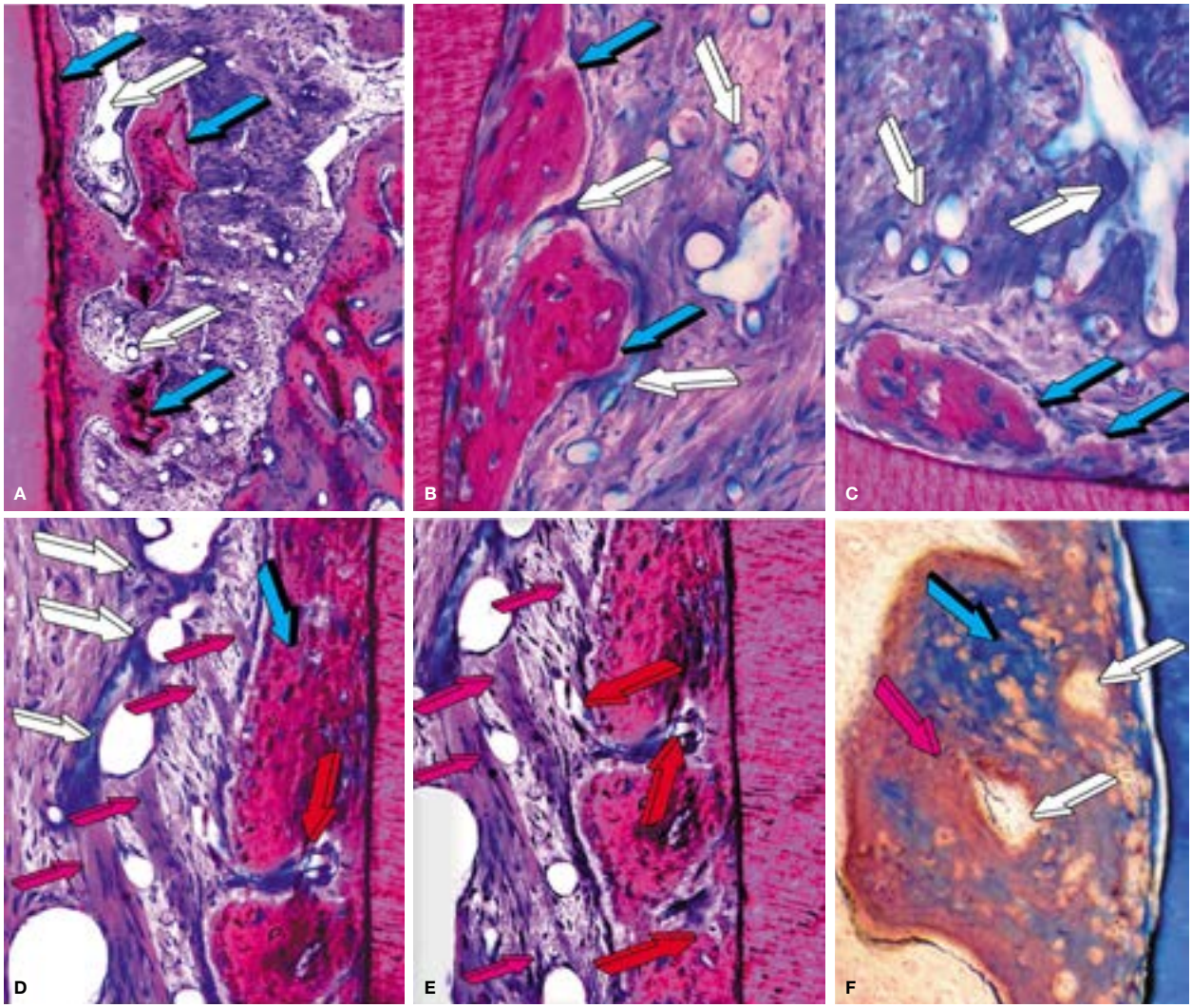


Figure 8. Series of digital images of regenerated cementum with cementoid deposition facing a highly vascular periodontal ligaments space with capillary' sprouting supporting regenerative events on day 60 after implantation of 75µg recombinant human transforming growth factor-β_3 (hTGF-β_3) in Matrigel®Matrix and implanted in Class II furcation defects of the non-human primate *Papio ursinus*.[19]

A. Extensive cementogenesis (light blue arrows) extending within the newly formed ligament's space with prominent vascular invasion and capillary sprouting within the periodontal ligament space (white arrows).

B. Regenerated tissues by the hTGF-β_3 in Matrigel® Matrix display an exquisite relationship whereby sprouting capillaries (white arrows in B) touch newly deposited cementoid (light blue arrows in B).

C. Prominent angiogenesis and capillary sprouting within the newly formed periodontal ligament space (white arrows). Induction of cementogenesis along the exposed planed root surfaces with yet to be mineralized cementoid matrix (light blue arrows in C).

D, E. Details of the newly generated periodontal ligament space by recombinant hTGF-β_3 in Matrigel®Matrix with cementum and cementoid matrices morphologically and molecularly connecting via collagenous conduits (magenta arrows in D, E). The newly described vascular/cementoid fibers assembling the newly formed periodontal ligament' space connect and cross talk with the vascular angiogenetic and the cementoid components of the newly established periodontal ligament system. Note the tight morphological relationship of newly formed vessels surfacing and invading the newly deposited cementum (orange arrows in D,E).

F. Detail of regenerated cementum by 75µg hTGF-β_3 on day 60 with areas of mineralization (light blue arrow) and cementoid yet to be mineralized cementoid (magenta arrow) outlining vascular invasion of the newly formed cemental matrix by the recombinant hTGF-β_3 in Matrigel®Matrix.[19] Presented undecalcified sections were processed by the diamond saw cutting and grinding Exakt techniques.

Implanted defects were harvested on day 60 after implantation as undecalcified blocks containing the first and second mandibular molars surrounded by periodontal tissues.[2] Specimen blocks were embedded undecalcified in methyl methacrylate (K-PLast, Medim Germany).

Undecalcified serial sections including dentine and associated periodontal tissues were cut at 3 to 6µm in the

mesio-distal plane throughout the entire bucco-lingual extension of the furcation defects using tungsten carbide knives mounted on a Polycut-S motor-driven microtome (Reichert-Jung, Germany).[2]

Histological analyses showed for the first time that highly purified naturally-derived bovine osteogenic protein fractions set into motion the induction of cementogenesis with *de novo* induction of Sharpey's' fibers directly inserting into mineralized dentine (Figs. 7A, B, C) and within the newly forming cementoid matrix along the regenerated periodontal ligament system (Fig. 7D).[2]

Of interest, the insertion of Sharpey's fibers within the dentine and/or the cementoid matrix regulates the cellular trafficking close to the developing cementum whereby single fibers are directing staked progenitors towards the root planed surfaces for continuous cementoid induction (Figs. 7A, B, C, I magenta arrows).

The quality of the undecalcified sections allowed to identify histological features previously unreported such as the presence of condensations of cellular elements within the periodontal ligament space with condensed chromatin indicating *de novo* angiogenesis within the periodontal ligament space (Figs. 7B, C white arrows).[9,14,15]

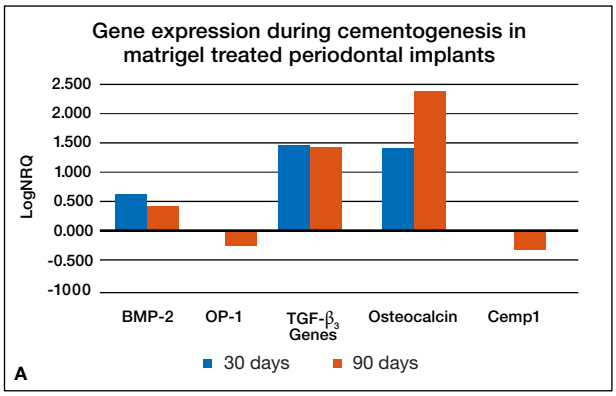
Capillaries were seen to be suspended by periodontal ligament fibers uniting the cementum to the basement membrane of the vessel (Fig. 7H). Fibers run from cementum to the vessels as a conduit between the angiogenic vascular and cementogenic microenvironments within the periodontal ligament system (Figs. 7H, I). "The role of the vessels in angiogenesis" is shown by an original Trueta' image[34] (Fig. 7G). The electron microscopy image shows the exquisite relationships between osteoblasts (magenta arrow) and endothelial cells (light blue arrow). Cellular compartments are only separated by the ultrathin basement membrane with its extracellular matrix components including laminin and type IV collagen. [27,34,46,87]

We also reported the presence of mesenchymal cells riding the fibers across the periodontal ligament space providing thus continuous progenitors cells to the forming cementum and cementoid matrices. Stacked cells are parked amongst the fibers against the root surface *de novo* initiating cementogenesis (Figs. 7H, I white arrows).[1,9,17,18]

The folding of the continuously erupting dental lamina of Carcharinus obscurus dusky shark shows pronounced immunolocalization of TGF-β_3 gene product (Figs. 6C,D).[1] TGF-β_3 also immunolocalizes cellular elements below the folding of the dental lamina (Figs. 6C,D).[1]

This vast pleiotropic multi-functional poli-faceted biological activity of the TGF-β_3 gene and gene product across phylogenetically distant species and genera is additionally shown by the morphogenetic drive to induce substantial cementogenesis along planed root surfaces in *Papio ursinus* (Fig. 8). The molecular rational for the induction of cementogenesis is that research experiments have shown that TGF-β signaling regulates cementum formation through Osterix expression.[94] The experiments using conditional knockout mice for Osteocalcin and *Tgfbr2* showed that TGF-β signaling is one of the upstream regulators of Osterix in cementoblast differentiation and cementum formation.[94]

Osterix (Osx) is a key regulator of cellular cementum formation.[94,95] Choi et al.[94] demonstrated that a functional lack of *Tgfbr2* determines a decrease in the expression of Osx thereby controlling the induction of cementogenesis.[94] TGF-β signaling master minds cementoblasts differentiation by directly regulating Osx expression via a Smad-dependent pathway.[94] The molecular complexities of the induction of cementogenesis are further highlighted by a study that shows that Osx-expressing cells express Wnt and that Wnts produced by Osx-activated



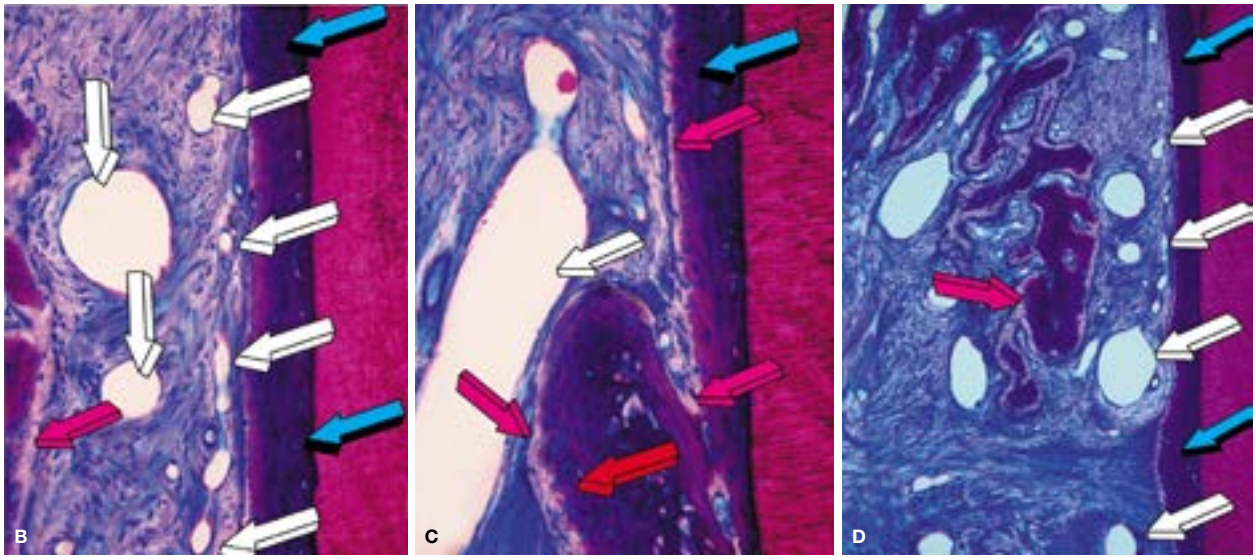
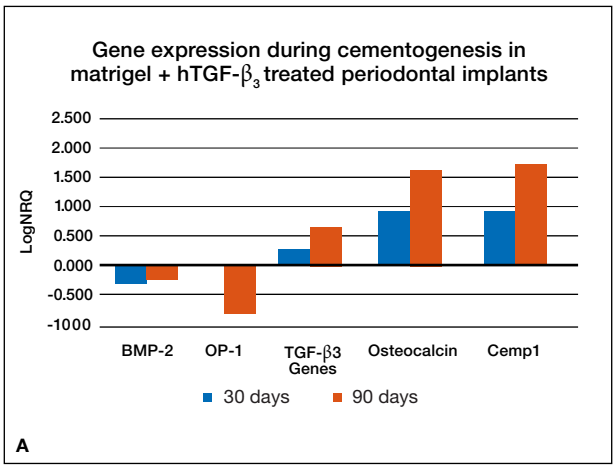
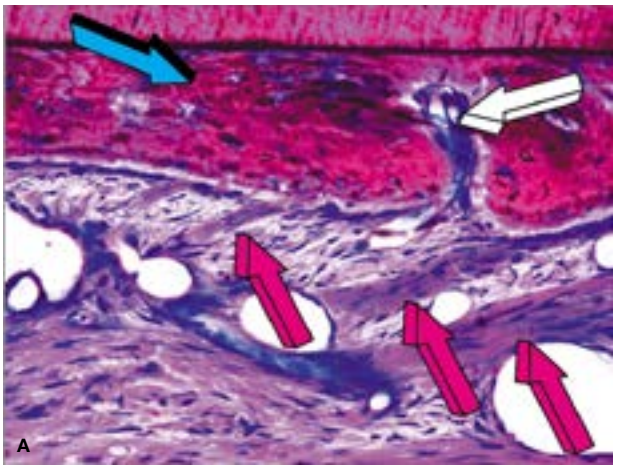
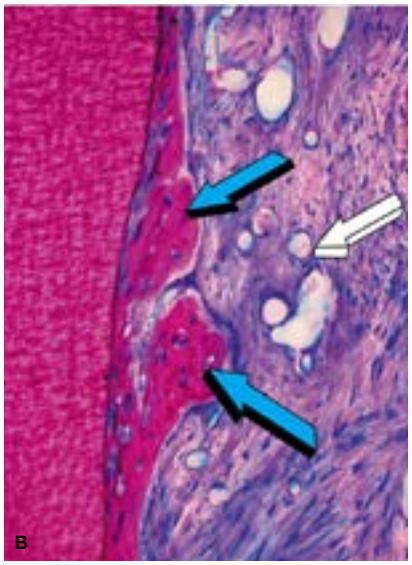


Figure 9. Gene expression analyses of Class II furcation defects in *Papio ursinus* implanted with Matrigel®Matrix solo and harvested on fay 60 after implantation.[19]
A. qRT-PCR analyses of Matrigel®Matrix solo harvested tissues show up-regulation of BMP-2, TGF-β_3, and Osteocalcin (OC). There is down-regulation of OP-1 and of cementum protein-1 (Cemp-1).[19]
B, C, D. Morphological analyses show induction of cementogenesis and capillary sprouting within the regenerated periodontal ligament space. [19] Note in **C**, the exquisite relationship between newly formed vessels (white arrow) and the newly deposited cementoid matrix (magenta arrows). There is cementogenesis expanding within the regenerated periodontal ligament space.







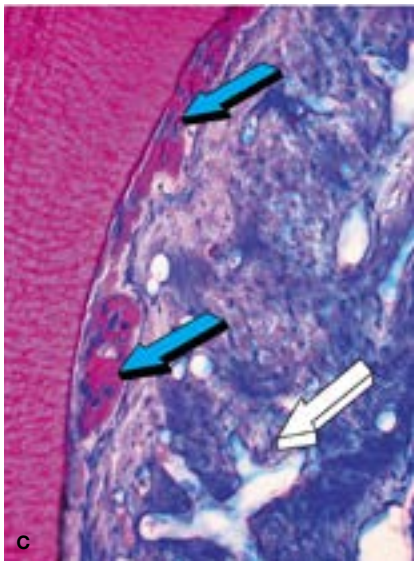


Figure 10. Gene expression analyses of Class II furcation defects in *Papio ursinus* treated with 75 µg hTGF-β_3 in Matrigel®Matrix and harvested on fay 60 after implantation.[19]
A. qRT-PCR analyses of Matrigel®Matrix show up-regulation of TGF-β_3, Osteocalcin (OC) and of cementum protein-1 (Cemp-1).[19] There was variable down-regulation of bone morphogenetic protein-2 (BMP-2) and osteogenic protein-1 (OP-1). Morphologically, the induction of cementogenesis is molecularly supported by up-regulation of the TGF-β_3 and Osteocalcin (OC), particularly by the over-expression of cementum protein-1 (Cemp-1) summarizes tissue induction and morphogenesis by the hTGF-β_3 isoform in furcation defects of *Papio ursinus*. There is extensive cementogenesis along the root surface (light blue arrow) with cementoid deposition and vascular invasion within the newly formed cementum (white arrow). The periodontal ligament space shows the presence of collagenous conduits (magenta arrows) that molecularly and morphologically connect the angiogenetic sprouting capillaries to the cementoid microenvironments. Note how newly formed vessels are in very intimate contact with the collagenous conduits ultimately providing superhighways for cellular migration and differentiation by molecular gradients across different molecular and morphological microenvironments.
B, C, D. Details of cementum and cementoid deposition (light blue arrows) along the curetted root surfaces of Class II furcation defects in *Papio ursinus*.[19] Capillary sprouting (white arrows) also penetrating the newly formed cementum and cementoid as invading capillaries within the newly deposited cemental matrices (white arrows in D).

cells regulate Wnts activated cementoblastic cells to proliferate and differentiate.[96] Additional and novel molecular pathways have shown that Osx, an essential transcription factor for osteogenesis and cementogenesis, positively regulates DICKKORF-related protein (Dkk-1) to down-regulate the Wnt/β-catenin pathway controlling osteoblasts and cementoblasts proliferation.[97]

The present experiments in *P. ursinus*' furcation defects super activated by 75 µg hTGF-β_3 in Matrigel®Matrix show up-regulation of Osteocalcin and Cementum protein-1 (Cemp-1). More importantly, and mechanistically determinant, the TGF-β_3 gene was up-regulated (**Fig. 10**).

Up-regulation of TGF-β_3 together with up-regulation of Osteocalcin and Cemp-1 resulted in the induction of substantial cementogenesis prominently forming along the planed and curetted root surfaces (**Fig. 10**).

The substantial induction of cementogenesis by the hTGF-β_3 isoform goes beyond the induction of cementogenesis; 75 µg hTGF-β_3 in Matrigel®Matrix besides *de novo* inducing cementogenesis along the exposed root surfaces set the induction of collagenous conduits that molecularly and morphologically connect the sprouting capillaries to the cementoid microenvironment (**Fig. 10**).

Of interest, there was variable down-regulation of OP-1 and BMP-2 (**Fig. 10**). In context of periodontal tissue regeneration, the induction of alveolar bone and cementogenesis by the hTGF-β_3 isoform may not require up-regulation of selected BMPs genes for the induction of periodontal tissue regeneration, as in heterotopic induction of bone formation, constructing bone organoids as shown in **Figure 2**.[11,58,61]

In our studies in Class II furcation defects of the Chacma

baboon *Papio ursinus* implanted with hTGF-β_3,[19] there is induction of substantial cementogenesis along the root surfaces with deposition of cementoid matrix extending within the periodontal ligament space. It is noteworthy that newly formed cementum is penetrated by vascular canals, not only penetrating the as yet to be mineralized cementoid matrix but also in tight apposition to the newly forming cementoid matrix along the planed root surfaces (**Fig. 8B**). Implantation of hTGF-β_3 in Matrigel®Matrix show the substantial induction of both cementogenesis and alveolar bone regeneration with the induction of periodontal ligament fibers within a highly vascularized periodontal ligament complex (**Fig. 8**).[19]

The induction of cementogenesis with capillary sprouting within the periodontal ligament space was also observed to a certain extent in control defects treated by extracellular matrix components in Matrigel®Matrix solo.[19] Previous studies did show the morphogenetic inductive capacity of Matrigel Matrix™ solo in modulating the epithelial phenotype.[87]

Capillary sprouting was seen in close proximity of the newly formed cementum that however per se showed the presence of vascular canals within the newly forming cementoid matrix (**Fig. 8**). Identified vascular canals are seen within constructs attached to dentin matrices and penetrating the as yet to be mineralized cementoid (**Fig. 8F** magenta arrow). Capillaries penetrate the newly formed cementoid, surrounded by mineralized newly formed cementum (white arrows) (**Fig. 8F**).

High power morphological analyses show the previously unreported drive of vascular invasion, capillary sprouting and angiogenesis in constructing regenerating cementum by doses of the recombinant hTGF-β_3 (**Figs. 8,10**). The unique and first morphological observations of vascular canals surrounded by cementoid matrix within mineralized cementum are shown in **Figures 8** and **10**. Close to the newly formed cementum in the periodontal ligament space there is a rich capillary sprouting and network almost attached to the cementoid matrix facing the periodontal ligament space (**Figs. 8,10**). This significant angiogenesis and capillary sprouting defines a novel term for the induction of cementogenesis, i.e. "cementogenesis in angiogenesis" as we have previously defined "osteogenesis in angiogenesis".[27,28,45]

Of great interest, newly formed capillaries within the periodontal ligament (**Fig. 8C,D,E**) show a pattern of alignment and organization within the ligament space with fibers running from the vascular endothelial compartment to other capillaries or directly into the newly synthesized cementoid layer (**Figs. 8D,E**).

This morphological finding suggests that the newly formed capillaries within the periodontal ligament space provide a tri-dimensional construct geared to provide a biological structural passageway for both progenitors and soluble molecular signals from the vascular angiogenic compartment to the cementoid compartment along the root surface controlled by morphogenetic gradients across anatomical boundaries. Such boundaries include collagen fibres, endothelial basement membranes and the extra-cellular matrix with soluble morphogenetic signals in solution. Nature thus constructs somehow simple passageways for movement across gradients of soluble morphogenetic signals which may be both in solution or bound to extracellular matrix components including type IV collagen, entactin, nidogen and laminin, the whole ensemble constructing the induction of tissue morphogenesis.[27,87]

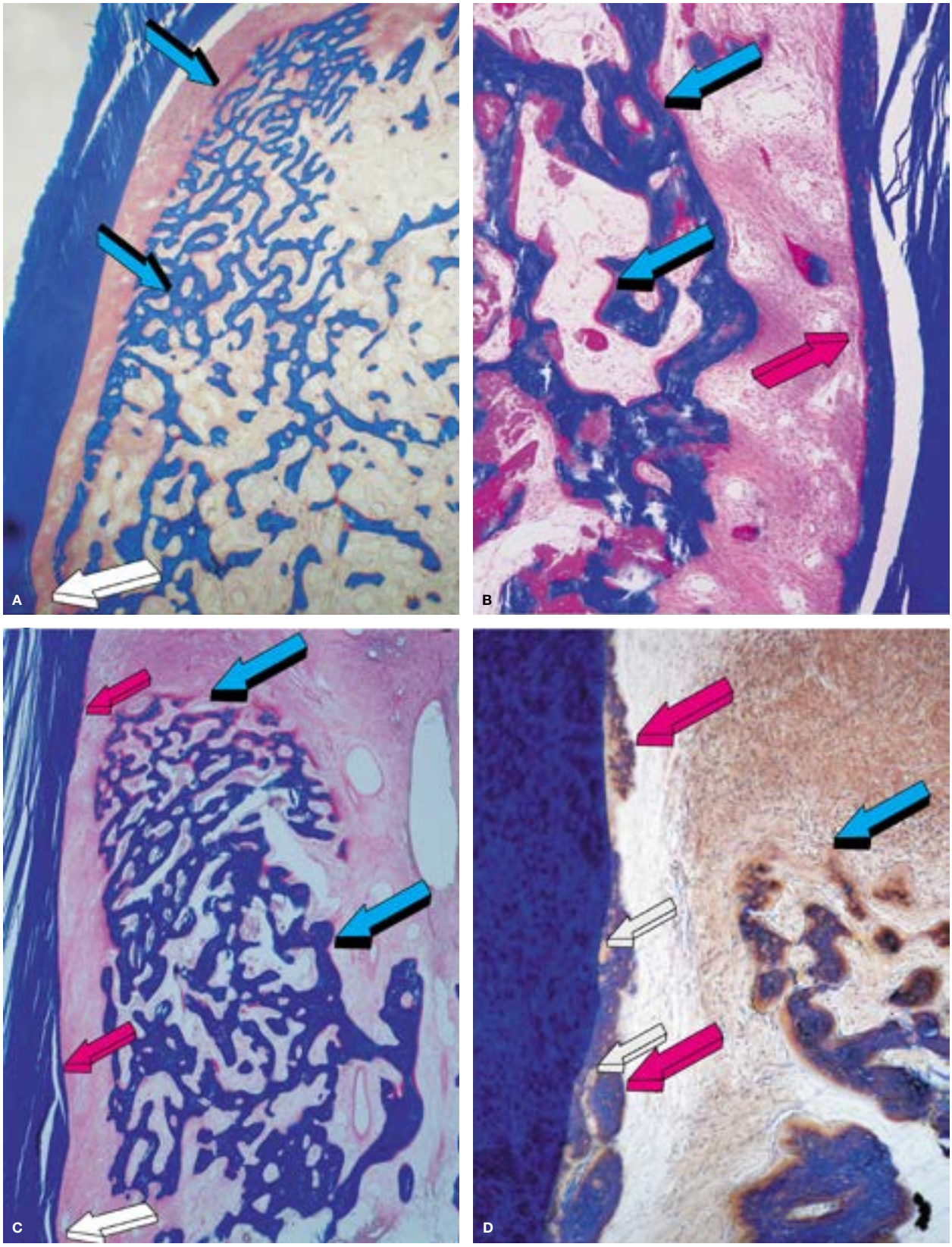
Finally, to further understand periodontal tissue induction and regeneration, we were able to implement one of the first *in vivo* studies correlating tissue induction and morphogenesis with molecular biology analyses of a set of morphogenetic genes controlling cementogenesis and the induction of alveolar bone in Class II furcation defects of *Papio ursinus*.[19]

Harvested tissues, i.e. cementum and alveolar bone on day 30 (whilst debriding the furcation defects created on day 0 of the experiments) and on day 90 (60 days after debridement and implantation of Matrigel®Matrix solo or 75µg of hTGF-β_3 in Matrigel®Matrix) were processed for quantitative reverse transcription polymerase chain reaction (qRT-PCR).[19] Results showed induction of cementogenesis by Matrigel®Matrix solo on days 60 after implantation of Matrigel®Matrix once again indicating the critical role of basement membranes component's in controlling tissue induction and morphogenesis.[13,18,19,89] There was induction of angiogenesis (**Figs. 9B,C,D**) with up-regulation of BMP-2, TGF-β_3 and Osteocalcin particularly on day 90 with a two fold increase with respect to day 30 (**Fig. 9A**).

Control Matrigel®Matrix solo specimens showed down regulation of cementum protein-1 (*Cemp1*) and up-regulation of TGF-β_3 on both periods (**Fig. 9A**).[19] These results together with up-regulation of Osteocalcin also at both time periods may account for the cementogenic drive as shown morphologically by Matrigel®Matrix solo-treaded furcation defects (**Figs. 9A,B**).[19] The data once again show the critical role of extracellular matrix components in the modulation of inductive phenomena as regulated by specific basement membrane components, particularly laminin and type IV.[46,27,87]

Implantation of Matrigel®Matrix reconstituted with 75 µg hTGF-β_3 showed downregulation of BMP-2 and OP-1 genes with up-regulation of TGF-β_3 and particularly of Osteocalcin both on days 30 and 90, with *Cemp1* up-regulation between 30 and 90 days, the latter with a fourfold increase on day 90 as compared to day 30 (**Fig. 10A**). The reported gene expression profile (**Fig. 10A**)[19] resulted in substantial tissue induction and morphogenesis as shown morphologically by the induction of cementogenesis along the planed root surfaces 60 days after implantation of hTGF-β_3 (**Figs. 8,10,C,D** and **inset A**).

In ending, we would like to answer the question set at the very beginning of this communication: "Does the presence of multiple forms of BMPs have a therapeutic significance?" The selected second last iconographic plate of this review shows histological results outlining different morphological outcomes directly related to the specific amino acid sequence domain of each tested isoform singly or in binary application (**Fig. 11**). Molecularly, the presence of multiple forms of BMPs underlies the biological significance of apparent redundancy, and indicates multi-


A
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C
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Figure 11. Does the presence of molecularly different yet homologous BMPs reflects a therapeutic significance? Morphological tissue induction by the structure/activity profile of different bone morphogenetic proteins' isoforms with the induction of qualitatively different regenerative pathways. Implanted proteins in Class II furcation defects of *Papio ursinus* were equally delivered by allogeneic insoluble collagenous bone matrices as carrier.

A, B. Periodontal tissue induction by naturally-derived highly purified bone morphogenetic protein fractions containing BMP-3, BMP-2 and other proteins of the natural milieu of the extracellular matrix of bone.[2] Highly purified naturally-derived osteogenic fractions induce cementum (magenta arrow in B), periodontal ligament with oriented fibers from the newly formed cementum to the regenerated alveolar bone (light blue arrows in A, B) covered by osteoid seams.

C. Tissue induction and morphogenesis by binary application of 100 µg recombinant human osteogenic protein-1 (hOP-1) and 100 µg human recombinant bone morphogenetic protein-2 (hBMP-2) on day 60 after implantation in Class II furcation defects of *Papio ursinus*.[8] Binary application hOP-1/hBMP-2 restored the induction of cementogenesis (magenta arrows) minimal or absent in hBMP-2 treated defects.[8] At the same time, the binary application hOP-1/BMP-2 also restored the induction of alveolar bone formation (light blue arrows) very limited in furcation defects treated with doses of hOP-1 singly.[5,8,9] The structure/activity profile reflects the recapitulation of embryonic development, whereby OP-1 is preferentially expressed and immunolocalized along the newly formed cementum also patterning the developing periodontal ligament fibers during craniofacial development of mouse pups.[7] In marked contrast, BMP-2 is expressed in the alveolar bone with no expression during cementogenesis or periodontal tissue induction.[7] Postnatal tissue induction recapitulates embryonic development with significant cementogenesis by hOP-1 with lack of alveolar bone induction, with pronounced alveolar bone induction with large osteoid steams by hBMP-2 with however limited if any cementogenesis.[8] Tissue induction and morphogenesis initiated by local administration of naturally-derived or recombinantly produced hBMPs exploits a functionally conserved process originally deployed in embryonic development.[1,6,9,26,27,93]

D. Induction of periodontal tissue regeneration by binary applications of recombinant human osteogenic protein-1 (hOP-1) and recombinant human transforming growth factor-β_3 (hTGF-β_3) (20:1 ratio by weight).[98] Note the haphazardly yet substantial induction of cementogenesis (magenta arrows) along the planed dentine surface. Vascular invasion within the cementoid matrix (white arrows) constructs a previously unreported cementogenic drive by hTGF- singly or in binary application with hOP-1. Pronounced induction of osteoid seams (light blue arrow) during alveolar bone regeneration. (A, B, C) undecalcified sections from blocks embedded in KPlast cut at 4-7 µm stained free-floating with a modified Goldner's trichrome stain.[2]

D. Undecalcified section cut and ground with the Exakt precision parallel cutting unit and wet-grinding and polishing on the Exakt micro-grinding system to a final thickness of 27µm.[98]

ple synergistic and synchronous interactions during tissue induction and morphogenesis beyond the realm of bone induction and regeneration.[7,9,27]

Implantation of highly purified osteogenic fractions after gel filtration chromatography onto tandem Sephacryl S-200 columns shows regeneration of alveolar bone (Fig. 11A), newly formed cementum with periodontal ligament fibres as collagenic bundles uniting the newly formed bone to the regenerated mineralized cementum with tightly inserted Sharpey's fibres (Fig. 11B).[2]

A carrier matrix of insoluble collagenous bone with highly purified osteogenic fractions purified greater than 60,000 fold with respect to the crude guanidinium extract[2,27] has had a lesson to teach: optimal osteogenesis with the induction of cementogenesis with a functionally orientated periodontal ligament is the result of several genes and gene products expressed and secreted during regeneration that singly, synergistically and synchronously initiate, maintain and control tissue induction and morphogenesis.

We found that the original polyedric multifaceted morphogenetic drive of the intact bone matrix has all the required morphogens to set tissue induction and regeneration comparable with recombinant human proteins as shown by results comparing highly purified naturally derived osteogenic fractions to recombinant human osteogenic proteins in non-human primate models.[9,15,18]

To potentiate the biological activity of hBMP-2 with limited cementogenic induction, a combination study with binary application of 100 µg hOP-1 and 100 µg hBMP-2 1:1 ratio by weight was implemented in *Papio ursinus*.[8] The study showed that periodontal tissue induction and morphogenesis were qualitatively different when the morphogens were applied singly, with hOP-1 inducing substantial cementogenesis.

hBMP-2 treated defects showed, on the other hand, limited cementogenesis but a temporal enhancement of bone formation.[8] Binary application showed cementogenesis together with the induction of alveolar bone regeneration with marked osteoid synthesis (Fig. 11C).

In Class II furcation defects of *Papio ursinus*, binary application hOP-1/hTGF-β_3 20:1 ratio by weight showed substantial induction of periodontal tissue induction tempered however by the anatomy of the furcation model that could not hold the rapid induction of large ossicles within the treated furcation defects. Cementogenesis was substantial, and characterized by irregular thickened cementum patches along the exposed and planed root surfaces (Fig. 11D).[98]

The biological acceptance of the inductive activity of a single recombinant human morphogen above the natural milieu and equilibrium of a pleiotropic bone matrix endowed with several naturally derived proteins clustered within the extra cellular matrix of bone has been the fundamental biological error of biotech companies developing recombinant hBMPs for translation in clinical contexts. Together with companies, far too eager clinician scientists embraced the powerful biological activity of a single recombinant human morphogen with no proper efficacy data beyond *in vitro* and *in vivo* rodent models' experimentation.[27,28,61-63]

Additional problems from the biotech industry were the firm decision to market single BMPs proteins as a recombinant human bone morphogenetic protein without consideration whatever to the structure/activity profile, possibly because of the impending FDA regulations on approving or not approving osteogenic proteins and certainly a single recombinant human protein rather than a combination thereof, mimicking the multiple morphogenetic capacity of purified chaotropically extracted bone matrices.

A final, and as it turned out, lethal error of biotech companies, was to seek approval for much higher doses than the doses used and filed in pre-clinical animal studies. Aside the vague rational that higher doses were needed in clinical contexts, FDA approval was requested for much higher doses of recombinant proteins than the doses used in pre-clinical studies including non-human primates to initiate human osteoinduction. It turned out that even massive dose of several milligram proteins per gram of carrier were needed to yield insufficient regeneration often inferior to autogenous bone grafts.[28,45,91]

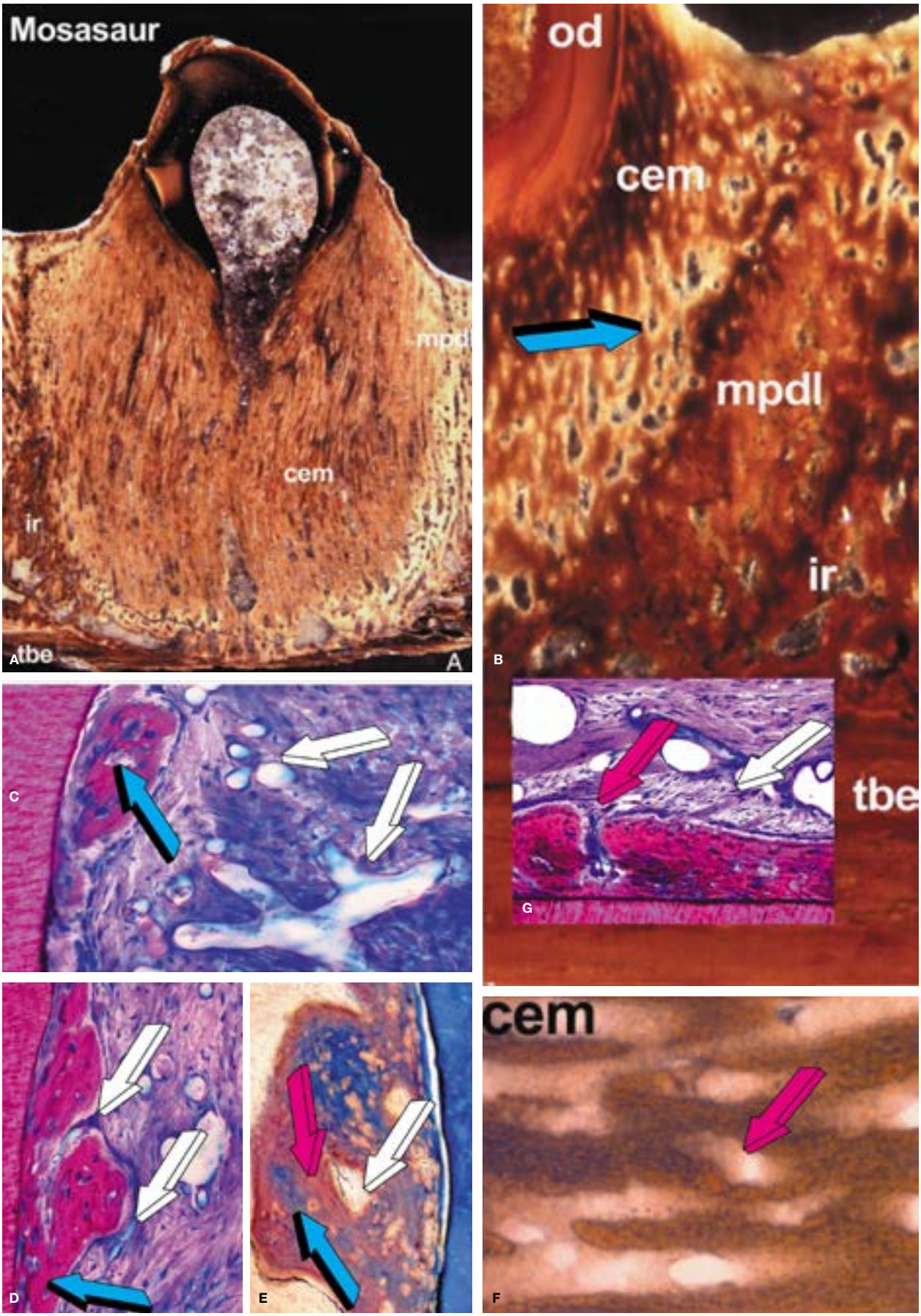
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Figure 12. The TGF-β_3 gene and gene product: The antiquity of cementogenesis, cementogenesis in angiogenesis, and cementum' evolutionary refinement from extinct Mosasaurs to extant non-human primates *Papio ursinus* showing the induction of cementogenesis in angiogenesis masterminded by the recombinant human transforming growth factor-β_3 (hTGF-β_3) implanted in Class II furcation defects of *Papio ursinus*.
A. Massive cementum formation (cem) uniting mosasaur' roots with mineralized periodontal ligament (mpdl) and interdental ridge (ir).
B. The undecalcified section of the mosasaur Halisaurus sternbergi shows the construction of a trabecular-like pattern of cementum (cem) uniting the root (od) to the mineralized periodontal ligament (mpdl). The trabeculations of the extinct cementum (cem) house vascular canals as shown in F (magenta arrow).
A, B, F. Images courtesy of Xianghong Luan, Department of Oral Biology, University of Illinois, Chicago, IL, USA.[99]
C, D. Induction of cementogenesis along planed root surfaces treated with 75 µg hTGF-β_3 implanted in Class II furcation defects of *Papio ursinus*.
C. Newly formed cementum with the induction of vascular canals (light blue arrow) facing a highly vascularized periodontal ligament space (white arrows).
D. Newly formed capillaries (white arrows) contact the newly formed cementum (light blue arrow) facing the periodontal ligament space.
E. Cementogenesis in angiogenesis with vascular canals (white arrow) penetrating the newly formed cementoid matrix (magenta arrow) with foci of mineralization (light blue arrow) across the newly formed cemental matric by the hTGF-β_3.
G. Synthesis of the induction of periodontal tissue regeneration by the hTGF-β_3 implanted in Class II furcation defects of *Papio ursinus*.[19] Substantial deposition of cemental matrix and mineralization of cementoid by day 60 after implantation. Pronounced vascular invasion and capillary sprouting within the cemental matrix (magenta arrow) with the induction of collagenic conduits uniting the newly formed cementum with capillaries nascent within the periodontal ligament space (white arrow). This tri-dimensional vascular-cementum system offers a continuous flow of progenitors to move and migrate across boundaries of the periodontal ligament space controlled by morphogenetic gradients with inductive morphogens bound to extracellular matrix components of the invading and sprouting capillaries.
C, D, G. Undecalcified sections cut and processed with the Exakt diamond saw cutting and grinding system to 27-30 µm and stained with methylene blue/basic fuchsine.[19]
D. Undecalcified section cut and ground with the Exakt precision parallel cutting unit and wet-grinding and polishing on the Exakt micro-grinding system to a final thickness of 27µm.[19]

The induction of substantial cementogenesis in angiogenesis as observed in hTGF-β_3-treated specimens but particularly the induction of large trabeculated constructs along the planed root surface indicates that the TGF-β_3 gene and gene product are recapitulating in extant *Papio ursinus* the induction of trabeculated cementum with vascular canals as observed in extinct Mosasaurs, 168-165 Ma (**Fig. 12**).[1,99] It is likely that the TGF-β_3 gene and gene product have been deployed and re-deployed during phylogenetically ancient evolutionary pathways controlling the induction of mineralized matrices including cementum across distant phyla (**Fig. 12**).

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Intraradicular rehabilitation of a necrotic, immature tooth using MTA, a fiber post and composite resin - A case report

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ABSTRACT

Endodontic treatment of necrotic, immature teeth with open apices can present challenges to debridement, disinfection, and optimal obturation. These teeth may have widely flared canals and thin radicular dentinal walls that are susceptible to fracture. Management of the open apex can be performed using a mineral trioxide aggregate (MTA) apical plug. To ensure a better prognosis in such structurally compromised teeth, internal radicular reinforcement using fiber posts and a self-adhesive cement has been suggested. The present case report illustrates the management of a necrotic, immature maxillary right central incisor in a 10-year-old patient using the MTA apical barrier technique and canal reinforcement using a fiber post.

Keywords

Apexification, calcium hydroxide, fiber post, mineral trioxide aggregate.

INTRODUCTION

Studies on the prevalence of dental trauma have shown 20%-30% of children sustain traumatic dental injury to their permanent dentition.[1] The majority of these incidents occur before root formation is complete and may result in pulpal inflammation or necrosis. With the loss of vitality and subsequent arrested root development, the open and sometimes divergent apical morphology, along with thin and fragile dentinal walls, represents both an endodontic and restorative challenge. It is imperative that these structurally compromised teeth are preserved in the young patient, as alternative treatment options such as implant-supported restorations or fixed prostheses require completion of craniofacial growth for acceptable outcomes.[2] Although regenerative procedures are the current protocol, clinical translation is relatively new in its inception and requires further research. Therefore, we chose a current and clinically reliable procedure for the treatment of this presenting case.

Thus, the purpose of this case report is to discuss the intricacies of treatment of a fractured, necrotic, immature maxillary central incisor using the MTA apical barrier technique and fiber post placement.

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CASE REPORT

A 10-year-old male patient with non-contributory medical history was referred for evaluation and treatment of his fractured immature maxillary right central incisor. He had suffered a traumatic sporting injury with loss of the coronal fragment of the tooth and subsequent loss of vitality 12 months prior. Therapeutic dressings of calcium hydroxide had been applied by his general dentist at the local community clinic to induce apical closure. However, patient compliance regarding regular attendance had been poor.

Fig. 1

Clinical examination revealed a complicated crown fracture of the maxillary right central incisor with evidence of an interim glass ionomer restoration over the access cavity (Fig. 1). Periapical radiographs demonstrated an incompletely formed root apex with normal apical tissues. There was evidence of an intracanal calcium hydroxide dressing. A root development stage 2 to 3 was established[3] (Fig. 2).

Due to a history of poor compliance in attending regular appointments, the mineral trioxide aggregate (MTA) apical barrier technique (ProRoot MTA; Dentsply Tulsa Dental, Johnson City, TN, USA) was chosen as the most viable treatment option. Consent from both the child and attendant parent was obtained with a detailed explanation of treatment rationale. On the first visit, root canal treatment was initiated. Local anaesthetic infiltration was administered using 2% lidocaine with 1:80 000 epinephrine (Lignospan Special, Septodont, Saint-Maur-des-Fosses, France) over the maxillary right central incisor.

Following rubber dam application, access to the pulp chamber was gained. Working length was then established using an apex locator (Root ZX) (J Morita MFG Corp., Kyoto, Japan), with accuracy further confirmed with a periapical radiograph (Fig. 3).

Cleaning and shaping was carefully performed using large stainless-steel K-files (Dentsply Maillefer, Baillagues, Switzerland), supplemented with copious irrigation using 1% sodium hypochlorite (NaOCl) (Endosure 1% Hypochlor, Dentalife, Victoria, Australia). After drying with sterile, ab-

Fig. 2

Fig. 3

Fig. 4

Fig. 5

sorbent paper points, the root canal system was dressed with calcium hydroxide paste ($Ca(OH)_2$) (Calxyl OCO PRÄPARATE® GMBH, Dirmstein, Germany) using a lentulo spiral. A temporary coronal restoration was established with a sterile cotton pellet, Cavit (ESPE, Seefeld, Germany) and Fuji IX glass ionomer cement (GC, IL, USA). The patient was scheduled for a second visit after six weeks.

The tooth was asymptomatic during the entire post-operative period, and the provisional restoration was still intact at the second visit. Local anaesthesia was accomplished with Lignospan Special. After isolation with rubber dam, the provisional restoration was removed from the access cavity.

A copious amount of 1% NaOCl was ultrasonically activated to remove the $Ca(OH)_2$ paste from the canal. Before MTA application, the canal was irrigated with 15% ethylenediaminetetraacetic acid (EDTA) (Endosure EDTA 15% Solution, Dentalife, Victoria, Australia) to remove the smear layer and again with 1% NaOCl. The root canal was then dried with sterile absorbent paper points. White ProRoot MTA was mixed with sterile water according to the manufacturer's instructions.

The application of an apical barrier of 4-5mm of MTA was completed using a Lee block (San Francisco, USA) and Buchanan Pluggers (Sybron Endo, Orange, CA, USA). It was further compacted using indirect ultrasonic compaction. Thus, a 5mm apical plug was obtained and a radiograph exposed to verify density and position of the MTA plug (Fig. 4). After application of MTA, a paper point moistened with sterile water was left in contact with the MTA plug and the access cavity sealed temporarily using Cavit and Fuji IX glass ionomer cement.

At the next visit 24 hours later, the provisional access cavity restoration was removed under rubber dam application. A Buchanan's plugger was then inserted to confirm the complete setting of the MTA apical plug. The root canal was then irrigated with 1% NaOCl, followed by saline and dried with paper points. A Rely-X Fiber Post (3M ESPE, Germany) was trimmed and cemented with Rely-X Unicem Self-Adhesive Universal Resin Cement (3M ESPE, Germany) - shade A2. No additional instrumentation was needed to accommodate the post due to the widely flared canal walls, thus preserving intraradicular dentine. Composite aesthetic restoration was completed using AdperTM ScotchbondTM Multi-purpose adhesive (3M ESPE, Germany) and a layered stratification technique incorporating Filtek Supreme XTE Universal Restorative Composite (3M ESPE, Germany) A2 body and A1 enamel shades. Soflex discs (3M ESPE, Germany) were used for aesthetic recontouring and polishing.

Occlusion was adjusted for centric and eccentric excursions. A final post-operative radiograph was taken (Fig. 5). The patient and his parents were satisfied with the aesthetic appearance of the restoration (Fig. 6). Use of a custom fitted mouthguard was advised for any contact sports to mitigate against any possible future fracture.

It was further reiterated that the treatment provided is to ensure preservation of the tooth till craniofacial growth is completed, hence due care is advised.

Fig. 6

The patient was recalled after 12 months. He reported that no symptoms had occurred and no complications were noted. The restoration still appeared acceptable (Fig. 7). A periapical radiograph demonstrated that the fiber post and restoration remained satisfactory with normal periapical tissues (Fig. 8).

Fig. 7

Fig. 8

DISCUSSION

Apexification is defined as a method to induce a calcified barrier in a root with an open apex or the continued apical development of an incompletely formed root in immature teeth with necrotic pulps.[4] Traditionally, the most commonly used material for apexification is calcium hydroxide.

Success rates are reported to be in the mid 90% range.[5] Disadvantages to this technique include the need for multiple appointments, extended treatment time, possible patient compliance issues and susceptibility to re-infection.[6] There also exists the possibility of weakening of tooth structure[7,8,9] with subsequent root fracture.

Considering these significant disadvantages, an alternative treatment to traditional apexification with calcium hydroxide may offer a better prognostic outcome. Studies have indicated MTA as an alternative to calcium hydroxide.[10,11] The advantages of MTA include excellent biocompatibility,[12] induction of hard tissue,[11] and good sealing properties.[13,14] Additional advantages include a shorter treatment time and development of a good apical seal.[15,16]

Despite these advantages, the root canal walls in these teeth remain thin, weak, and susceptible to fracture. Thus, restorative protocols able to reinforce the root architecture are important.[17,18] It has been hypothesized that filling root canals with an adhesive material with a similar elastic modulus to dentine could improve the fracture resistance and stress distribution in immature teeth.[13,19] Materials which have a modulus of elasticity similar to dentine enable the equitable distribution of forces along the root canal walls. Several materials have been used in an attempt to reinforce teeth, with composite resin and fiber posts showing promise.[20]

Composite resin has the ability to bond to root dentine walls, increasing the strength of the roots.[19] Unfortunately, it has relatively low strength under tensile stress.[21] Studies have also shown that thermocycling might significantly reduce the flexural strength of composite.[22,23,24] An alternative to increase fracture resistance would be the use of fiber posts.[18,25-27] Fiber posts have a modulus of elasticity similar to dentine and can be adhesively bonded to dentine, decreasing the risk of restorative failure and supporting tensile stress more effectively.[28,29] Fiber posts might also more evenly distribute forces along the root, reducing stress concentrations.[25,26]

Cementation procedures using self-adhesive resin cements are simpler than conventional bonding procedures used in root canals. Additionally, self- adhesive resin cements appear to have low shrinkage due to their viscoelastic properties.[30] Polymerization shrinkage is also reduced by a lower volume of material as the fiber post occupies most of the space in the root canal. In this case, no additional intraradicular dentine removal was required to accommodate post cementation, further maintaining structural integrity of the tooth.

CONCLUSION

Management of a necrotic, immature, and structurally compromised tooth through an approach employing the use of the MTA apical barrier technique and reinforcement with a fiber post can be a simple and efficient procedure with excellent aesthetic and functional results.

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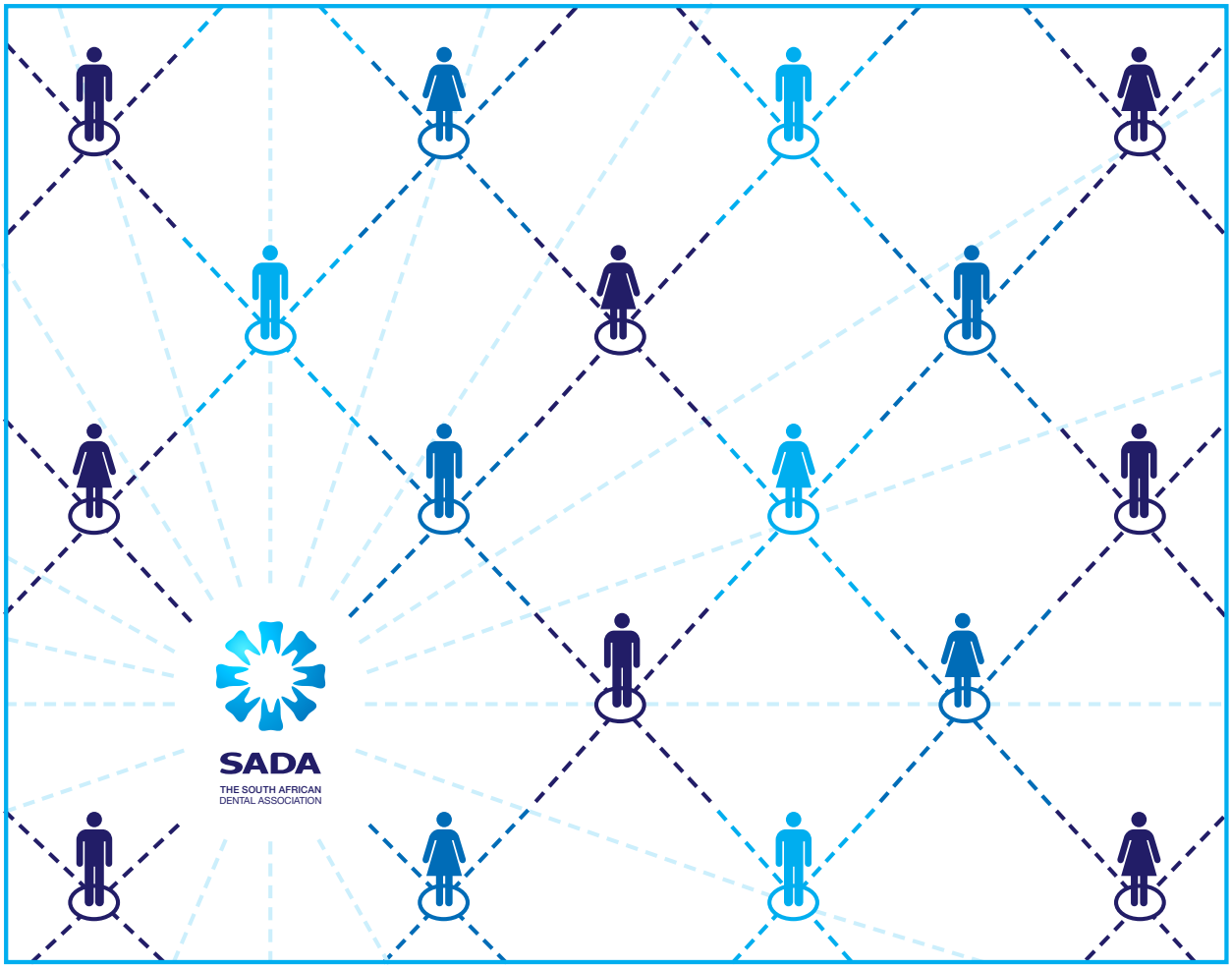

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Correctional repositioning of pathologically migrated maxillary premolars through periodontal therapy

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K Joshi[1], CS Baiju[2], S Bansal[3]

ABSTRACT

Pathological tooth migration (PTM) is the displacement of teeth as a balance among forces that maintain the position are disrupted. It is a common occurrence in a patient suffering from periodontitis. Its treatment includes periodontal therapy followed by a complex interdisciplinary approach to rectify the tooth position. However, it has also been observed that in certain cases periodontal therapy alone can cause a corrective repositioning of the teeth leading to a closure or a reduction in the displacement.

Present case report depicts a nineteen-year-old, healthy nonsmoker male patient with generalized Stage IV Grade C periodontitis. Deep periodontal pockets in #24 and #25 were observed along with a pathological migration of 1.6mm. The patient underwent conventional periodontal surgical intervention. It was noted that the therapy resulted in a reduction of the gap from 1.6 to 0.2mm and distal migration of #24 and a bucco-mesial migration of #25 in the course of one year of follow up.

Thus, an early diagnosis and treatment of PTM through the restoration of periodontal health at the right time can cause a corrective repositioning of the teeth in a predictable direction.

Keywords

Periodontitis, bicuspids, pathologic tooth migration, root Planing, spontaneous reposition.

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INTRODUCTION

Periodontitis is one of the most common oral diseases with an estimated prevalence of 50% in the adult population,[1] while the global burden of severe periodontitis is observed to be at 11.2% approximately.[2]

The disease culminates in loss of clinical attachment and the supporting bone which may predispose the teeth to move from their positions. Pathologic migration refers to tooth displacement that results when the balance among the factors that maintain a physiologic tooth position is disturbed by periodontal disease.[3]

The primary forces that maintain a stable position of the tooth are the intrinsic forces generated by opposing resting pressure of tongue and lip, the extrinsic forces caused by various habits, forces of dental occlusion such as the occlusal contact or inclinations and the force from the periodontal ligament.[4] In periodontitis the anomaly in pathological migration of teeth (PTM) resides with the weakened state of the periodontium.

In studies conducted by Martinez- Canut et al.[5] and Towfighi et al.[6] it was found that incidence and proportion of PTM rise with an increase in the severity of the periodontal disease. In cases of moderate to severe periodontitis a prevalence of 30.03% was observed and an association with incremental bone loss, tooth loss, gingival inflammation, and attachment loss was ascertained. PTM may present itself as facial flaring, a diastema, rotation, extrusion or tipping.

The progressive movement of teeth in abnormal positions with a resultant unpleasant change in esthetics compels the patient to seek dental therapy, which can involve a complex multidisciplinary approach. However, it has been recognized that developing mild to moderate pathological movements in the maxillary anterior may respond with a corrective repositioning after the conventional periodontal therapy alone. The present case report is an illustrative depiction of the possibility of spontaneous repositioning of PTM even in maxillary premolars after periodontal surgical therapy.

Footnotes:

- *mm- millimeter
- #11- maxillary right central incisor
- #21- maxillary left central incisor
- #23- maxillary left canine
- #24- maxillary left 1st premolar
- #25- maxillary left 2nd premolar

CASE REPORT

A nineteen-year-old male patient reported to the Department of Periodontology, with the main complaint of bleeding gums and perceivable rotation in upper front teeth. The patient was a systemically healthy nonsmoker, while the medical and familial history was found to be non-contributory. The intra-oral examination on the 1st visit revealed an insufficient oral hygiene maintenance with an abundance of supra and subgingival calculus (Fig.1A). Therefore, before the initial recording of periodontal status, the patient was educated regarding the etiology of periodontal disease, was subjected to supragingival scaling and provided with instructions for the measures of adequate plaque control.

The initial periodontal inspection was conducted on second visit. On examination, the case was diagnosed as generalized Stage IV Grade C periodontitis. It was noted that the gingiva was soft and edematous with a tendency to bleed when probed and exhibited a presence of periodontal pocket in 73% of the sites in the range of 5 to 9 mm. A periodontal pocket depth of 9 mm distally and 7mm mesially was found at #24 and #25 respectively. While there was an absence of mobility with regards to the same teeth, a presence of pathological migration between them was observed.

The maxillary central incisors were non-vital, presented with severe loss of attachment, bone loss and grade III mobility in conjunction with the rotation of #11 and flaring of #21 further creating an occlusal hindrance. The individual periodontal prognosis for #11 and #21 was considered hopeless, however, the patient refused to undergo extraction before the completion of the periodontal intervention.

The patient was subjected to a rigorous regime of quadrant wise scaling and root planing. After the completion of non-surgical mechanical therapy (Fig. 1B), the patient was recalled for periodontal re-evaluation after 1 month and the diagnostic cast was made. The sites that displayed no further improvement and presence of deep periodontal pockets and an absence of further improvement were considered for surgical interventions. Open flap debridement with meticulous degranulation, followed by interrupted sutures was performed. Periodontal dressings were placed and post-operative instruction was provided.

Figure 1A. Oral hygiene status as seen during the 1st visit.

Figure 1B. Status after the completion of non-surgical therapy.

Figure 1C. Completion of periodontal therapy and prosthetic rehabilitation.

The patient was recalled after 7 days for the removal of sutures. 6 months post the completion of periodontal surgeries #11 and #21 were extracted followed by immediate placement of bi-cortical implants in the Department of Prosthodontics (Fig. 1C).

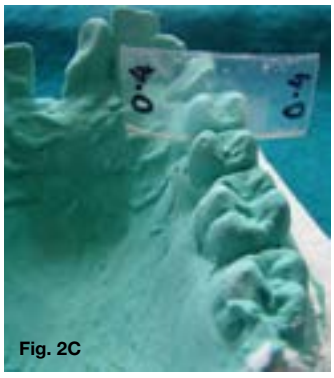

Figure 2A. A diastema of 1.6 mm as measured by gauge.
Figure 2B. Gap closure from 1.6 to 0.5 mm in 1 month, leading to a reduction of diastema by 1.1 mm.

Figure 2C. A remaining gap of 0.4mm, 6 months after the therapy.
Figure 2D. Diastema reduced to 0.2mm, 1 year post the therapy.

Clinical outcome

The patient was recalled after 1 month, 3 months, and 6 months and 1 year after the periodontal surgical interventions in which the oral hygiene was checked, maintained and instructions were reinforced. The diagnostic cast was fabricated at 1month, 6 months and 1-year recall visits.

On the dental cast and photographic records, it was retrospectively noted that #24 and #25 depicted a measure of pathological migration of 1.6mm [as measured by standardized cello tape gauges[7]] between the two teeth (Fig. 2A) along with a disto-palatal placement of #25 (Fig. 3A).

One month after the surgical intervention, a reduction in diastema from 1.6 to 0.5 mm (Fig. 2B) in conjunction with distal migration of #24 and a bucco-mesial migration of #25 was noted (Fig. 3B). Six months after the treatment, repositioning culminated in minor correction further reducing the gap to 0.4mm (Fig. 2C). A recall visit after one year depicted a closure of 0.2mm between #24 and #25 (Fig. 2D) and change in the occlusal relationship of bicuspids.

Figure 3A. A disto-palatal placement of teeth.

Figure 3B. Corrective occlusal repositioning after periodontal therapy.

A corresponding visible increase in the gap between the canine and 1st premolar was also noted from the initial of 0.6mm to 0.9mm after one month, 1mm after six months and 1.2mm one year after periodontal intervention.

DISCUSSION

Pathological migration of teeth can be multifactorial but its presence has consistently shown a positive correlation with loss of attachment, alveolar bone loss and gingival inflammation.[5,6,8] According to the equilibrium theory tooth in dentition remains in position of stability when the natural environmental forces acting on the crown produce a net resultant as zero.[9] However, periodontal disease causes a weakening of attachment apparatus which may change the capacity for dissipation of applied external forces causing the tooth to migrate. It has been observed that reestablishment of periodontal health can result in a corrective movement of light to moderately pathologically migrated single-rooted teeth.

The present case is a reporting on the spontaneous correction of maxillary premolars. In this it was observed that during a course of one year, restoration of periodontal health of the premolars precipitated into a gap reduction from 1.6mm to 0.2mm. A correction of 1.1mm occurred one month post the surgical intervention and of 0.1mm after six months and 0.3mm in the course of the next six months. A similar observation has been reported by Gaumet et al.[10] where they noted that a considerable amount of tooth repositioning occurred during the initial phase of the therapy. Further it was proposed that fibroblastic wound contraction during healing after periodontal treatment can generate enough forces that can lead to a corrective repositioning of the tooth.

It was also noted that after periodontal therapy, the premolars #24 and #25 moved in a distal and mesiobuccal direction respectively with a corresponding increase in the gap between #23 and #24. This observation can be attributed to the opinion that pathological migration of teeth usually occurs in a direction opposite to the deepest pocket due to the expansive pressure of granulation tissue.[11] Consequently, upon establishment of health and reduction of granulomatous tissue, the teeth move back in the direction of deepest probing depth.

The phenomenon of spontaneous repositioning of pathologically migrated teeth after the periodontal therapy has been known for quite some time. The few studies and reports that have been conducted on this have mainly focused on the repositioning of single rooted anterior teeth, while no reporting on the effect or movement of teeth adjacent to the pathologically migrated teeth has been done. The present report indicates that a prompt restoration of periodontal health in nascent cases of PTM can generate enough forces to induce a repositioning predictably. It depicts a possibility of movement even in premolars and also reports on the corresponding movement of adjacent teeth leading to an adjustment of space with an overall increased occlusal harmony.

Conflict of interest

Authors declare no conflict of interest.

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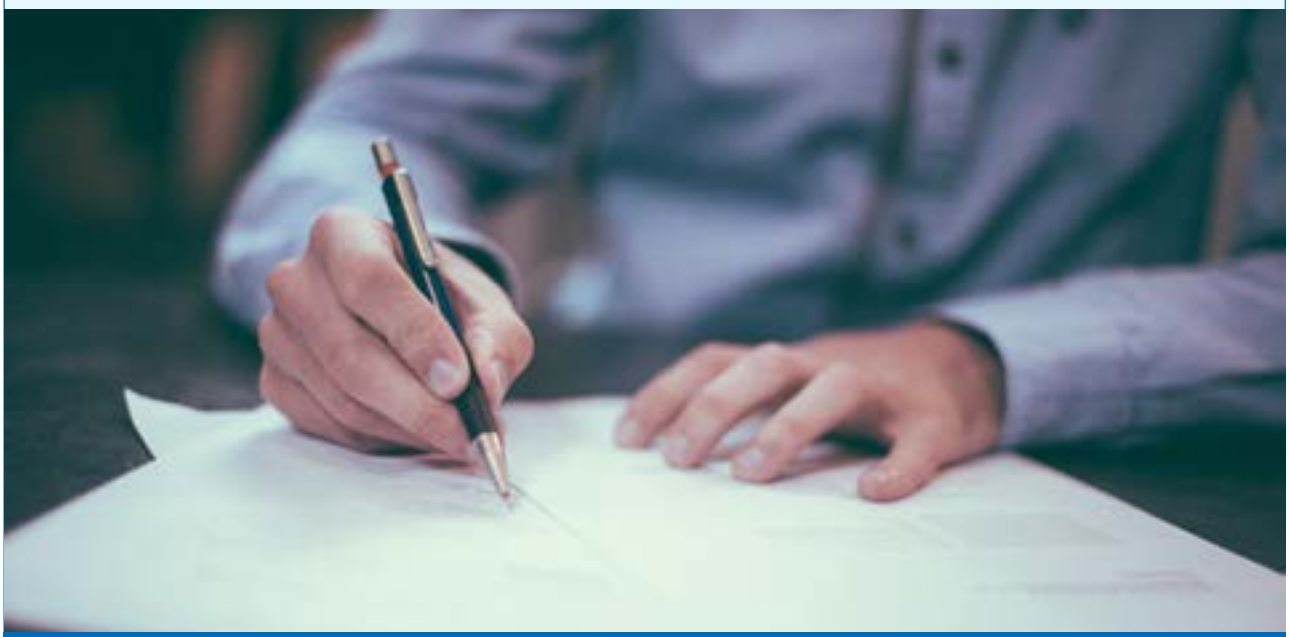

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A review of the 2030 Human Resources for Health Strategy: Implications for dentistry in South Africa

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A Bhayat[1], NR Nkambule[2], TK Madiba[3]

ABSTRACT

Introduction

The South African National Department of Health (NDoH) released a report in March 2020: "2030 Human Resources for Health (HRH) Strategy: Investing in the Health Workforce for Universal Health Coverage".

This report, has implications for the training of dental personnel and the planning of dental services in South Africa (SA). The aim was to summarise and critique the HRH strategic document with reference to dentistry.

Methods

This was an independent review of the report and included recommendations and implications for the training of dental personnel in SA. The report employed two models to predict the number of dental personnel that will be required; one on achieving provincial equity and the other on improving access to Primary Heath Care (PHC) facilities. The calculations were based on dental personnel employed in the public sector and the number of uninsured people in SA.

Results

The first model predicted a shortfall of 486 dentists, 60 specialists, 13 Dental Technicians (Dent Tech), 162 Dental Therapists (DTs) and 104 Oral Hygienists (OHs). The second model, based on PHC utilization, predicted a surplus of 341 dentists and a shortage of 1128 OHs and 1164 DTs. In order to meet these shortages, NDoH would have to allocate R840 million or 2.3 Billion rands respectively, depending on which model is chosen.

Conclusion

Irrespective of the model utilised, the NDoH needs to create and fill more dental posts, especially in provinces with low dental practitioner to population ratios. Dental training institutions need to align the training of dental graduates to meet the demands as set out in the report.

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2. **Ntombizodwa R Nkambule:** Second author - 30%
3. **Thomas K Madiba:** Third author - 30%

INTRODUCTION

The report titled "2030 Human Resources for Health (HRH) Strategy: Investing in the Health Workforce for Universal Health Coverage" was released in March 2020. This document was developed by the Ministerial Task Team (MTT) which was established by the former Minister of Health (Dr Aaron Motswaledi).

The MTT consisted of various stakeholders and academics from different sectors of health and was one of the most comprehensive HRH reports produced. The MTT was established to draft the document and to pave the way forward for the training and planning of health care workers in South Africa (SA).

The report consists of two components; the forecast of health workforce needs and costs until the year 2025 and the five goals that have been identified to improve health care delivery in SA by the year 2030. This review analyses only the 2025 human resource needs and its implications for dentistry; a subsequent paper will be published critiquing the five goals in terms of dentistry.

The report utilized three different models to forecast the health workforce needs and costs for the year 2025.[1] The first model was based on achieving inter provincial equity amongst health care workers, the second model used the Primary Health Care (PHC) approach package of delivering health services and the third model identified the shortfall in medical specialists. Since the third model did not include any dental specialists, this model was not analysed and hence was not reported on in the current review.

In terms of dentistry, the ratio of human resources to population varies considerably across the world and as such the World Health Organization (WHO) does not specify an ideal ratio.[2] However, in Africa the ratio is approximately 1:150 000 compared to industrialized countries which have a ratio of 1: 2000 dentists to population ratio.[2] Hence when planning human resources in dentistry, this should be taken into account.

AIM

The aim was to analyse and critique the HRH strategic document with particular reference to the impact it could have on dental personnel.

METHODS

This was an independent review of the HRH strategic document with inputs from three community dentistry specialists. The recommendations and interpretations are the views of the authors and not necessarily from the report itself. It is essential to understand how the number of health care practitioners and the population utilising the public health care services were calculated in this report as the results and recommendations are based entirely on these calculations.

The calculation of the health workforce needs and costs with regard to dentistry

The most common means to determine the number of dental personnel (dentists, dental specialists, oral hygienists, dental therapists, dental assistants and dental technicians) is to utilise the registers of the Health Professionals Council of South Africa (HPCSA) and the South African Dental Technicians Council (SADTC).[3,4] However, these registers contain the details of all dental personnel (DP) including those who have emigrated, retired or changed their profession. Many DP continue to pay their annual fees and maintain their membership even though they might not be practicing in SA. This results in an overestimate of the number of DP and hence an over estimate of the DP to population ratio which has a significant impact on the training, planning and distribution of DP.

As a result, the MTT used an innovative method to try and achieve a more accurate number of the current practising health care workers in SA. They utilized the number of health workers employed in the public sector in 2019 from the Governments Personnel and Salary system (PERSAL). This method ensured that all DP employed in the public sector were included in the forecasting models for the year 2025. The MTT did not include private practitioners in these calculations.

The number of DP registered with the HPCSA and the SADTC in 2020 and those employed within the public sector are shown in Table 1.[4,5] Approximately 20% of all registered dentists, 45% of DTs, 20% of OHs and only 5% of D Techs were employed within the public sector.

The prediction and calculation of the costs required in employing additional DP was also determined using the PERSAL system. The PERSAL system has specific grades of salaries for different DP and as such, the cost were calculated by including inflation and applying it to the different salary grades.

The calculation of the number of health care users

The number of health care users is usually based on the population of the country and predictions of population growth are calculated using various tools and forecast methods. However, the MTT defined the number of users of the public health care system as those who did not have medical aid insurance coverage.[6]

Since the health care workers were limited to the public sector, the MTT decided to use the population that would utilise the public sector and hence subtracted the number of insured people from the total population both nationally and per province. The 2018 National General Household Survey reported that 16.5% of the population were covered by medical aids and assumed the remaining 83.5% would utilise the public sector for their health care treatment.[7,8,9] Hence the ratio of heath care worker to population was based on the number of uninsured people both provincially and nationally.

Model 1 (Achieving inter-provincial equity)

This model was based on improving inter-provincial equity in the public sector by 2025. South Africa, like the majority of countries has a huge disparity across its nine provinces. As a result, the ratio of health care workers to population varies across the provinces from low to acceptable levels of DP to population ratios.

This inequitable distribution of DP places strain on some of the provinces and as a result impacts on the quality of health care being delivered. Therefore, the MTT ranked the nine provinces according to their ratio of health workers to the uninsured population based on the PERSAL system. The objective was to improve the practitioner to population ratios especially in the six lowest provinces.

The MTT decided to improve the ratios to the level of the third highest province - which was termed the 3rd Rank Province – (3rd RP) equity target ratio. The third highest province was chosen as the target as this would bring the lower two tertiles at least to the minimum level of the first tertile.

Then the number of additional health workers and budget required by 2025 was calculated in order to achieve the 3rd RP target ratios as per other similar studies.[1] The objective was to try and have all the provinces at a similar ratio to ensure that all communities have fair and equitable access to health care services.

Model 2 (Primary Health Care approach)

This model was based on utilization rates of the Primary Health Care (PHC) package by all uninsured citizens in SA. This was compiled with the assistance of the Medical Research Council (MRC) and predicted the number of DP that would be required to offer appropriate and acceptable access to PHC services.[10] The PHC service offers a range of treatments defined in the 2010 document on Revitalising PHC.[11]

The current 2018-19 public sector PHC utilisation rate is an average of 2.1 visits per person per year; but based on the burden of diseases and coverage level guidelines from the National Department of Health (NDoH), patients should ideally access PHC facilities approximately 3.2 times per annum.[1] This model therefore calculated the number of DP that will be required to provide all uninsured people access to an average of 3.2 visits per annum.[1]

Table 1. A breakdown of the number of dental personnel registered with the HPCSA and SADTC (2020) and those on the PERSAL (2019).

Category of DP	HPCSA and SADTC register for 2020	Number on PERSAL 2019	% working in public sector
Dentists	6155	1 235	20%
Dental Specialists	520	146	28%
Dental Therapists	764	342	45%
Oral Hygienists	1223	246	20%
Dental Technicians	1040	53	5%
Combined Total	9702	2022	21%

Table 2. Ratio of dental personnel per 100 000 uninsured population.

Health worker category	Total numbers	National density (per 100 000 public sector population)
Dentists	1 235	2.55
Dental Specialists	146	0.30
Dental Technicians	53	0.11
Dental Therapists	342	0.71
Oral Hygienists	246	0.51

Table 3. Inter-provincial variation in dental personnel ratios per 100 000 public sector population.

Category	National average	1st Rank Province	3rd Rank Province	5th Rank Province	9th Rank Province
Dentists	2.55	NC: 4.02	WC: 3.41	EC: 2.68	KZN: 1.58
Dental Specialists	0.30	GP: 0.95	FS: 0.04	MP: 0.02	KZN/NC/NW: 0.00
Dental Technicians	0.11	WC: 0.23	NC: 0.10	NW: 0.06	KZN: 0.02
Dental Therapists	0.71	LP: 2.60	NC: 0.82	GP: 0.39	FS: 0.00
Oral Hygienists	0.51	LP: 1.19	GP: 0.41	KZN: 0.34	NC: 0.21

EC: Eastern Cape; FS: Free State; GP: Gauteng Province; KZN: Kwa-Zulu Natal; LP: Limpopo Province; MP: Mpumalanga Province; NC: Northern Cape; NW; North West; WC; Western Cape

Table 4. Oral health care workers required to obtain third highest inter provincial equity by 2025.

	Maintain Status Quo				3rd Rank Province Equity Target			
	Target ratios		Health worker gap		Target ratios		Health worker gap	
Category	Min	Nat Ave	Numbers	Cost (billion)	Min	Nat Ave	Numbers	Cost (billion)
Dentists	1.58	2.84	22	R 0.02	3.41	3.49	486	R 0.53
Dental Specialists	0	0.19	49	R 0.08	0.04	0.21	60	R 0.10
D Techs	0.02	0.09	0	R 0.00	0.1	0.13	13	R 0.01
DTs	0	0.66	46	R 0.03	0.82	1.05	162	R 0.12
OH	0.21	0.48	38	R 0.03	0.41	0.57	104	R 0.08
Total	0.36	0.85	155	R 0.16	0.96	1.19	815	R 0.84

Table 5. Number and costs of dental personnel needed using the PHC model by the year 2025.

	Actual FTEs (PERSAL)	FTEs Required		Total Expenditure		Estimated Gap in 2025	
Category	2019	2019	2025	2019	2025	FTEs	Costs (R billion)
Dentist	275	-	-	-	-	-275	-341
Dental Therapist	-	1 037	1 128	562	773	1 128	773
Oral Hygienist	-	1 509	1 642	818	1 125	1 642	1 125
Dental Assistant	443	2 310	2 513	676	930	2 070	766
Total	718	4856	5283	R2.056	R2.828	4565	R2.323

Table 6. Average and predicted selected health care worker salaries from 2019 to 2030.

Health worker category	2019	2025	2030
Dentist	R 1 302 849	R 1 726 083	R 2 182 068
Dental Therapist	R 981 843	R 1 300 798	R 1 644 433
Oral Hygienist	R 546 180	R 723 608	R 914 766
Dental Assistant	R 546 180	R 723 608	R 914 766
Total	R 546 180	R 723 608	R 914 766

RESULTS

The ratio of DP employed on the PERSAL to the uninsured population in SA is shown in Table 2.[1] There was a wide disparity between the number of dentists (2.55), DTs (0.71), OHs (0.51) and D Tech (0.11) per 100 000 public sector population.

Results from Model 1 calculations

The current inter-provincial variations in DP ratios per 100 000 public sector population showed that the Northern Cape (NC) had the highest ratio of dentists to population (4.02) while Kwa Zulu Natal (KZN) had the lowest (1.58) (Table 3).[1]

Limpopo Province (LP) had the highest number of DTs and OHs per public population while Free State (FS) and Northern Cape (NC) had the lowest ratio respectively. Gauteng had the highest ratio of dental specialists (0.95) while NC, NW and KZN had very few or no dental specialists at all.

Due to the disparity in the population to staffing ratio amongst the nine provinces, some provinces had a higher population to practitioner ratio compared to others. In order for all nine provinces to achieve a similar ratio of population to practitioner ratio, the model used the third ranked province as a benchmark.

Using this model, government would require an additional 486 dentists, 60 specialists, 13 D Techs, 162 DTs and 104 OHs (Table 4).[1] It would cost the state approximately 840 million Rands to achieve these required numbers.

Results from Model 2

This model predicted a shortage of 1128 DTs, 1642 OHs and 2070 DAs by the year 2025 (Table 5).[1] These shortages were calculated by subtracting the actual Full Time Equivalents (FTEs) in 2019 from FTEs required in 2025. This model also reported a surplus of 275 dentists as shown in Table 5.[1]

Dental Technicians were excluded from this analysis as the PHC package does not include rehabilitative services such as prosthodontic and orthodontic services. Although dental specialists are also not included in the basic PHC package of care, the PHC approach allows for secondary and tertiary facilities to offer specialised services such as maxillofacial and oral surgery. It is likely, that the bulk of specialists required would be employed at secondary and tertiary facilities and would include maxillo-facial surgeons.

The second column of Table 5, the actual FTEs based on the 2019 PERSAL, is the number of full-time dental personnel per facility in relation to all full-time health care workers nationally. Since there were so few DTs and OHs compared to other health care workers, their FTEs were negligible and hence not recorded. This was confirmed by the large number of DTs and OHs that will have to be employed to achieve the national ratio in line with other mid-level workers. The NDoH would have to allocate in excess of 2.3 Billion Rands to achieve the required number of DP as suggested in the report.

DISCUSSION

Although the calculation of the number of human resources was innovative, the calculations of ratios between DP and the population were based on the number of DP employed in posts within the public sector only. Hence, any shortfall or surplus that was calculated meant that there was a shortage or surplus of filled posts within the public sector and not necessarily a shortage/surplus of DP in the country. As a result, any recommendations of training additional DP need to be interpreted with caution as there could already be sufficient numbers of DP in SA, but not enough funded posts that can be filled within the public sector.

The low number of D Techs to 100 000 uninsured people (0.11), could be due to the limited number of dental prosthesis and rehabilitative services offered at public dental facilities.[12] Most rehabilitative services are offered at the tertiary institutions and it is likely that most of the D Techs were employed at those institutions.

The limited number of prosthodontic and orthodontic services rendered at the public dental facilities are usually outsourced to private laboratories as it is more cost effective compared to employing a full time D Tech together with all the necessary laboratory equipment.

A strength of using the PERSAL system in predicting HRH needs is that funding for additional posts can be easily calculated as the public sector has specific salary ranges for the different health care worker categories. If this report used the HPCSA or any other registers, calculating the salaries and financial costs would be cumbersome and complicated as salaries vary tremendously among private health care workers.

Although these registers have limitations, they do provide a trend which can be used to compare the numbers of DP working in the public and private sectors. Approximately only 20% of all registered DP were employed within the public sector in 2019. This comprised of 45% of all DTs, 28% of all specialists, 20% of all dentists and 20% of all OHs. Only 5% of D Techs worked in the public sector and this could be due to the minimal amount of rehabilitative services rendered at public health facilities. This relatively low number of DP employed in the public sector could be due to a lack of posts, poor financial remuneration or due to a lack of services that are being rendered.[13]

The 20% of DP that were employed within the public sector had to provide dental care to as much as 80% of the South African population and this could be one of the many reasons why communities don't have adequate access to curative and preventive dental care.

Regarding the utilization of the public sector, this report assumed that all uninsured members will exclusively utilise the public sector and all insured members will exclusively utilise the private sector.

This is not the case as many insured patients use the public sector and vice versa. Therefore, it does have a weakness and hence the results and forecast needs to be interpreted with caution.

Interprovincial equity model

It was surprising that the most urbanised provinces; Gauteng, KZN and Western Cape (WC) did not have the best practitioner to population ratios as was expected. This could be due to the population density in these provinces.

Similarly, it was interesting to note that LP had the best ratios for both DTs (2.60) and OHs (1.19). This could indicate that the number and type of oral health personnel in this province was in line with the national plan of increasing the number of mid-level workers to offer dental services.

The number of required DP is not the actual number required to train but the number of posts that would have to be created and funded in different provinces across the country in order to have a fair and equitable distribution of oral health care workers. This implies that most of these posts will have to be in the 6 provinces that have the lowest DP to population ratio. Additional dentists, dental specialists and D Techs need to be employed in KZN, more DTs need to be employed in FS and more OHs in the NC provinces.

Unfortunately the model combined all dental specialists into one category and as such the calculation of the number and type of dental specialists required could not be accurately quantified. The majority of specialist were employed in Gauteng and this was possibly due to the three dental schools that are located in Gauteng. These dental schools would have employed the majority of specialists due to the training of both under and post graduate dental students.

The provinces with very few specialists; NW, KZN and NC do not have any training facilities for dentists and dental specialists and this could be a reason for the low number in these provinces.

Primary Health Care Utilization model

The reason for the surplus of dentists in this model is due to the PHC basket of services which can be rendered by DTs, OHs and DAs. If this model is used to calculate the HRH needs, then training institutions would have to increase the number of DTs, OHs and DAs in order to meet the demands. In addition, provinces would have to create and fill these posts accordingly.

It is unlikely that training institutions would be able to graduate the large numbers of DTs (1128), OHs (1642) and DAs (2513) that have been predicted in this model. Another option would be to retain the dentists in the public sector until sufficient numbers of OHs and DTs are available.

If the South African government introduces the NHI in the near future, it will be based on the PHC package of services and hence the number and type of personnel required will be similar to the requirements as laid out in this model. It is also essential to realise that mid-level workers have been identified as the key role players in delivering health care services to the uninsured population. As a result, more emphasis must be placed on the training of mid-level workers (DTs and OHs) in the dental field.

Forecasting the oral health care workers needs for 2025

There are generally two ways to improve the ratios of DP to the uninsured population. One is to increase the numerator by increasing and then filling the number of DP posts within the public sector; and the other mechanism would be to decrease the denominator. The denominator could be decreased by reducing the uninsured population through having more people on medical aid schemes either by decreasing the medical aid membership fees, increasing employment rates and subsequent access to medical aids or by increasing the type and number of benefits from medical aid companies.

Impact of COVID-19

These predictions are fluid and depend on a variety of external factors. With the advent of COVID 19, these predictions could all be skewed as the pandemic has had serious direct and indirect effects on the South African landscape. Due to the lockdown, the economy has shrunk and unemployment has increased. Any factor that increases unemployment will increase the number of uninsured people as they would not be able to afford medical aid fees and hence, essentially reduce the ratio of DP to 100 000 population. If the mortality rate increases drastically due to COVID 19, that could reduce the population and hence also impact on the DP to population ratio. In addition, anecdotal evidence has shown that COVID-19 has been responsible for a large number of deaths amongst health care workers which would also negatively impact on the health worker to population ratio.

Training and retention

In addition to increasing the number of qualified DTs and OHs to meet the shortfall, Government would also have to develop means of retaining them within the public sector. DTs have a high attrition rate; some go back to study dentistry while others change their profession completely.[14] If government decides to train and employ mid-level workers as per the HRH document, the issue of retention within the professions and within the public sector is a crucial factor that needs to be addressed.

Many DTs and OHs cite poor financial remuneration as the main reason for exiting or not applying for employment within the public sector.[14] This issue could be partly addressed by introducing Compulsory Community Service (CCS) for the OH and DT graduates.[15] This would ensure a continuous stream of newly qualified graduates that would be able to render their services in provinces where their services are urgently required.

The average and predicted salaries for selected health care workers is shown in Table 6. Oral hygienists and DTs, on average, earn less than half (48%) the salary of a dentist and around 73% of other similar health care workers such as physiotherapists, occupational therapists and speech therapists.[1] Therefore, in order to make the oral hygiene and dental therapy professions attractive and retain these personnel in their respective careers within the public sector, government must re-examine their financial remuneration packages.

Model 3 (Determines the number of medical specialists)

Since this model did not include dental specialists, this model was not analysed nor critiqued.

Recommendations

1. The NDoH must create and fill more public sector dental posts especially in provinces where there is a shortage of oral health personnel. The creation of more posts could also assist in addressing the misdistribution of DP by increasing the number of DP employed in the public sector.
2. Compulsory Community Service for OH and DT graduates should be discussed and analysed as an option which could ensure a continuum of primary dental care for communities in need.
3. Training institutes must align the type and number of DP being trained with the disease burden and the current shortages of dental staff as indicated in this report. There should also be programs and courses developed to improve the career pathways of mid-level DP.
4. A national database should be developed to keep track of all health care professionals including their practicing status and geographical practice location. This will allow for better predictions and planning of health personnel. This should include both the public and private sectors and must be updated annually to ensure correctness and adequate and appropriate planning.
5. The number of dental specialists employed in the public sector needs to be analysed. In those provinces where there is a shortage, more specialist posts need to be created and filled.
6. Lastly, government must identify mechanisms in which it can retain mid-level staff in their professions and within the public sector and one option would be to improve their financial remuneration.

CONCLUSION

Irrespective of the model utilised, there is a dire shortage of all types of dental personnel within the public sector. As a result, the NDoH needs to create and fill more posts, especially in provinces with low dental practitioner to population ratios. In order to deal with the shortage of personnel, dental training institutions need to align their training of graduates to the needs and demands as set out in the report.

To ensure equity, access to dental care and prevention of dental diseases, both an increase in the posts within the public sector and an increase in the number of oral health personnel will be required. The NDoH must also identify mechanisms in which it can retain mid-level oral health workers in their professions and within the public sector.

Acknowledgement

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What's new for the clinician?
- Excerpts from and summaries of recently published papers

SADJ July 2021, Vol. 76 No. 6 p374 - p377

Compiled and edited by V Yengopal

1. The effects of frenotomy on breastfeeding and reflux

KW Slagter, GM Raghoebar, I Hamming, et al. Effect of frenotomy on breastfeeding and reflux: results from the BRIEF prospective longitudinal cohort study. Clin Oral Invest. 2021; 25: 3431-39.

INTRODUCTION

The World Health Organization (WHO) considers breast milk as the best source of nourishment for infants. Although exclusive breastfeeding is recommended up to 6 months of age, globally only 40% of children under this age are exclusively breastfed and this is mainly due to negative breastfeeding experiences.[1]

There are many different causes for negative breastfeeding experiences such as poor weight gain, necessitating supplementation, poor latch, maternal nipple pain, and oral restrictions like a tongue-tie (ankyloglossia) and/or lip-tie. Ankyloglossia (either the decrease in mobility for the tongue by classic anterior tongue-tie or a submucosal restriction, a posterior tongue-tie) and a superior tethered labial frenulum can cause altered latch and sucking mechanics.[1] Studies have shown that show that a frenotomy, if adequately performed, can improve breastfeeding scores and relieve nipple pain with little or no serious complications.

Another factor associated with breastfeeding difficulties is gastroesophageal reflux. Gastroesophageal reflux is a common phenomenon in infants, but the differentiation between gastroesophageal reflux and gastroesophageal reflux disease can be difficult.[1] Symptoms of reflux are non-specific, and there is increasing evidence that the majority of symptoms may not be acid-related. In children with infant gastroesophageal reflux symptoms, clinical improvement has been suggested following a frenotomy of a tongue-tie.[1]

Slagter and colleagues (2021)[1] reported on a longitudinal study that sought to assess Breastfeeding and Reflux Improvement by the Efficacy of a Frenotomy (BRIEF) in infants with breastfeeding problems up to 6 months after treatment. Breastfeeding self-efficacy for mothers was used as the primary outcome measure. Secondary outcome measures were nipple pain during breastfeeding, gastroesophageal reflux symptoms, and complications up to 6 months after treatment.

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MATERIALS AND METHODS

Participants were 175 eligible consecutive breastfeeding women with healthy infants under 6 months with breastfeeding problems. The 175 eligible women were from a group of 338 women referred by external general practitioners. The other 163 mothers were not considered eligible for this study because their infants were premature, twins, or were already revised for tethered maxillary labial frenulum (upper lip-tie) and/or ankyloglossia (n=84), their infants received exclusively formula (n=41), or their infants not seem to have oral restrictions (n=38).

Before enrolment into the study, a structured medical background history of mother and infant, pregnancy, birth, and breastfeeding history was done. For the infants, the oral examination consisted of reporting sucking blisters, shape of the palate, retrognathia, location of attachment of the frenula, blanched frenula with elevation, anatomical restriction of elicited lateral lingual movement (impaired transverse tongue reflex), abnormal floor of mouth elevation of the tongue, and presence of thrush. The sucking evaluation consisted out of the notification of abnormal gum/lip pressure, cupping of the tongue against the finger, seal on the finger, and the nature of the sucking tongue movements. Their mothers were assessed for usual causes of breast or nipple pain such as nipple damage (abnormal latch/suck dynamic or breast pump trauma/misuse), dermatosis infection, and vasospasm.

The frenotomy procedure was standardized by using an electrosurgical procedure. Topical anaesthetic cream (xylocaine 5%) was applied with a cotton swab on the surgical site. A dispersive electrode was placed under the patient. The tongue was elevated while the tip of the active electrode was applied to the frenulum. Regarding (anterior) tongue-tie releases, midline tissue was incised starting at the anterior edge of the frenulum. An approximately

1-mm-deep central window was incised in the mucosa overlying the genioglossus muscle. The window in the mucosa was then extended laterally on both sides to release the mucosa, taking care not to disturb the fascia of the underlying genioglossus muscle. The appearance of a diamond-shaped wound was considered as a full release. Upper lip-tie releases were performed by lifting the upper lip, while the maxillary labial frenulum was released off the alveolar ridge up to the mucogingival junction. Immediately after the procedure, the infant was offered the breast or breastmilk by a bottle. Post procedural stretching exercises were advised to avoid reattachment of tissue by gently elevating the tongue and upper lip and massaging the wound four times per day for several weeks. Acetaminophen 60-120 mg suppository max 3 times per day was advised for analgesia if needed.

The infants were assessed at 1 week, 1 month, and 6 months after intervention via electronic correspondence using an Internet-based compliant survey portal (Typeform). All infants were followed clinically as per the office protocol. According to protocol, all patients had a routine follow-up after 1 week. When symptoms persisted or worsened following initial improvement, the mothers were offered a second procedure when a restriction was identified. During every follow-up visit, a routine assessment for post-operative complications was performed.

Breastfeeding self-efficacy was measured using the validated Breastfeeding Self-Efficacy Short Form (BSES-SF). BSES-SF is a 14-item survey rated on a five-point Likert-type scale. The Likert scale ranged from 1 = "not at all confident" to 5 = "always confident." Sum scores were calculated with a range from 14 to 70, with higher scores indicating higher levels of breastfeeding self-efficacy.

To evaluate nipple pain with breastfeeding, the pain score was measured with the Visual Analogue Scale (VAS) with a range from 0 to 10 with 0 = "no pain" to 10 = "severe pain." Infant gastroesophageal reflux was measured using the validated Infant Gastroesophageal Reflux Questionnaire Revised (I-GERQ-R). I-GERQ-R is a 13-item survey with strong internal consistency designed to evaluate the severity of gastroesophageal reflux symptomatology. The I-GERQ-R utilizes ordinal response scales to measure the severity of symptoms associated with infant gastroesophageal reflux disease (GERD). Scoring involves the summarization of 12 items (score range, 0-42), where lower scores reflect lower symptom severity.

Besides the study related outcomes, in addition, development in motor and cognitive growth after 6 months' post-surgery was assessed. Participating parents were asked to complete out questionnaires within 1 week by mail. Participants were excluded from the analysis if the 6 months' questionnaires were missing.

RESULTS

The study sample consisted out of 175 eligible breastfeeding women with healthy infants out of 338 woman visiting the clinic during the study period. After 6 months, 146 patients were included in the analyses; 29 patients were lost to follow-up. All patients but one received both a tongue-tie release and a frenotomy. Eight (4.6%) patients needed a second lingual frenotomy within 1 month after the initial treatment for either lack of improvement of symptoms or recurrence of symptoms after initial improvement.

Frenotomy improved BSES-SF, I-GERQ-R, and VAS nipple pain scores significantly after 1 week. This improvement was still significant 1 month after treatment for both BSES -SF and I-GERQ-R. Six months after treatment, I-GERQ-R scores remained significantly better in the 49 infants that presented with gastro-oesophageal symptoms at baseline. More importantly, 60.7% of infants still received breastmilk 6 months after treatment.

No post-operative complications were observed. In addition, motor and cognitive development was normal in all patients. In one (0.7%) patient there was temporary hyper granulated tissue of the wound. The majority of infants needed little, if any, analgesia post treatment.

CONCLUSIONS

the researchers concluded that Frenotomy of a tongue-tie and or lip-tie is a safe procedure with no reported post-operative complications after 6 months. Surgical release of the tethered oral tissues was shown to result in significant improvement of breastfeeding self-efficacy, nipple pain, and gastroesophageal reflux problems. Improvements occur early (1 week postoperative) and continue to improve to 6-months postoperative.

Implications of practice

Clinicians should encourage patients with newborns to visit their dentists to check for the presence of either anterior and/or posterior tongue-tie/s as these could potentially cause breastfeeding difficulties.

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1. Slagter KW, Raghoebar GM, Hamming I, et al. Effect of frenotomy on breastfeeding and reflux: results from the BRIEF prospective longitudinal cohort study. Clin Oral Invest. 2021; 25: 3431-9.

2. Buffered 2% articaine versus non-buffered 4% articaine in maxillary infiltration: randomized clinical trial

KS Amorim, VTS Fontes, AC Gercina, et al. Buffered 2% articaine versus non-buffered 4% articaine in maxillary infiltration: randomized clinical trial. Clin Oral Invest. 2021; 25: 3527-33.

INTRODUCTION

The molecular structure of all local anesthetics consists of 3 components: (a) lipophilic aromatic ring, (b) intermediate ester or amide linkage, and (c) tertiary amine. Clinical local anesthetics (LAs) belong to one of two classes: aminoamide and aminoester LAs. LAs are bases compound, weak soluble in water, and unstable when exposed to the air. In order to make feasible their injection, these bases are combined with hydrochloric acid to form local anaesthetic salt, in which form they are quite soluble in water and comparatively stable, becoming mostly a solution with an approximate pH of 5.9.[1]

Usually, epinephrine is added into local anesthetics solution at a ratio of 1:100,000 or 1:200,000 to balance blood vessel dilatation, leading to blood vessel constriction at the site of application, prolonging anaesthesia duration. However, the sodium bisulphite is added as an antioxidant to stabilize that kind of vasoconstrictor, which makes the solution even more acidic (pH approximately 3.5). Injection of these acidic solutions may consequently present negative effects, such as burning, some degree of tissue injury, relatively slow-onset anaesthesia, and unsatisfactory activity in the presence of infection and inflammation (even lower pH).[1] To compensate for the low pH, the organism itself performs a physiological buffering mechanism, which takes time and directly influences the onset of local anaesthetic action.[1] Another alternative for changing the pH of the local anaesthetic solution is to buffer it with sodium bicarbonate. Increasing the pH of the solution to the approximate to physiological pH (around 7.4) can result in the elimination of injection burning, reduction of tissue injury, and onset time.[1]

Amorim and colleagues (2021)1 reported on a trail that sought to compare the anaesthetic effect of 2% buffered articaine hydrochloride with 4% non-buffered articaine, regarding onset and length of pulpal and soft tissue anaesthesia, and pain during injection.

MATERIALS AND METHODS

This was a controlled, randomized, crossover, triple-blind clinical trial. The test solution was contained a 2% articaine hydrochloride solution with 1:200,000 epinephrine and 0.84% sodium bicarbonate (buffer) The control solution (solution 2), was a commercially used 4% articaine hydrochloride solution containing 1:200,000 epinephrine.

The manipulation of the solutions occurred exclusively and immediately before performing the procedure. Therefore, the content remained sterile due to the preparation conditions. To guarantee the blinding, the same researcher prepared the solutions alone, in other environment either from the volunteer or from the operator who only performed the anaesthesia. Moreover, both solutions (commercial and buffered) were delivered directly to the researcher who executed the anaesthesia, already coupled to the carpule syringe wrapped in sterile paper. Therefore, none of the researchers or patients was able to identify the solutions used during this study.

The inclusion criteria were healthy individuals aged over 18 years, a similar level of education (able to respond to the Visual Analog Scale-VAS), previous experience of local anaesthesia, no history of complications due to ocal anaesthesia, and presence of healthy upper canines responsive to “pulp tester” electrical stimulation. Volunteers who met any of the following conditions were excluded in the study: pregnancy, breastfeeding, systemic impairment, which contraindicated anaesthesia, history of an allergic reaction to any component of the used anaesthetic solutions, and patients that could present risk or interference on pulp tester response such as volunteers under orthodontic treatment or with extensive restorations in the upper canines.

Information about the study was explained to each volunteer prior to local anaesthetic injection and they were blinded to the anaesthetic agent used.

For oral supraperiosteal injections, the needle injected the anaesthetic solution without touching the bone to minimize pain. The anaesthetic injection speed was always 1 mL/min. All participants received supraperiosteal injections of 1.8 mL of local anaesthetic (1 cartridge) performed by the same operator.

This study was carried out in two sections. To establish the order of which solution would be administered in each section, the researchers used a randomization worksheet taking into consideration patient one to patient forty-two and the two solutions in two different sections without repeating the same solution. In one of the sections, the participants randomly received supraperiosteal buccal anaesthesia in the upper canine apex with solution 1 (2% buffered articaine with 1:200,000) or solution 2 (4% articaine 1:200,000 epinephrine). In the second section, the participants received the supraperiosteal buccal anaesthesia in the upper canine apex with the remaining solution, and then all patients received both solutions.

To assess the onset and length of pulpal anaesthesia, an electrical pulp test device (Pulp Tester Digital TP-10) was used. For evaluation of onset and length of soft tissue anaesthesia, calibrated nylon filaments with the predetermined force of 300 gf (SORRI® Esthesiometer Kit) were applied against the gum until deflection and then it was observed if the volunteer reported any painful sensation.

At the end of each session, the volunteers were asked about the pain during injection and registered it in the visual analog scale (VAS).

In addition, a pH meter device measured the pH of the solutions with nine different vials of each solution: solution 1, solution 2, and the 4% articaine with 1:100,000 epinephrine solution used to obtain the solution 1.

RESULTS

This study involved 42 health volunteers; most of them were women (28) aging from 19 to 28 years old, with a mean of 20 years old. There was no difference between the two anaesthetic solutions (onset of soft tissue anaesthesia, p=0.5386; length of soft tissue anaesthesia, p=0.718; onset of pulpal anaesthesia, p=0.747; length of pulpal anaesthesia, p=0.375), except for pain during the injection which was lower when buffered 2% articaine was used (p=0.001) and the pH. The pH analysis revealed that the solutions differed from one another (p<0.01).

CONCLUSIONS

The researchers concluded that the buffered 2% articaine with 1:200,000 epinephrine presented onset and length of pulp and soft tissue anaesthesia similar to 4% articaine with 1:200,000 epinephrine. Furthermore, the buffered 2% articaine with 1:200,000 epinephrine solution provided less pain during injection.

Implications for practice

With the absence of pain being a noted practice builder, clinicians should take note of these findings that may contribute to their patients' stress and pain free experience when presenting for dental treatment.

Reference

1. Amorim KS, Fontes VTS, Gercina AC, et al. Buffered 2% articaine versus non-buffered 4% articaine in maxillary infiltration: randomized clinical trial. Clin Oral Invest. 2021; 25: 3527-33.

Do the CPD questionnaire on page 383

The Continuous 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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6 View and print your CPD certificate.

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Gardner syndrome

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S Rajbaran Singh[1], AI Black[2]

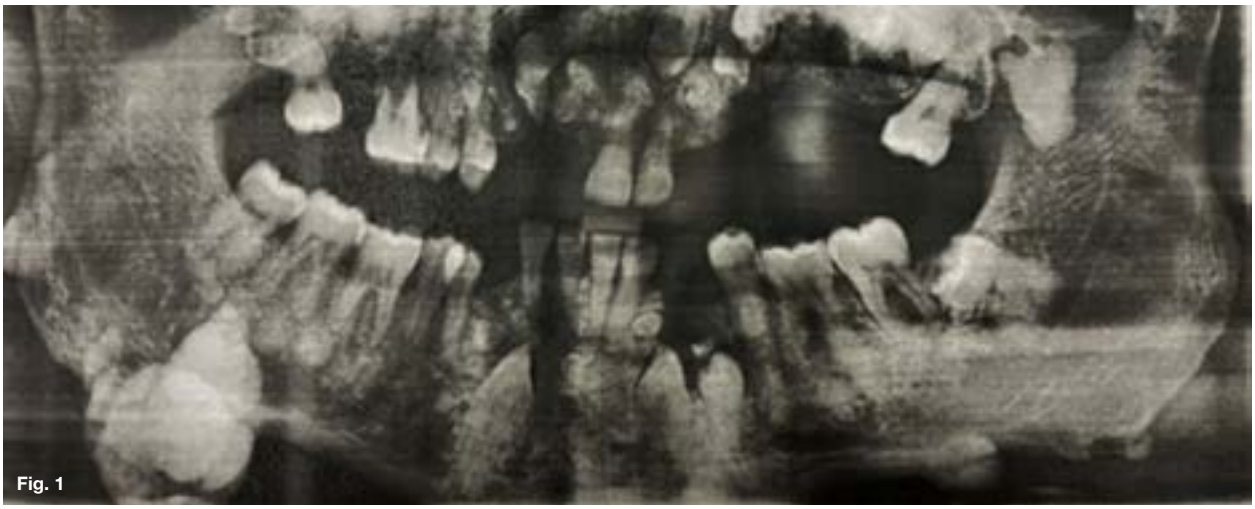

Fig. 1

INTERPRETATION

A 58-year-old male patient was referred for a panoramic radiograph after having presented with a hard swelling of the right mandible. Panoramic radiographic examination (Fig. 1) demonstrated multiples dental anomalies and variable bone densities in both jaws prompting clinicians to "dig" further. Teeth 17, 12, 11, 26 and 27 were missing. Teeth 13, 23, 24, 25, 38, 34, 33 and 43 were unerupted. An unerupted supernumerary left mandibular molar appeared in the region of the mandibular coronoid process. Multiple, small, well-defined radiopacities of density comparable to odontogenic material were evident in the anterior maxilla and mandible. These opacities often demonstrated radiolucent borders consistent with the finding of multiple odontomas. Both jaws demonstrated variable bone density. Cottonwool like opacities partially blending into adjacent trabeculae were evident in the mandible and maxilla posteriorly. The contour of the inferior border of the mandible bilaterally in proximity to the angle was irregular with multiple, well-defined, smooth, lobulated homogenous radiopacities suggestive of osteomas. The radiographic features of multiple osteomas, odontomas, variable bone density, supernumerary and unerupted teeth warranted the referral of the patient for gastroenterological investigation to exclude Gardner Syndrome.

Gardner syndrome (GS), described as a variant of Familial adenomatous polyposis (FAP), comprises a classic triad of colonic polyps, multiple osteomas and an array of soft tissue tumours. A mutation of the Adenomatous polyposis coli (APC) tumour suppressor gene results in GS. Reported to have an incidence ranging between 1 in 8,000 and 1 in 14 000 live births, GS bears no ethnic nor sex predilections and presents with a variety of colonic and extra-colonic manifestations.[2] GS may present between 2 to 70 years of age and polyp formation carries a 100% risk of malignant transformation by the fourth decade.[3,4] Bone manifestations precede intestinal polyps with osteomas presenting in up to 82% of patients. The maxilla and mandible are most often affected by osteomas with the frontal bone being the most common site for osteomas of the skull. The angle of the mandible commonly demonstrates lobulated osteomas that arise from the mandibular cortex.[5] Most GS patients demonstrate a variety of dental anomalies that include unerupted teeth, congenitally missing teeth, supernumerary teeth, altered root morphology and odontomas. Recognition of the extra-colonic manifestations on panoramic examination facilitates the timeous identification of patients with GS and prompt referral for management.

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Looking beyond the physical management of patients with head and neck cancer

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ABSTRACT

Cancers of the head and neck region often leave patients with conspicuous defects, as well as limitations in physical and psycho-social functions. Rehabilitation is challenging and can never fully restore the anatomical, physiological, or functional characteristics that have been lost.

Ideally newly diagnosed cancer patients should be managed by a multidisciplinary team of specialists from various allied fields who will be able to educate them and help them decide on the most appropriate and suitable treatment options. Patients must understand the processes, be of possible side effects and comprehend the limitations aware of rehabilitation. At the same time, clinicians may need to consider issues of distributive justice when deciding which patients will receive which resources, especially in financially limited institutions and countries.

The biggest challenge to us as clinicians as well as community members is to try and treat all patients holistically and to address both their physical and psychosocial needs. This requires a fervent commitment to action, and that we all stand together and help each other through difficult times.

INTRODUCTION

Cancers of the head and neck region often leave patients with conspicuous defects, as well as limitations in physical and psycho-social functions. Rehabilitation is challenging and can never fully restore the anatomical, physiological, or functional characteristics that have been lost. Ideally newly diagnosed cancer patients should be managed by a multidisciplinary team of specialists from various allied fields who will be able to educate them and help them decide on the most appropriate and suitable treatment options. Patients must understand the processes, be aware of possible side effects and comprehend the limitations of rehabilitation. At the same time, clinicians may need to consider issues of distributive justice when deciding which patients will receive which resources, especially in financially limited institutions and countries.

Challenges faced by newly diagnosed head and neck cancer patients

Many patients who develop head and neck cancer may be unaware of it until it becomes physically noticeable or functionally limiting. Studies have documented a sense of "fatalism about cancer" especially amongst those whose knowledge is based on past experiences of family members or friends.[2] If the latter only sought treatment in the late stages of their cancer, their outcomes would most likely have been worse, and their ensuing morbidity greater than if it had been treated timeously.

Seeing these poor outcomes in others, may compound the patient's fear and reluctance to seek medical help themselves. They may also delay going to the doctor in the hopes that the cancer will heal itself, out of fear of the unknown, or due to a lack of finances and access to medical facilities. Others may try home remedies or seek help from religious counsellors, alternative therapists, or traditional healers. Patients often look for medical help when the pain, appearance, odour, or functional impediment is too great to handle or conceal. By that time, their tumours may have spread to involve any

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3. **Portia T Nethononda:** Third author - 20%

number of surrounding facial areas, requiring far more extensive and invasive means of ablation. The delays in treatment are compounded by long waiting lists and limited staff and facilities at government hospitals.

Initially the patient's presentation, diagnosis and clinical situation should be discussed by a multidisciplinary team of specialists from various allied fields. These include head and neck surgeons, radiotherapists, prosthodontists, plastic surgeons, maxillofacial surgeons, ENT surgeons, audiologists, social workers, dieticians, and psychologists. Treatment may be with surgery, radiotherapy, chemotherapy, or a combination of these modalities, depending on the clinico-pathological and histological diagnosis and tumour site and size.

Patients are usually present in these discussions and may find themselves being examined and discussed by a number of people who tend to talk amongst themselves using technical terms that are difficult to comprehend. The scenario can be scary and intimidating, especially for the newly diagnosed cancer patients, who may already feel as if they have just been handed a death sentence. Their fear is compounded if they can't understand the discussions, which are seldom in layman's terms. In addition, rehabilitation after cancer treatment is a "long process with uncertain outcomes" and not all patients are alerted to this.[3]

They are then expected to make decisions and give consent to treatment without having had the time to fully comprehend the totality of their situation. This cannot be considered ethical for a number of reasons. Their anxiety and duress can impact on their decision-making processes, they may not have been provided with complete or clear education and explanations, and may not have sufficient understanding of the risks and benefits of each option. Autonomy also requires that they be given time to discuss their choices with family members, friends, employers, or other clinicians, in order to get a second opinion. It has been noted that many peoples' health literacy is worse than their general literacy which impacts on their ability to "obtain, process and understand both written and verbal cancer information". They may also struggle to "comprehend information which contains unfamiliar medical vocabulary".[2] Clinicians may also struggle to quantify the risks, due to the unpredictable nature of cancer and varying patient responses to therapy. Moreover, patients may try to put on a "brave face" infront of family members who have accompanied them, and avoid discussing their situation for fear of upsetting those closest to them.

The patient's treatment choice and decision may be further compromised if one member of the team is more authoritative and biased towards a certain regime. In training institutions patients are generally screened and treated by registrars under the guidance of a consultant. The former are required to fulfil certain procedural quotas during their training time, and may be tempted to "persuade" patients into accepting the treatment modality that fits their needs. Others may be torn by their desire to provide ideal treatment, yet having to settle for carrying out only those procedures that fall within the budgetary constraints of the hospital.

Clinicians may be guilty of adding to the patient's confusion by playing down the severity of the proposed treatment with phrases such as "you have cancer, will you prefer to have it cut out (surgery) or to have the machine (radiotherapy)?" Patients may not be given all the relevant information and could have misperceptions about the implications and side effects of each, yet are expected to make an informed and considered decision almost immediately. For example, if they opt for surgery, they should have an indication of the extent of the resection, if reconstruction will be possible surgically, and if so, how this will be achieved. Will donor sites be involved, will they have limitations in terms of facial appearance and function, the timing and number of operations anticipated, predicted success rates and associated costs. When radiotherapy is an option, they must understand what the procedure will entail, including awareness of the number and timing of sessions that must be strictly adhered to, common side effects such as xerostomia, trismus, limited movement, loss of taste, smell, vision or hearing, mucositis, recurrent oral infections, post radiation caries and the worst scenario, osteoradionecrosis.

Chemotherapy may leave them feeling nauseous, weak, with taste loss or dysgeusia, decreased immunity, and hair loss. Side effects of the latter two are time- and dose-dependent, and may be transient or permanent. Patients also need to know that some tumours may require a combination of surgery, radiotherapy or chemotherapy, and that individual responses and recovery rates are variable and unpredictable.

A further consideration is the harsh reality that in many third world countries and government institutions, waiting lists are prohibitively long, and equipment is not always available or operational. Thus, a patient who needs urgent surgery may only be given a theatre booking months later, by which time the tumour could have spread or become inoperable. Alternatively, one who should be treated with radiotherapy may not receive it if the hospital lacks the appropriate radiation facilities, or if equipment is broken.

These patients will be forced to settle for a less suitable treatment option along with greater adverse side effects. This raises the controversial and debatable issue of distributive justice, and fair allocation of limited resources.

A number of theories have been proposed to help decide on the fairest and most equitable way to share goods and services, in this case health care services and facilities.[4]

Utilitarian's would advocate sharing resources in a manner that results in the greatest good for the greatest number of people. Libertarianists believe people must get the health care services that they can afford and supports the concept of private health care. In communitarianism the health care needs of the community are given priority over those of individuals, while in egalitarianism everyone would receive an equal distribution regardless of their ability to pay.[5] In the case of cancer patients, the choice and decision is even more difficult as there are a number of additional considerations such as the age of the patient, their tumour type, stage and prognosis, their ability and willingness to comply with the treatment protocol, the costs of the intervention and subsequent rehabilitation, and their prognosis if they are not given the recommended therapy.

Emotional factors, family counselling and home care

Facial features and attractiveness "influence the reactions and judgements of other people".[3] Those considered more attractive are often perceived as being smarter, nicer and more successful than their less attractive counterparts, are received more positively at work and considered more popular in social settings.[3] Any sudden change in their facial appearance may cause profound psychological difficulties in terms of adaptation, self-acceptance and social adjustment.[3] In cancer patients, the anxiety and depression may be compounded by the fact that changes are sudden, and the resulting deformities can be patently visible and functionally limiting. They also have to deal with the uncertainty of their prognosis, risks of cancer spread and fear of death.

Some patients develop "marital problems, depression and anxiety, addictions, dysmorphic body images, post-traumatic stress disorder and poor satisfaction with life".[6] "The patient's personality, ability to cope, amount of social and family support, degree of pain, duration of hospital stay, loss of occupation, anxiety levels, and concern about their physical appearance may all affect their ability to adjust psychologically to their cancer and facial disfigurement".[7]

Home support from both family and trained counsellors is imperative to help integrate them into a normal way of life again. At the same time, throughout their treatment, from the demanding and information loaded consultation session, therapy, healing, rehabilitation, and post treatment monitoring, the focus is primarily on the patient, their treatment, and the outcomes. There is seldom much time or consideration given to the accompanying family members. However, they are an integral part of the team as they will need to provide emotional and/or physical support for the patient in the stressful months and years ahead.

They need to be included in the decision-making process, given advice on what to expect and how to manage the challenges of a debilitated family member, provided with dietary counselling, and introduced to a social worker or psychologist who will be able to "support the supporters". They may also have to take on the unpleasant task of helping patients clean their defects, insert, remove, and clean their prostheses, monitor the area for recurrences and apply necessary medication or dressings. To an inexperienced person this can be upsetting and emotionally disturbing.

Encouraging and providing physical and emotional support

For patients where surgical reconstruction will not be possible, they need to be advised about the possible prosthetic options, and where they can access these. Ideally the prosthodontist must be part of the multidisciplinary treatment team. This will allow them to make acquaintance with the patient and their families, and provide them with realistic expectation of what is achievable with a prosthesis.

They can provide information that other clinicians assume to be known. For example, a person scheduled to have an orbital enucleation or exenteration must understand that the prosthetic ocular or orbital replacement will never have vision. One who will be fitted with an obturator, or facial prosthesis must know that it will need some form of mechanical retention, that frequent adjustments and replacement are required due to material degradation, and that it will never restore their speech and mastication to pre-operative levels.

The World Health Organisation defines health as "A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".[8] This definition makes health depend on "whether the person has established a state of balance within themselves and their environment".[9] It entails that both the patient and their treating doctors remain aware of the need to work together in removing or alleviating the disease as well as help them adapt psychosocially.[9]

Treatment of cancer patients is far too often focused only on the physical eradication of the ailment, and ignores the mental and social aspects of health. It is thus not surprising that head and neck cancer patients hold the highest suicide rates, especially amongst married men. Predictors of suicidal tendencies were self-reported psychiatric histories, substance use as a coping mechanism, reduced quality of life, increased burden of head and neck cancer-related morbidity, pain, speech and masticatory impairment, and psychological distress.[10]

They also reported that medical and pharmacological interventions alone were not enough when it came to treating cancer patients, and stressed the importance of establishing structures within society to address their

mental state, and strengthen their family relations. They proposed creation of support groups where survivors could meet with those about to go through the process, in order to encourage and assist each another.[10]

CONCLUSION

When treating patients with head and neck defects, clinicians need to adopt a holistic approach towards establishing if someone is in "good health". They cannot only concern themselves with treatment of the disease and ignore the person suffering with it. They should make it their mission to find out how their patients feel about themselves and their condition, how the illness has affected their lives and that of their families, its impact on their work, and its effects on them psychosocially. They are instrumental role players in helping patients fight the ailment, as well as to live fruitful lives despite the associated side effects.[9]

The biggest challenge to us as clinicians as well as community members is to try and treat all patients holistically and to address both their physical and psychosocial needs. Included in this task is the need to promote health within the community, and to engage the support of those in allied medical disciplines, family members, friends, schools, the media, and even the legislature. This is a challenge which is before us as clinicians and as a community right now, and which requires from us a fervent commitment to action. In this sense it entails that we all stand together and help each other through all of our difficult times.

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CPD questionnaire

This edition is accredited for a total of 3 CEUs: 1 ethical plus 2 general CEUs

GENERAL

Perceptions of academic staff about mentoring in a Faculty of Dentistry in a public university in South Africa.

1. Select the CORRECT answer.
   The National Development Plan (NDP) 2030 mandated the Department of Higher Education and Training (DHET) to meet certain goals. Identify the statement that identifies those goals as referred to in this article:
   A. Increase the number of qualified librarians, peer-reviewed publications, and graduating master's students
   B. Increase the proportion of PhD qualified academic staff, publication count, and doctoral graduates.
   C. Increase the number of peer-reviewed publications, librarians, and doctoral graduates.
   D. Increase the number of undergraduate students who benefit from free tuition.
   E. None of the above

2. Which answer is CORRECT.
   The Department of Higher Education and Training introduced the University Capacity Development Program (UCDP) for the development of:
   A. Undergraduate academic programs, undergraduate students, and academic staff
   B. Postgraduate academic programs, undergraduate students, and academic staff
   C. Students, staff, and academic programs
   D. Undergraduate academic programs, undergraduate students, and administrative staff
   E. Postgraduate academic programs, undergraduate students, and administrative staff

3. Select the CORRECT answer.
   The methodology of this study had the following characteristics:
   A. Cross-sectional study using a questionnaire and randomized sampling
   B. Prospective study using a questionnaire and purposive sampling
   C. Cross-sectional study using a questionnaire with closed-end questions
   D. Prospective study using a questionnaire with both closed-end and open-ended questions
   E. Cross-sectional study using a questionnaire and purposive sampling

Evaluation of preparation times of WaveOne Gold reciprocating instruments compared to two analogous counterparts

4. Choose the CORRECT answer.
   Rotary vs. reciprocating root canal preparation technique show:
   A. less debris accumulation with reciprocating technique
   B. more cleaning effectiveness with rotary files
   C. rotary files have a lower incidence of breakage
   D. Not one of the above

5. Select the CORRECT option.
   WaveOne Gold Glider have the following characteristics:
   A. ISO 17 tip size
   B. Variable taper from 2% at D0 to 6% at D16
   C. Rectangular cross section
   D. Rotating instrument

6. Select the CORRECT answer.
   In this study there was:
   A. A significant difference between the canal preparation times between WOGG/PWOG and EGP/PEOF ($p< 0.05$)
   B. A significant difference between the canal preparation times between WOGG/PWOG and OFGP/POFS ($p< 0.05$)
   C. A significant difference between the canal preparation times between EGP/PEOF and EGP/PEOF ($p< 0.05$)
   D. No significant differences between the canal preparation times of the three groups tested ($p>0.05$)

Oral health knowledge, attitudes, and practices of undergraduate students at a South African University of Technology

7. Choose the CORRECT answer. The habits researched in this study were structured around drinking alcohol and smoking. The results showed differences between males and females.
   A. It was noted that more males smoke than females
   B. Nearly 80% of the participants had never smoked
   C. Over 99.1% of participants have never had an alcoholic drink
   D. Over 60% drink over (n=2) alcoholic drinks per week.

8. Select the CORRECT option. Literature suggests some of the risk factors causing oral health disorders worldwide include the following:
   A. poverty
   B. diet and smoking
   C. poor oral hygiene
   D. All the above

9. Choose the CORRECT option.
This was a cross-sectional descriptive study design that used the following methods:
A. Qualitative method only
B. Both qualitative and quantitative methods
C. Quantitative method only
D. None of the above

Correctional repositioning of pathologically migrated maxillary premolars through periodontal therapy

10. Select the CORRECT answer.
Pathological tooth migration is:
A. displacement of tooth when balance among factors that maintain physiologic position is disturbed
B. change in position of teeth when occlusal forces exceed adaptive capacity
C. displacement of teeth due to bifurcation and trifurcation involvement of multirooted teeth
D. change in position of teeth due to incomplete periodontal therapy

11. Which option is CORRECT.
In periodontal disease the abnormality in pathological migration primarily rests in:
A. Abnormally located proximal contacts
B. Unreplaced missing teeth
C. Weakened periodontium
D. Increased width of periodontal space

12. Choose the CORRECT answer.
After periodontal therapy, during spontaneous repositioning, pathologically migrated teeth tend to move:
A. Straight in the direction of site that exhibited greatest initial probing depth
B. Axial inclination of posterior teeth, tipping of anterior teeth
C. Flaring in the anterior teeth
D. Diametrically opposed to the site exhibiting the most severe destruction

13. Choose the CORRECT option. The rate of tooth spontaneous repositioning after therapy is observed as:
A. Slow in the beginning that becomes rapid later
B. Rapid in the beginning that becomes slow later
C. Remains same throughout
D. No change in position

A review of the 2030 Human Resources for Health Strategy: implications for dentistry in South Africa

14. Choose the CORRECT answer.
How was the current number of registered oral health care workers in South Africa determined in the South African National Department of Health 2030 Human Resources for Health Strategy report?
A. The report used the Health Professions Council of South Africa (HPCSA) database
B. The report used the Governments Personnel and Salary (PERSAL) system
C. The report used a combination of the HPCSA and PERSAL systems
D. The report used the 2018 graduation lists from the dental schools

15. Which is the CORRECT model.
Which of the models that was used reported a possible excess of dentists by the year 2025?
A. Primary Health Care approach model
B. Achieving Interprovincial Equity model
C. Specialist and auxiliary staff model
D. Public Sector Health model

16. Select the CORRECT answer.
Using the Primary Health Care (PHC) model, how much of additional funds (in Billions) would the National Department of Health have to allocate in order to meet the necessary oral health workforce needs?
A. R2.323
B. R2.056
C. R2.828
D. R2.070

Clinical Window: What's new for the clinician?

17. Select the CORRECT answer.
In the BRIEF study, the number of patients that needed a second procedure was:
A. 29
B. 8
C. 38
D. 1

18. Which option is CORRECT.
A very high acid concentration in a solution would most likely be reflected by which of the following pH score:
A. pH 3.4
B. pH 7.0
C. pH 12.2
D. None of the above

Radiology Case Report: Gardner syndrome

19. Choose the CORRECT answer.
Gardner syndrome arises as a result of a mutation in which of the following genes?
A. APC
B. p53
C. BCL2
D. SWI/SNF

20. Select the CORRECT answer.
Gardner's syndrome comprises a classic triad of:
A. Colonic ulcers, multiple osteomas and an array of hard tissue tumours
B. Colonic polyps, multiple osteomas and an array of soft tissue tumours
C. Colonic polyps, multiple osteblastomas and an array of hard tissue tumours
D. Colonic ulcers, multiple osteoblastomas and an array of soft tissue tumours

ETHICS

Looking beyond the physical management of patients with head and neck cancer

21. Choose the CORRECT answer.
    Looking beyond the physical management of patients with head and neck cancer, newly diagnosed cancer patients:
    A. should not be stressed by having fine details of their conditions explained
    B. should not be informed that treatment outcomes are uncertain
    C. should not delay treatment by taking too long to decide on therapy
    D. may not be competent to make treatment decisions based on their anxiety
    E. should avoid being confused by opinions of family and friends

22. Select the CORRECT option.
    Unethical factors that can influence a patient's treatment include:
    A. Where one member of the team is biased towards a certain regime
    B. Treatment being dictated by registrar quota needs
    C. Treatment based on available budget
    D. Only A and B above are unethical
    E. All of the above are unethical

23. Which of the following options is CORECT.
    Clinicians should not stress newly diagnosed cancer patients and should:
    A. down play the severity of their condition
    B. down play the proposed treatment times and associated morbidities
    C. not expect patients to decide on their preferred treatment options
    D. None of the above are correct
    E. Only A and B above are correct

24. Which is the CORRECT answer.
    Which of the following statements is not correct?
    A. Distributive justice deals with fair allocation of limited resources
    B. Utilitarianism seeks the greatest good for the greatest number of people
    C. Libertarianism do not support private health care
    D. Communitarianism prioritize community needs
    E. In egalitarianism everyone receives an equal distribution

25. Choose the CORRECT answer.
    The World Health Organisation definition of health implies:
    A. Only that the patient be rendered disease free
    B. That a person establishes a state of balance within themselves
    C. That clinicians are also responsible for helping patients adapt to their illness
    D. Only A and C are correct
    E. Only B and C are correct

Online CPD in 6 Easy Steps

The Continuous 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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