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Medical and Dental Hydrology

Hydrothermalism refers to the water / steam manifestations seen on the ground as a result of waters welling up from the deep underground areas. Due to their heated origins, they usually contain a number of dissolved minerals and algae. Their physical and chemical properties have long been revered and valued for their many purported therapeutic effects. The father of Medicine, Hippocrates may have been one of the first to study the healing properties of water. However, it took many centuries for medical hydrology to become recognised as a branch of medicine, and only in1986 was it officially accepted by the World Health Organisation as a complementary tool1. Dentistry too has embraced hydrology by supporting the valuable role of water fluoridation plays in tooth and bone development, prevention of dental caries, and possible remineralisation of enamel. In the early 1940's, the US Public Health Service appointed a dentist, Dr. H.T. Dean, to carry out research into the possible link between water fluoride levels and tooth staining. He undertook a series of epidemiological investigations, culminating in his famous "21-City Study". The results published in 1942, showed that mottling of the teeth was rare at fluoride levels below 1ppm, while at the same time there was evidence of a caries preventive effect at 1ppm. Numerous other studies followed and in 1945, Grand Rapids, Michigan, became the first town in the world to institute artificially fluoridated water.

This treasured landmark and tourist attraction has been described as "An ethereal icy blue heaven, where white steam rises up from the vibrant water, closed in by black snow-capped rocks". Its geothermal waters originate 1.2 miles below the surface where freshwater and seawater combine at extreme temperatures, and pick up many therapeutic minerals and algae that account for its healing reputation and brilliant blue colouring.

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Our Front Cover for this Issue...

The Fontana di Trevi or Trevi Fountain in Quirinale, Italy
Fountains and springs are a symbol of new hope, vitality, and life. For this reason it was decided to features springs and fountains on the cover pages of the SADJ and use them as an analogy for dentistry and dental education. The first edition of 2022 features one of the world's most iconic and well-known water features, The Fontana di Trevi or Trevi Fountain in Quirinale, Italy.

The Trivium or intersection is symbolic of a meeting of minds. One cannot forever be taking from the fountain without adding back to the pool. The waters may be topped up with a wealth of knowledge coming from various sources, such as research and publications, presentations, discussions, reporting on cases and experiences, and teaching. At the Trevi fountain people add wealth by throwing coins into the water. Sharing wealth (knowledge) with others also has a beautiful ripple effect. The money is collected each night and given to an Italian charity called Caritas which supports a supermarket that gives rechargeable cards to the needy to help them purchase groceries. We hope that our sharing may also be collected and spread amongst those with a hunger for mental nourishment, growth and education.

Courtesy Prof Leanne Sykes

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Progression of Dentistry after COVID-19

SADJ February 2022, Vol. 77 No. 2 p55

Prof NH Wood - *MDent, PhD*

During the COVID-19 pandemic many changes and adaptations were forced onto the profession. This was most clearly demonstrated in the development and implementation of new educational approaches and pedagogies to ensure ongoing clinical competency training. Many dental students had to adapt rapidly to online teaching and learning environments, to a spectrum of innovative assessment methods, and to limited engagement in a clinical setting. This went together with revised clinical competency training methods and interventions to compensate for lost clinical time. The question that remains is whether these changes will remain in place after the pandemic, because practitioners qualifying during the pandemic are ultimately certified as clinically competent; or whether this innovative approach still requires further scrutiny and validation.

The advancement in educational techniques and philosophies is paralleled by technological development and a steady evolution of the modern dental practice. We are seeing higher demands from patients to deliver suitable interventions in shorter times. There is also a rapid development in dental materials sciences which is in part fueled through commercialization. Ultimately the dental practice is a business that needs to protect profits to remain viable and to deliver services. To achieve this, many have to adapt to the general direction that dentistry is going in today or face more demanding challenges. Ultimately if the practitioner's hands are idle, there is no income, and many practices already paid a heavy price during the lockdown phases of the pandemic.

The modern dental practice needs to remain competitive and relevant in the fast-evolving dental profession. One of the main challenges faced by many colleagues is how to stand out and distinguish their own clinic in the market. Practices are continually faced with attracting and retaining patients, difficult decisions such as equipment investment, implementing new treatments and procedures, delivering on continuing professional development requirements and updating clinical skills. Many have reworked patient workflows and implemented teledentistry or teledental components into their daily practice as a direct answer to the COVID-19 restrictions. These newly adopted approaches and innovations to remain competitive have opened up a new discussion about reimbursement for these services rendered, limitations in scope, and appropriate skill development, and many of these novel developments still need to be tested and validated.

Dental education must be continually reworked to incorporate the latest picture of the modern dental practice in the country in conjunction with the needs of all the people. These aspirant practitioners need to be ready and competent to step into their new role with the least amount of disruption. Post-qualification development and delivery of training that is not affiliated to a particular dental school is playing an increasingly important role in the educational setting for practicing clinicians. With the rapid development of communications and information technology platforms, the acquisition and integration of knowledge by those willing to learn has become very easy. Regulatory and statutory bodies therefore run the risk of falling behind in the evolution of different scopes of practice and modernization of the profession, and they must be proactive to participate and facilitate the adaptation of dentistry's development. We may even find the need for implementation of new fields of specialization is much closer than anticipated.

https://www.freepik.com/free-vector/coronavirus

Modern dentistry will determine its own path, and this is an exciting journey to be on.

World Oral Health Day (WOHD)

SADJ MARCH 2022, Vol. 77 No. 2 p56

Dr Nthabiseng Metsing, Head: Professional Development, SADA

Last year, the FDI launched their three-year campaign theme: **BE PROUD OF YOUR MOUTH.**

Be Proud of Your Mouth is not about having a perfect mouth; it is also about having a healthy one.

The FDI would like people to value and take care of their oral health and to make the correct decisions in order to protect their oral cavity. This good oral status will require a lot of action: Be Proud of Your Mouth by doing this. For example, Be Proud of Your Mouth by visiting the dentist regularly; Be Proud of Your Mouth by brushing your teeth twice, a day; Be Proud of Your Mouth by cutting down on sugary treats. To inspire action, we need to explain 'why', and this is where the campaign strapline fits in.
In 2021, the FDI encouraged the public to take action by focusing on the importance of oral health in order to enhance overall health. Now in 2022, they are reiterating this message by highlighting the fact that an unhealthy mouth can severely impact every aspect of life. That is why they calling upon everyone to:

LOOK AFTER THEIR ORAL HEALTH FOR THEIR HAPPINESS AND WELL-BEING.

There is no denying that Oral health is multi-faceted as it allows one the ability to speak, smile, smell, taste, touch, chew, swallow and convey a range of emotions with confidence and without

pain, discomfort and disease. An unhealthy mouth can restrict your capability to perform these everyday functions, which can have a severe impact on your quality of life by affecting your emotional, social, mental, and overall physical well-being.

Poor oral health can negatively impact personal value and self-image, which is harmful to emotional well-being, contrary to this good oral health can help us keep a positive state of mind. There are also emotional advantages of smiling, and a healthy mouth can give you the confidence to smile more often, further improving general feelings of wellness.

A stable mental health status includes our emotional, social, and psychological well-being and this affects how we think, feel and act, and is important at every stage of life. Oral diseases have far reaching consequences from missing work and school, to low self-confidence and how you socialize, or even your ability to enjoy a simple meal. The encouraging news is that most oral health conditions are principally preventable and can be treated in their early stages to prevent further progression.

Human beings build their social well-being and interpersonal skills by interacting with others and not social isolation. Oral diseases can impact personal relationships and make us more resistant to social interactions. Feeling embarrassed about our teeth and mouth can result in social withdrawal and isolation. A healthy mouth can also lead to better sporting performance and help prevent sports injuries.

The notions of emotional, social and mental well-being can sometimes be explained in different ways because they generally overlap.
For the purposes of this campaign, the following definitions have been applied:

- Emotional well-being: how we think, feel and relate to ourselves. It is about having healthy self-esteem.
- Social well-being: how we interact with others. It is about being positively engaged with the world.
- Mental well-being: it is mainly the absence of mental disorders. It is about our ability to cope with day-to-day life, work productively and the contribution we make to the community.

While we are cognisant of the fact that there are widespread disparities that exist around access to, and uptake of, oral health services and the financial constraints the governments are having, we know that Universal Health Coverage (UHC) especially for oral health services, cannot be achieved overnight. We also take advantage of moments like WOHD as an opportunity to persuade our governments to do more especially if a lot of the resources are channelled to primary healthcare and health promotion. Countries at all income levels can take steps towards achieving UHC by developing strong basic packages that integrate sound oral healthcare.

We encourage all our members to participate in this year's World Oral Health Day and encourage their patients to also participate. By posting the be proud of your mouth slogan all over social media and also adding photos of the mouths to show how they are looking after their mouth.

Let's all be part of the positive change that we want to see.

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Comparison of capsule-mixed versus hand-mixed glass ionomer cements

Part 1: compressive strength and surface hardness

SADJ March 2022, Vol. 77 No. 2 p57 - p64

S Arnold [1], N Warren[2], G D Buchanan[3], R Lombard [4]

ABSTRACT

Introduction

Dental restorative glass ionomer cements (GIC) are available as hand-mixed or capsulated products. Capsulation facilitates uniform ratios of powder to liquid, that should result in an optimal end-product. If this is evident, the degree to which capsulated GIC are mechanically stronger will aid in deciding when to use them instead of the hand-mixed variety.

Objectives

The compressive strength and surface hardness of hand-mixed GIC were compared to capsule-mixed equivalents.

Methods

Eighty samples were manufactured from hand-mixed GIC: Riva Self Cure; Fuji IX GP; Ketac Universal, Ketac Molar Easymix, and equivalent capsule-mixed GIC: Riva Self Cure; Fuji IX GP; Ketac Universal Aplicap and Ketac Molar Aplicap.

Compressive fracture strength was tested using a universal testing apparatus. Surface hardness was measured with a Vickers digital micro-hardness tester.

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ABBREVIATIONS FOR ARTICLE

- GIC – Glass Ionomer cement
- FIXC – GC Fuji IX GP capsule-mix
- FIXH – GC Fuji IX GP hand-mix
- RSCC - Riva Self Cure capsule-mix
- RSCH - Riva Self Cure hand-mix
- KUC - Ketac Unversal Aplicap capsule-mix
- KUH - Ketac Universal hand-mix
- KMC - Ketac Molar Aplicap capsule-mix
- KMH - Ketac Molar Easymix hand-mix
- ˚C – degrees Celsius
- % - percentage
- MPa - mega-Pascal/s
- VHN – Vickers Hardness Number
- rpm - revolutions per minute
- SD – Standard deviation
- IQR - interquartile range

Results

Significant differences were found between the compressive strength of RSCH and RSCC ($P = 0.027$), and, between KMH and KMC ($P < 0.001$). Significant differences in surface hardness were found between FIXH and FIXC ($P = 0.031$), KUH and KUC ($P < 0.001$), as well as KMH and KMC ($P = 0.006$).

Conclusion

Three capsulated forms of GIC (RSCC, KUC, KMC) demonstrated superior mechanical properties. Capsulated GIC offer advantages which may translate to clinical application.

Key words: Capsule-mix, Compressive strength, Glass ionomer cement, Hand-mix, Surface hardness.

INTRODUCTION

Dental materials are constantly evolving to offer therapeutic applications for the restoration of teeth, both the primary and permanent dentition.[1] Glass ionomer cements (GIC) are routinely applied for dental restorations as they demonstrate a unique ability to bond chemically to tooth structure.[2] This

results in excellent marginal adaptation and a sound seal between the set cement and tooth structure, preventing micro-leakage.[3,4] Bonding systems are not needed for glass ionomers, rendering these materials less technique sensitive [5] and more cost effective than resin composites, within the limitations of GIC clinical applications. As GIC absorb and release fluoride they can inhibit secondary caries formation.[6,7] As GIC are self-curing, they do not undergo polymerization shrinkage and can be placed in bulk.[7,8] The co-efficient of thermal expansion of these materials are similar to tooth structure, decreasing internal tension in the tooth structure adjacent to the restoration.[7,9] These materials are low in toxicity and biocompatible with both the dental pulp and surrounding soft tissues.[7,9]

GIC are commercially available for clinical use in two distinctive forms. Firstly, there is a two-bottle system consisting of a glass powder with a separate polyalkenoic acid liquid, which is hand-mixed.[10,11] Secondly there is a pre-packaged, capsulated formulation, containing a blend of glass powder and vacuum-dried polyalkenoic acid in one compartment,[10,11] with a second, separate compartment containing either distilled/deionised water or a solution of tartaric acid and water.[10,12] The capsulated form is mixed using mechanical mixing devices.[11]

Capsulated GIC have the advantages of a pre-proportioned, set powder to liquid ratio, standardised mixing techniques and standardised mixing times.[10,13] It can be argued that capsulated products could be more user-friendly and time efficient as compared to hand-mixed products.[14,15] Once mixed, the GIC can be injected into a prepared cavity directly from the capsule.[13]

The vibratory action of conventional mechanical mixing machines has been reported to lead to increased porosity in some capsulated GIC as compared to their hand-mixed equivalents.[13,16] Porosity within the cement acts as a source of concentrated stress, which negatively affects the set material's strength and homogeneity.[9,13,16]

Hand-mixed GIC, however, also have disadvantages. Operator variability is the leading cause of inconsistency of hand-mixed glass ionomer materials.[11,17,18] Both the density of the glass powder and mixing technique of the operator play a role in the actual volume of powder that is dispensed using the measuring scoop.[18] The volume of the liquid component is difficult to calibrate due to inconsistencies in the angle at which the bottle is held and the pressure exerted on the bottle by the operator when dispensing the liquid.[11,17,19] Air bubbles present in the liquid can influence the volume of liquid dispensed.[18] Both the mixing time and manipulation technique can contribute to operator-induced variability.[18] The environmental humidity and temperature have also been shown to influence the cement's consistency.[18]

In the clinical setting, the aforementioned problems are exacerbated as oftentimes the scoop and dropper bottle systems supplied by the manufacturer are not used, and the products are mixed according to the operators' desired consistency.[10,19,20] All these factors may result in a mixture not having the ideal characteristics when mixed according to the manufacturer's instructions.[18,19,21] The resulting material will subsequently be weaker, with altered chemical, mechanical and physical properties,[18,19] and inconsistent setting times.[18] Scientific literature reports conflicting evidence regarding whether capsulated GIC or hand-mixed GIC offer superior performance.[13,22] Dowling and Flemming[10] advocated the use of capsule-mixed glass ionomer restoratives due to the superior mechanical properties of these products. A study done by Kaushik *et al.,*[16] proved the contrary, and promoted the use of hand-mixed glass ionomer restoratives. White *et al.,*[23] reported that capsule-mixed glass ionomer luting cements have inferior mechanical properties to their hand-mixed equivalents. The findings of the study by Mitchell *et al.,*[24] however, showed that capsule-mixed glass ionomer luting cements were superior.

OBJECTIVES

The aim of this present study was to compare the compressive strength and surface hardness of four commercially available GIC in both their hand-mixed and capsule-mixed formulations.

METHODS

Ethical approval for this comparative in vitro study was obtained from the Research Ethics Committee of the Faculty of Health Science of the University of Pretoria (Protocol number: 206/2017). The materials tested in the present study included eight glass ionomers: Riva Self Cure Hand-mix (RSCH, SDI Ltd., Victoria, Australia); Fuji IX GP Hand-mix (FIXH, GC, Tokyo, Japan); Ketac Universal Hand-mix (KUH, 3M, St. Paul, Minnesota, USA); and Ketac Molar Easymix Hand-mix (KMH, 3M, St. Paul, Minnesota, USA), Riva Self Cure Capsules (RSCC, SDI Ltd., Victoria, Australia); GC Fuji IX GP Capsules (FIXC, GC, Tokyo, Japan); Ketac-Universal Aplicap Capsules (KUC, 3M, St. Paul, Minnesota) and Ketac-Molar Aplicap Capsules (KMC, 3M, St. Paul, Minnesota).

According to the information in the manufacturer's brochures for each product, these dental cements have similar compressive strength, surface hardness and wear resistance.[15,25,26]

This research was performed in a controlled environment meeting the manufacturer's recommendations of a temperature of 23 +/- 1˚C and relative humidity of 50 +/- 5%.[27,28] The test materials were mixed and dispensed into polytetrafluoroethylene (PTFE) cylinders with the following internal dimensions: six millimetres (mm) in height and four mm in diameter, in accordance with previously described methodology.[10,18,28,29,30] The moulds were constructed from PTFE tubing, supported by a custom-made Perspex® matrix.[13] Specimens were prepared by two operators with the same level of training in order to simulate operator variability.[19,29] Both dental operators had over ≥ 15 years of clinical experience and experience in Academic teaching and training (Dentistry) for ≥ eight years. The calibration of the two operators was ensured by both carrying out all preparation precisely as per the manufactures' instructions and all research procedures carried out strictly according to the research protocol.

The measuring scoops and liquid dropper bottles provided for each respective hand-mixed material were used to measure the exact quantities as prescribed by each

manufacturer. The powder and liquid quantities of the hand-mixed materials were intentionally not weighed to simulate the setting in clinical practice.

Four groups of ten cylindrical specimens were manufactured for each of the four hand-mixed and capsule-mixed glass ionomers for each test that would be performed. Following the manufacturer's instructions, the GC Fuji IX GP capsules were shaken to loosen the powder before activation.[31]

Following the manufacturer's recommendations, each capsule was activated for two seconds to break the membrane separating the powder and liquid compartments.[10,27,31] The capsules were then immediately placed into an applicable mechanical mixing machine.

The 3M ESPE capsules were mixed in the Rotomix™ (3M ESPE, United Kingdom) as follows: eight seconds vibratory action; three seconds centrifuging action, at a frequency of 2950 rpm (as recommended by the manufacturer).[10,13,27] Following the manufacturer's instructions, the other capsules were mixed by vibratory action, with an amalgam-mixer (Amalgamator SYG 200, SMACO, Switzerland) for 10 seconds.[10,27] Immediately after mixing, each capsule was placed in an appropriate applicator to facilitate the extrusion of the material.[10,27]

Following the respective manufacturer's instructions, each of the hand-mixed GIC, was manually mixed on a waxed-paper mixing pad using the scoop and dropper system provided.[19]
The cylindrical moulds were placed on a polyester sheet in the custom Perspex® matrix. The mixed cement for each sample of all groups was dispensed into the moulds within 60 seconds of mixing.[13,18,29] To minimise the incorporation of air bubbles the capsulated glass ionomers were extruded slowly which provided laminar flow with the nozzle positioned along one side of the mould.[10,29,32] The hand-mixed glass ionomers were dispensed into the moulds using a stainless steel spatula and were allowed to passively flow into each mould to minimise the incorporation of air bubbles.[10,18] A polyester sheet was placed over the filled moulds and the samples were compressed by applying slight pressure with a glass slab weighing 60 grams,[33] to extrude the excess material and flatten the surface.[9,33,34]

The Ketac Molar specimens were covered with petroleum jelly and the Ketac Universal specimens were not covered with any coating, according to manufacturer's instructions.[15,26] The specimens of the remaining test groups were covered with their respective coatings as recommended by the manufacturers.[35] An LED curing light (Valo, Ultradent Products Inc., South Jordan, USA), with a light-intensity of 450nm was used to cure the coatings for ten seconds.
All specimens were placed into glass containers of distilled water at a consistent temperature (37+/- 1°C) in an incubator (Binder ED[23], Tuttlingen, Germany) for one hour.[13,18,29] After this surplus cement was removed from the top and bottom of the moulds with silicon carbide paper (880 grit), under running water.[13] Each specimen was carefully removed from its mould and stored in distilled water at 37 °C for 23 hours and testing took place 24 hours after production.[18,29,36] Any specimen with visible defects such as bubbles or cracks was discarded and replaced to achieve optimal samples for the final number of samples.[18,29]

Table I. Results of the compressive strength testing for all specimens

Material	RSCH	RSCC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) (MPa)	86.8 (24.3)	110.8 (20.1)	0.027*
Median (IQR) (MPa)	88.3 (63.4 - 107.7)	109.7 (92.7 - 125.6)	0.045**
Min/Max (MPa)	41.4/114.7	85.2/149.4	

Material	FIXH	FIXC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) (MPa)	102.9 (22.2)	112.6 (13.5)	0.254*
Median (IQR) (MPa)	106.1 (89.4 - 121.5)	108.5 (101.7 - 126.5)	0.364**
Min/Max (MPa)	55.4/127.5	96.8/132.9	

Material	KUH	KUC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) (MPa)	110.2 (20.1)	125.2 (17.2)	0.090*
Median (IQR) (MPa)	112.7 (100.9 - 122.7)	121.7 (115.2 - 144.1)	0.131**
Min/Max (MPa)	78.5/145.4	100.3/153.0	

Material	KMH	KMC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) (MPa)	89.6 (13.6)	138.7 (18.4)	<0.001*
Median (IQR) (MPa)	85.3 (81.1 - 92.5)	141.3 (122.5 - 155.0)	<0.001**
Min/Max (MPa)	72.8/115.2	109.2/163.1	

* Two sample t-test
** Non-parametric Wilcoxon Rank-Sum test

Compressive fracture strength

A universal testing apparatus (MTS Criterion Model C45.305, MTS Systems Corporation, MN 55344-2290, USA) was used to measure the compressive fracture strength of each specimen. The flat, circular ends of each cylindrical specimen were placed between the plates of the testing apparatus.[55] Moist filter paper was placed on each circular surface to prevent dehydration before testing.[37] A compressive load, which gradually increased at a rate of 1 mm/min, was applied along the long axis of each specimen, until the sample fractured.[10,18,27,29,30] The resulting data was analysed using the tester software - MTS Testsuite (TW Elite software, MN 55344-2290 USA). The load to fracture was recorded.

The following equation was used to calculate the compressive fracture strength*, P (MPa):

$$P = \frac{4F_f}{\pi d^2}$$

*where: Ff represents the load at fracture (N); π constant for Pi is 3.14 and d the mean diameter of the specimen in millimetres (mm).[10,17,29,37]

Surface hardness

The micro-hardness of the surface of each sample was digitally measured with a Vickers pyramid square diamond indenter (Future-Tech FV 700, Kanagawa, Japan). Five points were designated on one of the circular surfaces of each specimen before the surface hardness test was undertaken. The first allocated point was set in the midline of the long axis of the sample. The other four points were evenly spaced one millimetre apart, lateral (left and right) to the first point.[38] The indenter of the Vickers' hardness machine was pressed vertically into the surface of each sample with an opening angle of 136 degrees, at these five points of each specimen.[34] A load of 500 micro Newtons (mN) was applied by the indenter,[15,37] at each of the five pre-designated points on each specimen,[39] with a dwell time of five seconds.[34,40] The Vickers hardness number (VHN), was calculated by the instrument for each indentation according to the selected diagonals.[37] The mean VHN in N/mm^2 for each specimen was determined.[40]

Statistical analysis

Statistical analysis was performed using SAS (SAS Institute Inc, Carey, NC, USA), release 9.4, running on Microsoft windows for personal computer. The applied statistical tests, two-sided and P values less than 0.05, were considered significant. Mean values for compressive strength and surface hardness were compared using the two-sample t-test. Thus any significant differences between the means of the paired test groups could be determined. The non-parametric Wilcoxon Rank-Sum test was used to compare the median values of the paired groups.

The null hypothesis was that there would be no difference in either the compressive strength nor the surface hardness, between the hand-mixed glass ionomers and each material's equivalent capsule-mixed glass ionomer. Data was examined for normality by evaluating the data distribution and the Shapiro-Wilk test. The data showed normal distribution, despite a few exceptions which were determined to be chance outcomes.

RESULTS

The results of the compressive strength tests are reflected in Table I. A statistically significant difference (P = 0.027)

Table II. Results of the surface hardness testing for all specimens

Material	RSCH	RSCC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) (VHN)	53.4 (8.4)	59.6 (8.9)	0.124*
Median (IQR) (VHN)	56.3 (47.8 – 58.9)	56.9 (53.4 – 67.2)	0.290**
Min/Max (VHN)	38.6/63.5	46.5/75.8	
Material	**FIXH**	**FIXC**	**P-value**
Number of specimens (n)	10	10	
Mean (+- SD) (VHN)	61.2 (8.8)	72.8 (12.9)	0.031*
Median (IQR) (VHN)	56.9 (53.9 – 68.9)	72.3 (64.2 – 79.3)	0.034**
Min/Max (VHN)	52.4/74.7	55.0/93.3	
Material	**KUH**	**KUC**	**P-value**
Number of specimens (n)	10	10	
Mean (+- SD) (VHN)	53.4 (20.7)	97.4 (11.1)	<0.001*
Median (IQR) (VHN)	53.62 (34.8 – 72.2)	100.7 (83.9 – 104.8)	<0.001**
Min/Max (VHN)	28.7/89.5	81.2/112.8	
Material	**KMH**	**KMC**	**P-value**
Number of specimens (n)	10	10	
Mean (+- SD) (VHN)	60.8 (9.8)	73.7 (8.8)	0.006*
Median (IQR) (VHN)	57.1 (54.6 – 69.6)	75.6 (68.0 – 79.1)	0.019**
Min/Max (VHN)	48.3/79.4	54.9/85.3	

* Two sample t-test
** Non-parametric Wilcoxon Rank-Sum test

was found between the mean compressive strengths of the RSCH and RSCC paired groups, at 24.04 MPa. The difference between medians of these two materials was also statistically significant (P = 0.045), differing by 21.35 MPa. The mean compressive strength of KMH and KMC differed by 49.11 MPa. This difference was also statistically significant (P < 0.001), and the median values of these two groups differed by 56 MPa (P < 0.001). No significant differences were observed in the compressive strength of samples of the FIXH- and FIXC- groups (P > 0.05). Similarly, no significant differences were observed between the compressive strength of the samples of the KUH- and KUC- groups (P > 0.05).

The results of the surface hardness testing are represented in Table II. The surface hardness data for the FIXH and FIXC paired group exhibited a mean difference of 11.5 N/mm^2 in VHN values for the two groups, which was statistically significant (P = 0.031). In addition, the median VHN for the two groups differed by 15.36 N/mm^2, which was also statistically significant (P = 0.034).

The surface hardness between the KUH and KUC paired group was significantly different: the mean VHN for the two groups differed by 43.96 N/mm2 (P < 0.001) and the median VHN for the two groups differed by 47.03 N/mm^2 (P < 0.001).

The KMH and KMC paired group presented with mean VHN values that differed by 12.95 N/mm^2 (P = 0.006). The median VHN values differed for the two groups by 18.54 N/mm^2 (P = 0.019). There was no significant difference in the surface hardness of RSCH and RSCC, neither in the mean (P = 0.124), nor the median (P = 0.290).

DISCUSSION

Dental materials and the clinical application thereof is continuously evolving to try and produce dental restorations that are biologically compatible, have optimal mechanical properties, as well as the best possible aesthetics.[41,42] Testing the compressive strength and surface hardness of dental materials, gives a close indication to the potential longevity and wear resistance of these materials.[41] The compressive strength of a dental material can measure both the durability,[42] and the brittleness of a material.[40]

The present study indicates that there may be an advantage in the use of RSCC with respect to the compressive strength of this material. Significant differences were found between the mean and median compressive strengths of the RSCH and RSCC paired group specimens. Previous studies by Dionysopoulos *et al*.[38] and Mulder and Mohamed,[37] reported similar compressive strength values for RSCC to those found in the present study.

The present study showed that there was no significant difference in the compressive strength of the FIXH and FIXC specimens tested. Fleming and Zala,[22] previously found FIXH to have a lower compressive strength as compared to FIXC. Dowling and Fleming,[17] however, reported that FIXH had significantly higher compressive strength values than those of FIXC,[43] suggesting that the compressive strength of the hand-mixed version is superior for this material-paired group.[17] The compressive strength values from the present study were slightly lower as compared to the manufacturer's in-house research.[43] No definitive recommendations could therefore be made with regards to this material.

No significant differences in compressive strength were observed between the KUH and KUC groups in the present study. Similar compressive strength values for these materials were reported by Dionysopoulos *et al*.[44] Compressive strength values for this material, published by the manufacturer as in-house research demonstrated higher compressive strength compared to those of the present study.[15,26] The study conducted by Mulder and Mohamed,[37] reported slightly lower compressive strength values for KUC when compared to this present study.

In this present study, the compressive strength of KMC was significantly higher when compared to KMH. This finding suggests that the capsule-mix may be advantageous for clinical use, specifically where high compressive strength is important. This finding is in agreement with the findings of Nomoto and McCabe.[13] Dowling and Fleming,[17] however, found no significant difference between the mean compressive strength of KMH and KMC in their investigation. The compressive strength values for KMC in the present study correlate well with the findings of Fleming *et al.,*[29] regarding this encapsulated glass ionomer.

Determining correlations between mixing methods and mechanical properties of glass ionomer cements may be complicated.[13,17] The chemical composition and setting phase progression are the two most critical factors that regulate the mechanical properties of GIC.[13] The powder to liquid ratio can influence the mechanical properties of this material, as this influences the concentration of reinforced glass fillers particles in the set cement.[13]

The more powder added to a constant volume of liquid, the higher the concentration of reinforced glass fillers and the more resistant the product will be to compressive forces.[13] A reduced powder to liquid volume will reduce the reinforced glass filler content of the set cement, and reduce the material's ability to resist crack proliferation under compressive forces.[10] Billington *et al.,*[19] reported that the powder content of hand-mixed glass ionomers used in clinical practice was only 37% of that recommended by the manufacturer. Dowling and Fleming,[10] published similar findings, reporting a powder content below 50% of manufacturer's recommendations.

For RSC and FIX materials, the powder to liquid ratios for the hand-mix versions are slightly higher than those of the equivalent capsule-mix products. KUC also has a slightly higher powder to liquid ratio than KUH. The powder to liquid ratio of KMH is substantially higher than that of KMC. The reason for this high powder to liquid ratio in KMH (the hand-mixed glass ionomer), could be attributed to the highly granular nature of the powder, making it less dense, more flowable and more absorbent.[45] These differences in powder to liquid ratios between hand-mixed and equivalent capsule-mixed products may influence research findings when comparing mixing methods and mechanical properties. In striving to produce glass ionomers with ideal properties in either hand-mixed or capsule-mixed preparations, the challenge lies in finding an optimal balance between powder to liquid ratio, polyacid concentration and the molecular weight of the polyacid.[46]

Voids in the set cement could either be the result of insufficient wetting of the powder by the liquid, or the inadvertent inclusion of air during the mixing procedure. The presence of voids and the concentration of reinforced glass filler

particles have a notable impact on the mechanical properties of GIC.[13] The larger and the more voids present, the greater the probability of fracture at low levels of stress.[13] Xie *et al.,*[9] suggested higher compressive strength values to be related to more dense surface textures with fewer, smaller voids and tightly packed glass filler particles. Material failure has been attributed to surface irregularities and cracks in conjunction with internal and surface porosity.[22]

Surface hardness is defined as the ability of a material to resist permanent indentation or piercing when a force is applied to the material.[40] The harder the surface, the higher the Vickers hardness measurement (VHN) will be.[40] Xie *et al.,*[9] concluded that higher surface hardness values of glass ionomers are attributed to three factors: a variety of different shapes and sizes of glass particles, a highly fused particle-polymer matrix and a dense surface texture.

The present study found no significant difference in the VHN of RSCH and RSCC, which shows that neither of these two products offer an advantage over the other with respect to the property of surface hardness. Two previous studies reported similar values for surface hardness of RSCC with the values obtained in the present study.[37,38]

The present study identified significant differences in surface hardness between the FIX, KU, and KM paired groups. The capsule-mixed specimens of FIX, KU and KM exhibited significantly higher surface hardness numbers (VHN) in comparison to their respective, hand-mixed equivalents. In this present study, the surface hardness of KUC correlates well with the findings of both Alrahlah,[39] and those of the manufacturer.[15] Surface hardness values for KUC in the present study were higher than those reported by both Dionysopoulos *et al.,*[38] and Mulder and Mohamed.[37] The surface hardness values of FIXC from this present study were similar to those of the manufacturer (GC, Tokyo, Japan).[43]

The durability, strength, working and setting times of glass ionomer cements are dependent upon the use of the correct ratio of powder to liquid.[18,37] Studies have been conducted to determine the mechanical properties of the set glass ionomer cement when lower powder/liquid ratios are used than recommended.[22,37] Mulder and Mohamed,[37] evaluated and compared the actual powder/liquid ratios of several different commercially available capsulated glass ionomers. The capsules were disassembled, and the powder and liquid components were individually weighed. This study concluded that neither the compressive strength nor the surface hardness would be adversely affected by the findings.[37]

Manufacturers place precise values in grams for powder and liquid weights in product brochures and packaging. Furthermore, manufacturer's in-house research is based on these precise values.[37] A higher volume of powder to liquid ratio leads to shorter working and setting times, and higher compressive strength.[37] Final restorations mixed with a decreased powder to liquid ratio are more susceptible to acid erosion.[37,47] Capsulated GIC have been reported to be more costly per application in comparison to their hand-mixed equivalents.[18] Dental practitioners may thus elect to use hand-mixed glass ionomers instead of the capsulated equivalents of these materials. Prentice *et al.,*[36] experimented with the mixing times of GIC. It was found that optimal strength and handling properties required a capsule-mixing time of between eight to ten seconds.[36] Decreasing the mixing time was shown to prolong the working time and the setting time.[36] Increasing the mixing time led to increased viscosity of the material and reduced both the working and setting time.[36] The specimens that were mixed for 12 seconds showed an increase in modulus of elasticity and compressive strength.[36] If the mixing time was increase to 14 seconds, gelation occurred too quickly, rendering the dispensing and placement of the material very difficult.[36] This increased mixing time also decreased the modulus of elasticity and compressive.[36] In busy private practices, dentists may attempt to take advantage of the increased viscosity and decreased working and setting times of longer mixed capsulated GIC, however it is cautioned that this may negatively affect the mechanical properties of the final cement.[36]

The fluoride release profile of GIC could be influenced by the mixing method of these materials. De Moor *et al.,*[48] reported that mechanical mixing of capsulated GIC lead to a more predictable fluoride release than hand-mixed GIC.[48] Fluoride release is dependent on the acid-base and setting reactions.[47] This finding indirectly implies that both reactions are more consistent in capsule-mixed GIC.[48]

CONCLUSION

Within the limitations of the present study, it is evident that the correct mixing technique of glass ionomer cements is crucial to achieve the optimal mechanical properties of the final set material. The properties tested in this study showed that glass ionomer materials displayed variations that directly link the mixing technique to the resulting mechanical properties of the end-product.

The compressive strength of the capsule-mixed RSC was superior to hand-mixed RSC, indicating that the capsule-mix version of this material is advantageous for clinical use where occlusal forces are higher. Although FIXC performed better in surface hardness tests, no conclusion can be made about the superiority in compressive strength of the capsule-mix versus that of the hand-mixed product. Although not statistically significant, both the surface hardness and compressive strength of KUC were slightly better than those of KUH. Both the compressive strength and the surface hardness values of KMC were significantly higher than those of KMH.

Overall, the findings of the present study suggest that capsulated glass ionomer cements are superior to their hand-mixed counterparts. Therefore, these materials should be advocated for clinical use. The clinician is reminded that when using glass ionomer materials, optimal clinical results can only be accomplished if the correct mixing method/technique, mixing time and powder to liquid ratio are applied. This applies for both hand-mixed and capsulated variants of this dental material.

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the experiments for this study were provided by each one of the sponsors, without, any prerequisites, limitations and/or terms, and/or conditions in the testing of and/or recording or publication of any results, for each of the dental materials that were assessed. Thus, all reported findings of this current research study are objective and free of bias or influence from the sponsors.

Conflict of interest

The authors declare that they have no conflict of interest related to any aspect of this research project.

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Comparison of capsule-mixed versus hand-mixed glass ionomer cements

Part II: Porosity

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ABSTRACT

Introduction

Glass ionomer restorative cements (GIC) are routinely used in dental practice. During mixing, air incorporation may lead to higher porosity with subsequent weakening of the cement. The degree of porosity will determine whether capsule-mixed or hand-mixed GIC are mechanically stronger for clinical use.

Aim

To compare the porosity of four commercially available dental glass ionomer cements, supplied in both hand-mix and capsule-mix formulations, by evaluating number of voids (%), total volume of voids (mm^3) and volume percentage of voids (%).

Methods

Eighty samples were manufactured from hand-mixed GIC: Riva Self Cure; Fuji IX GP ; Ketac Universal, Ketac Molar Easymix, and equivalent capsule-mixed GIC: Riva Self Cure; Fuji IX GP ; Ketac Universal Aplicap and Ketac Molar Aplicap. Micro-CT scanning was used to evaluate porosity. The number of voids (mm^3), total volume of voids (mm^3) and the volume percentage of voids (%) were calculated.

Results

Riva Self Cure Capsules showed significantly less volume of voids (P = 0.005) and volume percentage of voids (P = 0.005) than Riva Self Cure hand-mixed. Fuji IX GP hand-mixed showed a higher number of voids (P < 0.001), but lower volume and volume percentage of voids (P < 0.001) when compared to Fuji IX GP capsules. The number of voids (P < 0.001), volume of voids (P = 0.004) and volume percentage of voids (P = 0.004) were significantly lower for both Ketac Universal and Ketac Molar capsules versus their hand-mixed equivalents.

Conclusion

Three capsulated forms of glass ionomer cements (Riva Self Cure, Ketac Universal and Ketac Molar) demonstrated decreased porosity, and may therfore be advantageous for clinical application.

Key words: Glass ionomer cement, Capsule-mix, Hand-mix, Micro-CT, Porosity

ABBREVIATIONS FOR ARTICLE

- GIC – Glass Ionomer cement
- FIXC – GC Fuji IX GP capsule-mix
- FIXH – GC Fuji IX GP hand-mix
- RSCC - Riva Self Cure capsule-mix
- RSCH - Riva Self Cure hand-mix
- KUC - Ketac Unversal Aplicap capsule-mix
- KUH - Ketac Universal hand-mix
- KMC - Ketac Molar Aplicap capsule-mix
- KMH - Ketac Molar Easymix hand-mix
- mm^3 - cubic millimetre/s
- ˚C – degrees Celsius
- % - percentage
- rpm - revolutions per minute
- MIDRAD - Micro-focus X-ray Tomography Facility
- NECSA - South African Nuclear Energy Corporation
- SD – Standard deviation
- IQR - interquartile range

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INTRODUCTION

Restorative dentistry concepts have changed over the years, with a modern focus on minimally invasive cavity preparation and the placement of adhesive restorative materials capable of re-mineralizing demineralized tooth structure.[1,2] Public demand for a non-metallic aesthetic restorations has also

increased.[3] Glass Ionomer cements have been developed to fulfil these requirements due to their unique material properties, which include chemical bonding to tooth structure, setting with an acid base reaction and fluoride release.[4] The applications of glass ionomer cements include: the restoration of primary teeth; class III and V restorations on permanent teeth; intermediated restorations; liners/ bases in the 'Sandwich technique'; the 'Art technique'; pit and fissure sealing and luting of indirect prosthesis.[5] Modern high viscosity glass ionomer cements like Ketac Universal, are now indicated for restricted stress-bearing Class I and restricted stress-bearing and non-stress-bearing Class II permanent restorations on permanent teeth.[6]

Glass ionomer cements consist of a mixture of calcium- or strontium-alumino-flouro-sillicate glass powder combined with a water-soluble polyalkenoic acid.[7] Two forms of glass ionomer cements are commercially available from dental material manufacturers. The first is a glass powder and separate polyalkenoic acidic liquid that is mixed by hand.[8,9] The second are the capsulated formulations, which require mixing in mechanical mixing triturators.[9]

Capsulation of glass ionomer cements offer several advantages over hand-mixed materials, these include: a pre-proportioned powder: liquid ratio, standardised mixing technique and times,[8,10] user friendliness and time efficiency.[6,11] The mixed cement can additionally be immediately injected into a cavity preparation directly from the capsule.[12] Dowling and Flemming[8] have advocated the clinical use of capsule-mixed glass ionomer cement with respect to the superior mechanical properties and as a solution to the problem of operator-induced variability (i.e. the variation between two or more individuals performing the same task, e.g. mixing dental materials) of hand-mixed materials.[8]

Several studies have however shown that the vibratory action of conventional mechanical mixing triturators may lead to increased porosity of set capsulated glass ionomers cements when compared to their hand-mixed equivalents, leading to weakening of the cement.[13,14] Mechanical mixing triturators with a combined rotational and centrifugal action have been advocated by some manufacturers and researchers to reduce porosity and void formation.[8,15] This recommendation has been debated, with Fleming *et al.*[15] and Dowling and Fleming[8] suggesting that these types of mixing triturators may not necessarily confer additional benefits as compared to conventional machines.

Porosity within glass ionomers acts as a source of stress concentration, negatively affecting the strength and homogeneity of the material.[12,16,17] Voids or porosity may be incorporated into a mixture by either air entrapment or inadequate wetting of the powder by the liquid.[12] Large voids have been reported to be responsible for material failure at low stress levels.[12]

The published literature shows conflicting evidence as to whether capsule-mixed or hand-mixed glass ionomers demonstrate increased porosity.[18] Mitchell and Douglas[14] evaluated the porosity of hand-mixed and capsule-mixed glass ionomer luting cements and found hand-mixed cements to contain more voids and voids of a larger diameter than the capsule-mixed equivalents.[14] Kaushik *et al.* however reported the opposite,[16] in their investigation hand-mixed glass ionomers demonstrated fewer voids per surface area as compared to the equivalent capsule-mixed versions.

AIM AND OBJECTIVES

The present study aimed to compare the porosity of four commercially available dental glass ionomer cements, supplied in both hand-mix and capsule-mix formulations. The objectives were to evaluate differences in number of voids (mm^3), total volume of voids (mm^3) and the percentage of voids (%) using Micro-CT assessment of the set materials following different mixing methods.

MATERIALS AND METHODS

Ethical approval for this in vitro, comparative study was obtained from the Ethics Committee of the Faculty of Health Sciences, University of Pretoria (protocol number: 206/2017).

The materials included for use in this study were: Riva-Self-Cure Hand-mix (RSCH, SDI Ltd., Victoria, Australia); Fuji IX-GP Hand-mix (FIXH, GC, Tokyo, Japan); Ketac-Universal Hand-mix (KUH, 3M, St. Paul, MN); and Ketac-Molar-Easymix Hand-mix (KMH, 3M, St. Paul, MN). Four equivalent capsule-mixed glass ionomers: Riva-Self-Cure Capsules (RSCC, SDI Ltd., Victoria, Australia); GC Fuji-IX GP Capsules (FIXC, GC, Tokyo, Japan); Ketac-Universal Aplicap Capsules (KUC, 3M, St. Paul, MN) and Ketac-Molar Aplicap Capsules (KMC, 3M, St. Paul, MN) were also included for comparison between hand- and capsule-mixed products.

The respective manufacturer's instructions were strictly adhered to at all times during the mixing and preparation of all specimens/ materials evaluated in this study, and are described in detail hereafter. The research was performed in a controlled environment as recommended by the manufacturers. The room temperature was 23 +/- 1˚C and relative humidity 50 +/- 5%.[15,19] All materials were mixed and dispensed in polytetrafluoroethylene (PTFE) moulds with the following internal dimensions: six millimetres in height and four millimetres in diameter.[8,20] The moulds were constructed from PTFE tubing and supported by custom-made Perspex® blocks.[12] Cylindrical material specimens were prepared by two dentists with the same level of training, to simulate operator variability.[21,22] Ten specimens in capsule-mix and 10 specimens in hand-mix were manufactured for each chosen material.

The FIXC were shaken to loosen the powder before activation.[23] All capsules were activated for two seconds to break the membrane separating the powder and liquid components.[8,15,23] The capsules were thereafter immediately placed into a mechanical mixing machines. The 3M ESPE capsule materials were mixed in the Rotomix™ triturator (3M ESPE, United Kingdom) as by manufacturer's instruction. The triturator was set to an eight second vibratory action and an additional three seconds centrifuging action at 2950 rpm frequency.[8,12,15]

All other capsules were mixed in an amalgamator (Amalgamator SYG 200, SMACO, Switzerland) for 10

Table I. Number of voids (n) per volume of all materials tested

Material	RSCH	RSCC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) voids	37944.2 (12566.7)	32152.7 (7126.8)	0.221*
Median (IQR) voids	38217.0 (25651.0-42226.0)	31515.0 (29779.0 – 35645.0)	0.199**
Min/Max voids	24102.0/66510.0	21066.0/47681	

Material	FIXH	FIXC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) voids	50495.6 (14080.4)	43939.4 (7458.6)	0.210*
Median (IQR) voids	51705.0 (37386.0 – 60995.0)	45954.5 (40243.0 – 48670.0)	0.545**
Min/Max voids	31696.0/71905.0	25813.0/50851.0	

Material	KUH	KUC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) voids	22305.6 (2825.1)	10122.0 (6314.8)	<0.001*
Median (IQR) voids	21794.0 (20489 – 23203)	8100.0 (6939 – 10270)	0.002**
Min/Max voids	18679.0/28917.0	5709.0/27469.0	

Material	KMH	KMC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) voids	16306.5 (4542.1)	9606.7 (2230.9)	0.001*
Median (IQR) voids	17075.0 (15107.0 – 19669.0)	10408.5 (7259.0 – 11102.0)	0.007**
Min/Max voids	8249.0/22674.0	6073.0/12105.0	

* Two sample t-test
** Non-parametric Wilcoxon Rank-Sum test

Table II. Total volume of voids (mm3) per volume of all materials tested

Material	RSCH	RSCC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) volume	0.9 (0.3)	0.4 (0.4)	0.005*
Median (IQR) volume	0.9 (0.6 – 1.2)	0.2 (0.2 – 0.7)	0.019**
Min/Max volume	0.6/1.2	0.1/1.2	

Material	FIXH	FIXC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) volume	0.3 (0.1)	0.9 (0.2)	< 0.001*
Median (IQR) volume	0.3 (0.3 - 0.4)	0.9 (0.7 – 0.9)	< 0.001**
Min/Max volume	0.2/0.5	0.5/1.1	

Material	KUH	KUC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) volume	0.5 (0.2)	0.2 (0.2)	0.004
Median (IQR) volume	0.5 (0.4 – 0.6)	0.2 (0.04 – 0.4)	0.007**
Min/Max volume	0.3/0.9	0.03/0.6	

Material	KMH	KMC	P-value
Number of specimens (n)	10	10	
Mean (+- SD) volume	0.5 (0.2)	0.3 (0.06)	0.010*
Median (IQR) volume	0.5 (0.5 – 0.7)	0.4 (0.3 – 0.4)	0.008**
Min/Max volume	0.2/0.8	0.2/0.4	

* Two sample t-test
** Non-parametric Wilcoxon Rank-Sum test

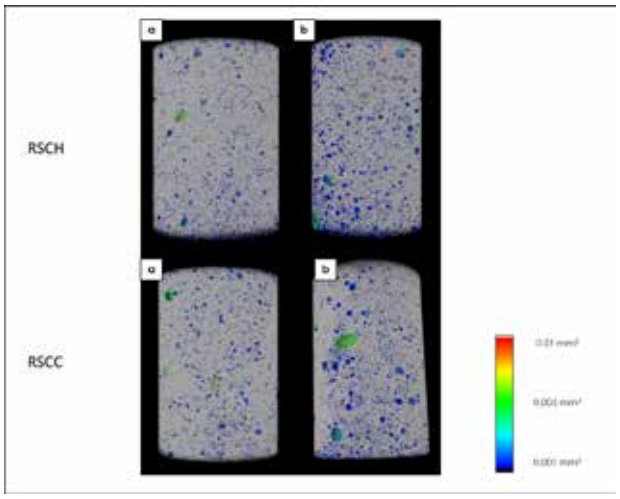

Figure 1. Micro-CT 3-D reconstructed images of RSCH and RSCC. Panel a) indicates the representative material samples with the smallest volume of voids and panel b) the specimen with the largest volume of voids.

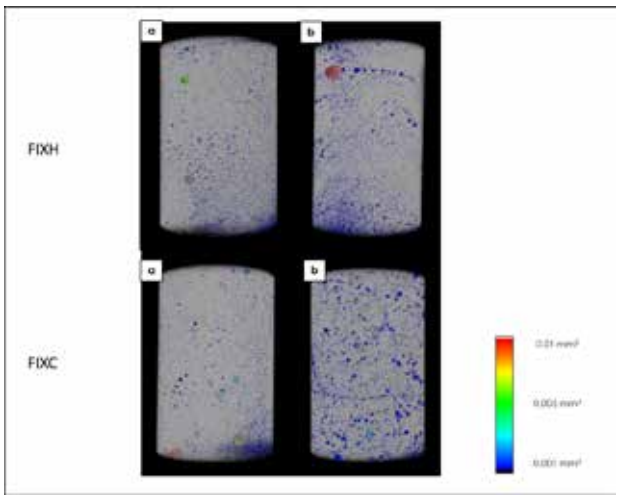

Figure 2. Micro-CT 3-D reconstructed images of FIXH and FIXC. Panel a) indicates the representative material samples with the smallest volume of voids and panel b) the specimen with the largest volume of voids.

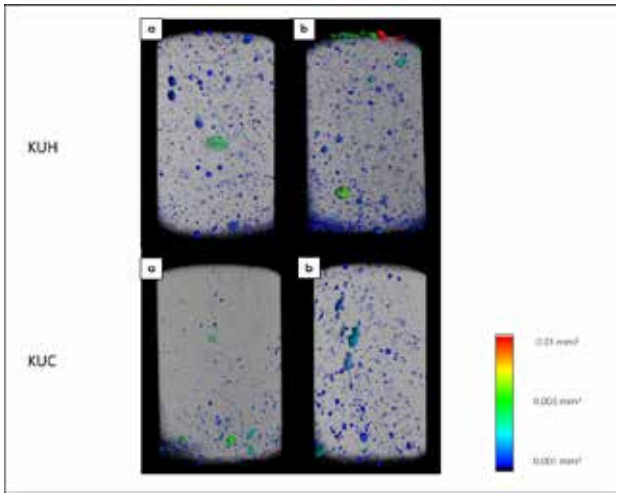

Figure 3. Micro-CT 3-D reconstructed images of KUH and KUC. Panel a) indicates the representative material samples with the smallest volume of voids and panel b) the specimen with the largest volume of voids.

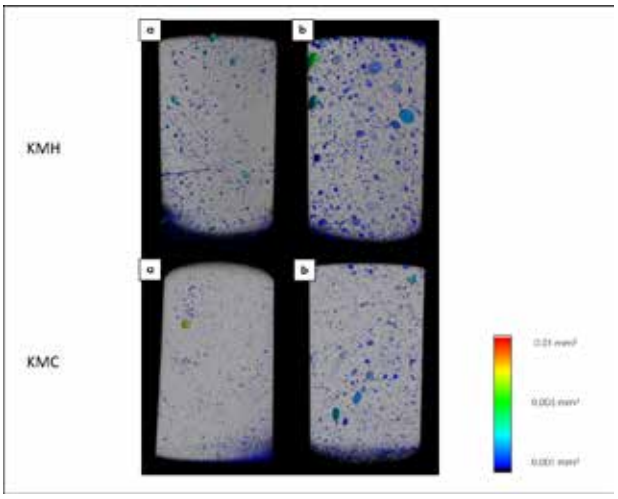

Figure 4. Micro-CT 3-D reconstructed images of KMH and KMC. Panel a) indicates the representative material samples with the smallest volume of voids and panel b) the specimen with the largest volume of voids.

seconds vibratory action.[8,15] Immediately after mixing, each capsule was placed in an appropriate applicator to facilitate the extrusion of the glass ionomer restorative material.[8,15] The hand-mixed equivalents were mixed on a waxed-paper mixing pad using the scoop and dropper systems provided to measure accurate quantities.[22] To simulate clinical practice, the powder and liquid quantities for the hand-mixed materials were intentionally not weighed.

The moulds were placed on a polyester strip in the Perspex® matrix. Mixed cement was dispensed into the moulds within 60 seconds.[12,20,21] The capsulated glass ionomers were extruded slowly to provide laminar flow and minimise the incorporation of bubbles with the nozzle positioned to one side of the mould.[8,21,24] The hand-mixed materials were applied to the moulds within 60 seconds using a stainless steel spatula and allowed to flow to minimise the incorporation of air bubbles.[8,20] A second polyester strip was thereafter placed over the filled moulds.

Both the capsulated and hand-mixed materials were gently compressed using a glass slab with a weight of 60 g[25] and slight pressure to extrude the excess material and flatten the surface.[5,17,19,21,25-29]

Coatings were applied for FIX, RSC and KM specimens and omitted for KU specimens according to manufacturers' instructions. All specimens were thereafter placed in distilled water in glass containers maintained at 37+/- 1°C in an incubator (Binder ED[23], Tuttlingen, Germany) for a period of one hour.12,20,21 After one hour, 880 grit silicon carbide paper was used under running water to remove surplus cement at the top and bottom of the moulds.[12] Each specimen was carefully removed from the moulds and stored in glass containers with 50 ml distilled water at 37°C. for 23 hours. Testing of the specimens commenced 24 hours after manufacturing.[20,21,30] Any specimens with visible defects such as bubbles or cracks, were discarded.[20,21]

Porosity evaluation

The XTH 225kV micro-focus X-ray/CT system (Nikon Metrology, Leuven, Belgium) situated at the micro-

Table III. Volume percentage of voids (%) per volume of all materials tested

Material	RSCH	RSCC	P-value
Number of specimens (n)	10	10	
Mean (+- SD)%	1.5 (0.5)	0.7 (0.6)	0.005*
Median (IQR)%	1.6 (1.1 – 1.9)	0.4 (0.3 – 1.2)	0.019**
Min/Max%	1.0/2.1	0.1/1.8	
Material	**FIXH**	**FIXC**	**P-value**
Number of specimens (n)	10	10	
Mean (+- SD)%	0.6 (0.1)	1.4 (0.3)	<0.001*
Median (IQR)%	0.5 (0.5 – 0.7)	1.5 (1.2 – 1.6)	<0.001**
Min/Max%	0.4/0.8	0.8/1.8	
Material	**KUH**	**KUC**	**P-value**
Number of specimens (n)	10	10	
Mean (+- SD)%	0.9 (0.3)	0.4 (0.3)	0.004*
Median (IQR)%	0.8 (0.7 – 0.9)	0.4 (0.1 – 0.7)	0.006**
Min/Max%	0.4/1.4	0.1/0.9	
Material	**KMH**	**KMC**	**P-value**
Number of specimens (n)	10	10	
Mean (+- SD)%	0.9 (0.3)	0.6 (0.1)	0.010*
Median (IQR)%	0.8 (0.8 – 1.2)	0.6 (0.5-0.6)	0.008**
Min/Max%	0.3/1.3	0.4/0.7	

* Two sample t-test
** Non-parametric Wilcoxon Rank-Sum test

focus X-ray radiography/tomography facility (MIXRAD) of the South African Nuclear Energy Corporation (NECSA), Pelindaba, South Africa was used for porosity testing. The system has an intrinsic spatial resolution volume ranging from 0.001-0.006 mm. The manipulator allowed for horizontal optimization to ensure maximum amplification of the samples. To convert 2D projections into 3D volumes, CT-Pro reconstruction software (Nikon XT software, USA) was used. CT-Pro 3D raw volume files were imported into VGStudioMax software (High-End Industrial CT Software, Heidelberg, Germany) allowing for the recovery and reconstruction of the X-rays into pinpoint sharp 3D-virtual images.

The number of voids per volume (n), the total volume of voids (mm^3) per volume and the volume percentage of voids (%) per volume of each specimen were determined.[14] The measured volume of each specimen was pre-set at 60,054688 mm^3. Voids greater than 0.001 mm^3 were included in the present study as these are considered to be significantly large.[14]

Statistical analysis

Statistical analysis was performed using SAS (SAS Institute Inc, Carey, NC, USA), release 9.4, running on Microsoft windows for personal computer. The applied statistical tests, two-sided and P values less than 0.05, were considered significant. Mean values for number of voids per volume (n), total volume of voids (mm^3) and volume percentage of voids (%) were compared using the two-sample t-test. Thus any significant differences between the means of the paired test groups could be determined. The non-parametric Wilcoxon Rank-Sum test was used to compare the median values of the paired groups.

RESULTS

The number of voids per volume of the tested materials are reported in Table I.

No significant differences regarding the number of voids between the RSCH- and RSCC- paired groups (mean, P = 0.221; median P = 0.199) or the FIXH- and FIXC- paired groups (mean, P = 0.210; median P = 0.545) were found. The number of voids present in the KUH- and KUC- paired group differed by mean values of 12183.6, which was statistically significant (P < 0.001). The median values of the two groups also varied by 13694 (P = 0.002). Significant differences regarding the number of voids between the KMH- and KMC- paired group mean values (6699.8, P = 0.001) and median values (6666.5, P = 0.007), were also found.

The volume of voids per volume of the tested materials are reported in Table II.

Three of the four hand-mixed materials RSCH (P = 0.005), KUH (P = 0.004) and KMH (P = 0.010) demonstrated a significantly higher mean total volume of voids when compared to the respective capsule-mixed materials (RSCC, KUC and KMC).

The FIXH- and FIXC- paired group also demonstrated significant differences in both the mean and median volume of voids (P < 0.001), however the hand-mixed material (FIXH) displayed a lower total volume of voids as compared to the capsule-mixed material (FIXC). The volume percentage of

voids (%) per volume of all materials are reported in Table III. Three of the four hand-mixed materials RSCH (P = 0.005), KUH (P = 0.004) and KMH (P = 0.010) demonstrated a significantly higher volume percentage of voids when compared to the respective capsule-mixed materials (RSCC, KUC and KMC). The FIXH- and FIXC- paired group also demonstrated significant differences in both the mean (P < 0.004) and median volume percentage of voids (P < 0.006), with the hand-mixed material (FIXH) displaying a lower total volume percentage of voids when compared to the capsule-mixed material (FIXC).

Micro-CT reconstructed 3D images providing a comparative visual indication of the number, size, volume and distribution of voids can be seen in Figures 1, 2, 3 and 4. The images selected for each material were made according to representative material samples displaying the smallest and largest volume of voids.

DISCUSSION

Testing and comparison of the mechanical properties of glass ionomers may have important clinical considerations as the mechanical properties of these materials, such as porosity and the presence of voids, may provide an indication of their long-term durability and wear resistance.[31] Micro-CT scanning allows for the non-invasive charting and evaluation of the microstructure of dental materials in three dimensions by producing high resolution images and rapid data acquisition.[13,32] Previous studies on glass ionomer cements by Nomoto *et al.*[13] and Chen *et al.*[33] demonstrated Micro-CT scanning to be highly effective to evaluate material properties. To the authors' knowledge, this is the first study evaluating porosity in set Riva Self Cure and Ketac Universal samples utilizing Micro-CT technology.

Small air inclusions, dispersed throughout the entire mass of the cement, were observed in all the scanned glass ionomers cements specimens examined in this study.

Larger air inclusions were also observed and these may be of clinical significance as they may contribute to material failure at lower stress forces and have a negative effect on the performance of the set material.[13]

Hand-mixing of higher viscosity glass ionomer cements should ideally produce an even diffusion of unreacted glass fillers throughout the plastic mass. However, if inadequate spatulation force is used during mixing, clumps of unreacted glass filler powder may form instead of an even diffusion of powder particles. Fleming and Zala previously identified such powder clumps in hand-mixed glass ionomer materials,[18] and reported that cracks or fractures of the set material will most likely commence from these sites.[18]

Fleming *et al.*[20] suggested that porosity may be introduced during hand-mixing of glass ionomer cements when a greater volume of powder is added to the liquid than that recommended by manufacturers. Greater powder volume necessitates increased pressure during spatulation to sufficiently mix the material, potentially leading to greater porosity of the end product.[20] It has been demonstrated that the use of a lower than recommended powder-to-liquid volume will result in reduced porosity, however this modification negatively affects the strength of the cement due to the lower concentration of reinforced glass filler particles in the set product.[20] Dowling and Fleming[8] suggested the powder content of glass ionomers routinely used in clinical practice may be as low as 50% of manufacturer's recommendations,[8] which could have substantial clinical implications.

No significant differences were found between the number of voids between the RSCH and RSCC specimens tested. However, the volume of voids and volume percentage differed significantly. This finding suggests that capsulated RSC may be beneficial for clinical use considering the reduction in porosity.

FIXC demonstrated significantly higher values for volume and volume percentage of voids as compared to FIXH. These findings could possibly be explained by operator induced variability which has been demonstrated to affect porosity during the mixing of glass ionomer cements.[20] During the present study, utmost care was however taken to accurately measure the powder and liquid volumes and mixing was completed according to manufacturer's recommendations. Kausnik *et al.*[16] reported capsule-mixed restorative glass ionomer cements to contain more voids per volume than hand-mixed products. Conventional mixing machines, without additional centrifugation, as used with FIXC materials, may be responsible for the increased porosity found in some capsulated glass ionomer cements (Figure 2).[18] The results of the present study support this finding.

Al-Kadhim *et al.*[34] compared hand-mixed and capsule-mixed glass ionomer luting cement and reported the capsule-mixed material to have larger voids and an increased volume of voids as compared to the hand-mixed equivalents. The decreased viscosity of glass ionomer luting cements as compared to restorative glass ionomer cements may be responsible for this finding. This assertion is supported by the findings of Nomoto and McCabe,[12] who demonstrated conventional mechanical mixing to introduce a type of foam or frizz in low-viscosity cement.

The 3M materials (KUC and KMC) were mixed according to manufacturer's instructions using a Rotomix™ mechanical triturator. The reduced volume of voids and volume percentage of voids of the 3M materials tested in the present study may be attributed to the added centrifugal action of the Rotomix™ triturator when mechanically mixing these products. Centrifuging has been shown to move air bubbles to the surface, allowing the air to "break out" before mixing is completed.[18] Studies have demonstrated that the added centrifugal action may only be beneficial for some cements and that performance is dependent on the initial viscosity of the cement mass.[12,18] Glass ionomer cements mixed in the Rotomix™ show decreased working and setting times due to prolonged mixing caused by centrifuging after rotation.[18] Issa *et al.*[35] examined the extrusion force, surface pH (indicating homogeneity), and porosity of capsulated glass ionomer cement when mixed with the Rotomix™, by hand and or with a conventional amalgamator and found the Rotomix™ to be beneficial when the examined properties were compared. A future study specifically aimed at using

the Rotomix™ for mixing all the capsulated test glass ionomer materials used in the present study, may provide valuable information and more conclusive results.

A solution to reduce porosity in glass ionomer cements, using applied ultrasonic excitation, was suggested by Coldebella *et al.*[25] In their study, ultrasonic excitation decrease the size and number of voids in tested materials.[25] High-vibration frequency caused the voids to collapse during the mixing process.[25] Ultrasonic wave application may therefore improve the setting reaction between the glass particles and the polyacid, and break up powder particle clusters formed.[25] Higher compressive strength and surface hardness, and increased bonding to enamel have been documented when ultrasonic vibration was applied to glass ionomer cement during the early setting reaction.[25]

CONCLUSION

Significant differences in the porosity of glass-ionomer cements were found between the hand-mixed and capsule-mixed equivalents tested in the present study. The results demonstrate that the method of mixing may significantly influence the porosity of dental glass ionomer cements. The results for FIX were inconclusive as to whether the capsule-mix or the hand-mixed materials are superior in terms of porosity. With reference to the RSCC, KUC and KMC materials, capsule-mixing resulted in significantly lower porosity than hand-mixing when the number, total volume and volume percentage of voids were compared. These findings suggest capsule-mixing to be advantageous as compared to hand-mixing regarding the porosity of these materials. A related research study by the authors, 'Comparison of capsule-mixed versus hand-mixed glass ionomer cements, Part 1: *compressive strength and surface hardness*', supports the conclusion that capsulated glass ionomer cements could be superior to their hand-mixed counterparts.

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Conflict of interest

The authors declare that they have no conflict of interest related to any aspect of this research project.

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The Knowledge and Participation of Community Health Care Workers in Oral Health Promotion

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ABSTRACT

Introduction

The human resource constraints in oral health has affected the delivery and sustainability of community oral health programs hence, in the West Rand District of Gauteng, Community Health Workers (CHW) are trained and integrated in Oral Health.

Aim

The study therefore sought to assess the level of oral health knowledge and referral practices of CHW working in the West Rand.

Methodology

The study utilized a cross-sectional descriptive study design and was undertaken in three West Rand district regions. A self-administered questionnaire was used to collect the data and data was analyzed using descriptive and the chi-squared bivariate statistics.

Results

Out of the 450 CHW working in the West Rand, n=148 of them participated in the study, their average age was 39; (SD:8.8) and had 9 years (SD:3.3) of work experience. As much as over 60% of participants reported to have been familiar with common oral conditions, they largely recognized tooth decay (48%) and information concerning the prevention of common diseases such as tooth decay and gum disease was inadequate. In terms of referral practices, they were poor as only (37%) referred when they recognized something unusual and (11%) never referred at all.

Conclusion

The oral health knowledge of the West Rand (CHW) was found to be inadequate, and this affected their ability to competently assess and refer common oral conditions.

Key words: Community Health Workers; Programs; Oral Health Promotion; Oral Disease Prevention

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INTRODUCTION

Oral health contributes significantly to a health-related quality of life (HRQoL).[1] The most common oral disease is tooth loss, which may lead to low self-esteem, psychosocial effects and malnutrition as a result of difficulty in chewing.[2] In addition, the effects of the pain caused by oral disease on individuals and families result in loss of workdays for parents and school absenteeism for children. This subsequently leads to a negative impact on socioeconomic development.[2] Furthermore, the burden of oral diseases globally has a disproportionately high bearing on the disadvantaged as well as socially marginalized communities because treatment costs are prohibitive while oral health systems are inadequately resourced to provide service.[3,4]

The human resource constraints in oral health and current staff shortages affect the delivery and sustainability of community oral health programs.[5,6,7] In other general health programs, the increased demand of health services has been addressed by task shifting from professional health workers to lay health care workers such as Community Health Workers (CHW).[8] CHW were officially integrated into the South African public health system in 2011 as part of efforts to re-engineer and reform primary health care in the country.[9] Thus, they have been shown to be effective in engaging closely with communities.[10] This approach is in line with the restructuring of health systems that is being advocated by the World Health Organization; with the idea of creating an environment where non-oral health personnel can educate, refer, and attend to basic dental needs in order to increase accessibility.[11]

Therefore, integration of Community Health Workers in community oral health promotion needs to be considered as CHW are generally trained to render health promotion services in the community, they are involved in health education, community engagement and linking communities to health services.[8,12] Their services have also shown to have brought about an improvement in health outcomes of HIV positive mothers and their infants. In addition, they improve community access to primary health care facilities for chronic diseases.[8,9]

In the West Rand District of Gauteng, CHW are trained in oral health as they are inducted in the district. However, there exists no documentation outlining the nature and dimensions of CHWs knowledge and participation in oral health promotion. It is therefore important to make this assessment in order to document their level of oral health knowledge and to identify what their role in oral health has been to date. The information will assist in addressing any knowledge gaps and also providing direction that is needed for improving the integration of community health workers in the district and ultimately oral health experiences of communities.

The aim of the study therefore sought to assess the type of oral health knowledge and referral practices of CHW working in the West Rand district of Gauteng.

METHODOLOGY

The study utilized a cross-sectional descriptive study design and was undertaken in three West Rand district regions that included; Mogale City, Rand West and Merafong City. The District has an estimated population of 838 594 residents.[13]

The population of interest was on 450 CHW who are deployed in various communities. Out of the 450 CHW, Participants were conveniently sampled according to an inclusion and exclusion criteria. The inclusion criteria comprised of CHWs who were from the chosen three health sub-districts and had some prior training in oral health promotion. An exclusion criterion entailed CHWs who were not trained in OHP and were not formally employed by the government.

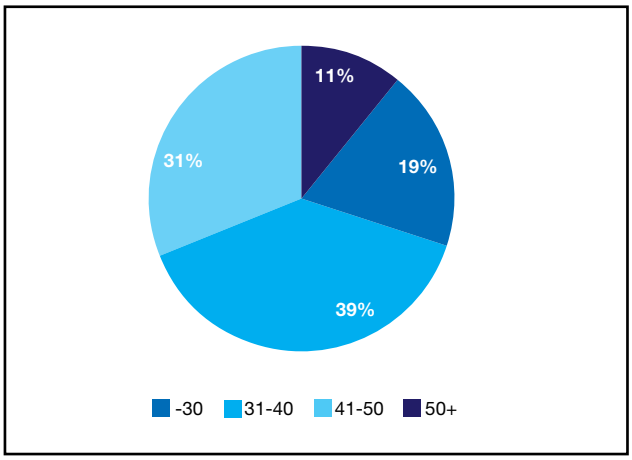
A self-administered questionnaire was used to collect the data. The questionnaire was adapted from a pre-existing questionnaire by Praveen et al (2014).[14] The questionnaire was assessed by the postgraduate committee at University of South Africa (UNISA) for face validity. Upon approval of the questionnaire by the university, the questionnaire was piloted on five trained CHWs, after the pilot, all the inconsistencies were addressed and the questionnaire was refined before its use on the study participants.

Ethical clearance was provided by the (UNISA) department of health studies REC 012714-039 (NHERC). Additionally, permission was sought from the district directors and clinic managers. Prior to administering the questionnaire, the researcher outlined the study to the participants, received their consent to participate in the study and assured them that their participation would be anonymous. In addition informed them that they were under no obligation to participate.

Data analysis

Data was captured on Microsoft excel spreadsheet, and imported to the STATA Statistical Software, version 14 for analysis. Descriptive summary statistics was utilized to determine socio-demographic characteristics and type of knowledge using means, standard deviation, frequencies and proportions. Relationships between dependent variables such as knowledge and referral patterns with education, training, and years of experience were assessed using the Pearson and Fischer's exact chi-squared tests.

Fig 1. Age distribution of participants



RESULTS

Sociodemographic information

Out of the 450 CHW, (n=148) completed the questionnaire and participated in the study. Majority of the participants were between the ages of 31-40. The mean age was 38.8 (SD:8.89). The mean years of work experience was 9.1 (SD:3.3), (Figure 1). They were largely females (94%) and just over half of them had matriculated (57%). The male participants were of a younger age, and the older participants had limited education. (See table1).

Table 1 : Socio-Demographic profile of participants

Variables	n	%	Mean Age (SD)
Gender			
Females	139	93.9	42.2 (8.7)
Males	9	6.08	29.2 (4.3)
Educational experience			
Secondary schooling	57	38.5	41.8 (9.1)
Matric	84	56.7	37.2 (8.4)
Tertiary	7	4.73	34.5 (5.8)

Knowledge; Common Oral Conditions

Of the 148, (N=93/ 62.8%) claimed they were familiar with recognizing common oral diseases. However when asked which specific common conditions they were familiar with (see table 2), 48% identified tooth decay, this was followed up by painful teeth, 36.5% and only 28% recognized all the listed common conditions.

Table II: Reporting on common oral conditions they were familiar with:

Common Oral Conditions Identified		
Oral Conditions	**n**	**%**
Tooth decay	71	47.9
Gingivitis	5	3.4
Crooked teeth	15	10.1
Painful teeth	54	36.5
Stained teeth	14	9.5
All above	41	27.7
Don't know	4	2.70

Knowledge; Prevention

In terms of prevention of tooth decay, majority of them 48% said tooth decay was prevented only by brushing, only 40,5 % correctly answered that tooth decay was prevented collectively by brushing, limited sugar intake and fluoride (see table 3). The knowledge concerning prevention of gingivitis (gum disease), only 27% answered correctly by choosing all of the above, which included regular correct brushing and balanced nutrition. A large majority 47% answered that gum disease was only prevented by regular brushing (see table 3).

Referral practices

Majority of the participants (41.2%) referred patients to oral health facilities when the patients were concerned about their

oral cavity. Less than half referred when they recognized something unusual in the mouth and 11% never referred patients to oral health facilities.

The Fischer's exact chi squared showed no significant associations between the identification of common oral conditions and education (p=0.81), years of experience (p=0.58) and training (p=0.72). In addition, no relationship was found between appropriate referral practices to education (p=0.73), years of experience (p=0.10) and training (p=0.62).

Table 3: Knowledge on prevention of tooth decay and gum disease.

How do you prevent tooth decay	n	%
Regular brushing	71	47.9
Limited sugar intake	28	18.9
Use of fluoride	7	4.7
All of the above	60	40.5
Don't know	0	0.0
How do you prevent gum disease		
Regular brushing	69	46.6
Correct brushing technique	52	35.1
Balanced nutrition	9	6.1
All of the above	40	27.0
Don't know	0	0.0

Table 4: Referral practices

Reasons for referral	n	%
Refer when patient is concerned	61	41.2
Refer when one sees something unusual	55	37.2
Refer for oral health preventative purposes	38	25.7
Never refer	16	10.8

DISCUSSION

The average age of participants was 39 years old and they had approximately 9 years of experience. As much as over 60% of participants reported to have been familiar with common oral conditions, their knowledge was elementary. They largely recognized tooth decay (48%) and information they had on prevention of common diseases such as tooth decay and gum disease was inadequate. In terms of referral practices, they were poor as only (37%) referred when they recognized something unusual and 11% never referred at all. No significant associations were found between knowledge and education, training and years of experience. In addition, no link was found between referral patterns and education, training and years of experience.

The majority of CHWs involved in oral health services in the West Rand Health District were 31 to 40 years, had a high school background and had many years of experience (9years). However, this did not translate in our results to having adequate oral health knowledge. This is similar to results reported from a study in Iran where it was observed that the longer the time passed after training of CHW, the lesser the ability of the workers to remember information on oral health.[15,16] In addition, CHWs might have received a once-off training upon commencement of their contract and no follow-up or re-training was done.[15] Participants' knowledge was especially limited. Despite them being trained and 62.8% claiming familiarity with common oral lesions, only 28% recognized all the common oral conditions. In addition, less than 30% answered correctly on information regarding the prevention of dental caries and gingivitis. The level of understanding of oral health conditions was clearly reflected to be poor and it is suggested that this is in most part attributed to the training intervention.[17,18] Culturally and linguistically relevant educational approaches have shown greater success than traditional didactic approaches that are commonly offered to CHW.[19]

It is a concern that only 37% of the respondents refer when they recognize something unusual and that they largely (47%) refer when someone is concerned about the condition of their oral cavity. This implies that they are not able to recognize unusual oral conditions and thus would be inadequately competent in undertaking appropriate referrals. It could be that their training does not emphasize how to differentiate between normal and abnormal oral conditions.[20] In addition, there was uncertainty and lack of preparedness on the functions they were expected to perform.[21] Intensive training that involves practical sessions and continuous follow up has been shown to be successful in Kenya for increasing CHW's knowledge, identification and referrals of oral HIV lesions of community members.[22]

Literature has shown that CHWs potentially have a vital role to play in the promotion of good oral health and prevention of oral health diseases as they form a key link between communities and the health system.[21] However, the study reflected our participants to be ill prepared to contribute to oral health and that their role and participation is generally poorly defined.[23] It is therefore recommended that CHWs should be exposed to regular training as a way of Continuous Professional Development (CPD). In addition, periodic monitoring and evaluation of the training and participation should be undertaken in order to address emerging gaps proactively.

Limitations of the study.

Little has been documented on the structure or various forms of training that the CHWs were exposed to, thus the study could not measure their training from a standard baseline. Hence the questionnaire was developed around basic oral health knowledge that was expected from non-oral health care workers; and the study was able to outline existing knowledge gaps that impacted on the oral health involvement of CHWs in the West Rand.

CONCLUSION

Considering that CHW participating in the study were trained in oral health and over 60% of them claimed to be familiar with common oral lesions, their oral health knowledge was not found to be adequate. This affected their ability to be able to competently assess and refer common oral conditions. The current training approach that they are exposed to needs to be reviewed and redesigned in order to equip them with the necessary skills required to effectively participate in oral health promotion and disease prevention.

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Retreatability of root canals obturated using a bioceramic sealer and gutta percha

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ABSTRACT

Introduction

The use of bioceramic sealers may, on occasion, complicate endodontic retreatment. This is due to their hard setting nature as well as adherence to root dentine which makes them more challenging to dislodge from root canals.

Aim

The aim of this *in vitro* study was to determine the retreatability of root canals sealed with a bioceramic calcium silicate-based sealer cement.

Materials and Methods

120 permanent human single rooted teeth were selected for the study. After working length and apical patency determination, the teeth were prepared using iRace™ Ni-Ti rotary files. Teeth were divided into four groups (n=30) and obturated as follows:

- Group 1: TotalFill BC™ points and TotalFill BC™ sealer with the master GP at WL using basic hydraulic technique
- Group 2: TotalFill BC™ points and TotalFill BC™ sealer with the master GP 3mm short of WL using basic hydraulic technique
- Group 3: GP and AH Plus™ with the master GP at WL using lateral condensation technique
- Group 4: GP and AH Plus™ with the master GP 3mm short of WL using lateral condensation technique
- D-Race™ retreatment files and Endosolv™ was used to remove obturation material.

Results

The Kruskal-Wallis H test, pairwise and comparison between groups showed that the type of sealer cement and the working length influenced both the retreatability of the canal and retreatment time. The differences were statistically significant ($p < 0.005$) at a 95% CI.

Conclusion

Fully extended GP will guarantee a passage for retreatment instruments to the apical area of the canal. The sealer and GP application technique during obturation should allow for full extension of the GP within the canal. Improper use of bioceramic sealers diminishes the chances of successful retreatment.

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INTRODUCTION

The aim of endodontic treatment is to prevent peri-apical periodontitis or treat it when it is present. This is achieved through mechanical shaping, removal of infected and/or inflamed pulp tissue and chemical irrigation to eliminate micro-organisms and their by-products. This is followed by placement of a hermetic root canal obturation and a coronal seal. The radicular and coronal seals prevent micro-leakage of bacteria and their by-products which are responsible for persistent peri-apical inflammation.[1]

Although there is considerable debate about which is more important between the root filling and the coronal seal, both the coronal and root canal seals are central in preventing bacterial re-entry and recolonization of the root canal system and the surrounding peri-apical tissues. The seal entombs any bacteria that may not have been removed during canal space preparation and irrigation; and prevents their re-entry from the oral cavity respectively.[2]

Functions of Endodontic Sealers

Conventionally, the obturation of the root canal system is done using a solid core material; mostly Gutta Percha (GP) cones together with a sealer cement which is in a paste form. The sealer flows and seals patent accessory canals, voids, apical deltas and ramifications which may be present in the root canal.[3] The sealer serves as a canal lubricant to facilitate placement of the root canal core material. The sealer also helps to create a bonded interface between the core material and the root dentine. The core material and sealer form a fluid-tight sealer that entombs any viable bacteria within the root canal system and prevents re-entry of new bacteria from the surrounding periodontal tissues.[4]

Since the most complex anatomical areas within the canal system are mostly occupied by the sealer cement, the development of new materials and techniques has been aimed at improving the sealer interface. Vertical and lateral condensation techniques were developed to minimize the

sealer interface and increase adaptation of the sealer and the GP to the root canal walls.[3]

Bioceramic sealers

Pre-mixed bioceramic based sealer cements were introduced in clinical practice in 2008.[5] Prior to this, there had been challenges encountered with the zinc-oxide eugenol-based cements and epoxy-resin based sealer cements. These challenges included poor biocompatibility, poor handling properties, hydrophobicity, shrinkage on setting and failure to form a true chemical bond with root dentine.[6,7]

Bioceramics are ceramic materials developed for use in medicine and dentistry.[8] Initially their use in endodontics was limited to perforation repair and retrograde filling materials in apical surgical procedures due to their poor handling properties.[9] Their use as endodontic sealers is as a result of improvement in the handling technology of nano-particulate matter. This improvement resulted in materials exhibiting optimal handling properties such as ease of dispensing and use. They also have inherent ability to use the moisture in dentine to drive the setting reaction within a clinically acceptable time.[8,9]

TotalFill BC™ sealer (FKG Dentaire SA, Switzerland) is marketed in various other regions as iRootSP™, Endosequence BC™ sealer and BC sealer. Its components are zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide fillers and thickening agents. The last two components' ratios in the mix are varied accordingly to produce other products with higher viscosities that are used as root repair materials.[11]

Application technique of Bioceramic Endodontic Sealers

Although the obturation techniques of lateral and vertical condensation used with conventional sealers can be used with these materials, their use (specifically for TotalFill BC) involves hydraulic condensation, also known as passive or bonded obturation. Pluggers and spreaders are not used in this technique. The GP cone is the condenser and the sealer is the filler. This takes a shorter duration, is less technique sensitive and there is minimal or no pressure exerted on the canal walls thus minimizing possibility of micro-crack formation within the root dentine.[3] TotalFill BC is compatible with both vertical and horizontal condensation techniques as well.[11]

According to the manufacturer, TotalFill BC is supplied as a premixed sealer paste with intra-canal application tips that are used to express a small amount of the material into the coronal third of the canal. A small file is then used to coat the canal walls with the material. The master GP is then coated with the cement and then slowly inserted into the canal to full working length. If needed, especially for oval shaped canals, more GP points can be added without laterally compacting the master GP. The manufacturer cautions against excessive cement since the precise fit of the master GP creates a hydraulic system in which the excess cement may prevent the master GP extending all the way to the working length.[11]

Salient properties of Bioceramic Sealers

Bioceramic sealers have excellent biocompatibility. Biomaterials that are biocompatible do not trigger any adverse reactions when they contact living tissues. The possible adverse reactions are toxicity, irritation, inflammation, allergic reactions and carcinogenesis.[12] Biocompatibility tests done on cell cultures showed TotalFill BC sealer to be more biocompatible than the commonly used calcium-based and zinc oxide-based sealer cements.[13] The biocompatibility of the root repair products of the same material has been shown to be comparable and, in some studies, better than that of MTA-based products.[10,14-17]

Bioceramics have been shown to have anti-microbial activity. This is because of their high pH upon setting and release of calcium ions. The calcium ions also stimulate repair through the deposition of mineralized tissue.[18] Remineralization increases the success rates of endodontic therapy. iRoot SP sealer (TotalFill BC sealer) has been shown to have a higher and prolonged bactericidal activity against strains of *E.faecalis,* an organism implicated in persistent peri-apical periodontitis after primary endodontic treatment.[9,19,20]

TotalFill BC sealer has been shown to have a long working time and a relatively short setting time which are both desirable properties of a root filling material.[21] In a study by Zhou *et al.*[21] which involved an indentation technique using a Gilmore needle; TotalFill BC sealer had a setting time of 2.7 hours with a mean standard deviation of 0.3. This was comparable to that of MTA Fillapex (Angelus) which was found to have the shortest setting time of two and half hours with a mean standard deviation of 0.3 hours. In the same study, AH Plus took eleven and half hours to set with a mean standard deviation of 1.5 hours. The setting time of a sealer cement (while allowing enough time for manipulation and placement) is a desirable property. Sealer cements that take longer time to set run the risk of reduced biocompatibility as a result of tissue irritation.[22] Separate studies have shown bioceramic sealers to have shorter setting times within the canal and less interference by the presence of residual moisture within the canal during the setting reaction.[21,23,24] Thus, the shorter setting times of bioceramic sealers (which allow time to apply but set early enough to avoid unnecessary irritation of the peri-apical tissues) is an advantage.

Bioceramic sealers like EndoSequence and MTA Fillapex have been shown to have favourable flow properties which meet ISO standards.[21] Adequate flow facilitates entry of the sealer into inaccessible areas such as isthmi, fins and lateral canals which are inaccessible to the gutta percha core material.[12]

The radiopacity of TotalFill BC sealer is 3.83 units of aluminium.[25] Even though the radiopacity of TotalFill BC was found to be lower than that of AH Plus in the study of Candeiro *et al.*[25] it is still within the acceptable standards of the ISO, which requires that root sealers have a minimum radiopacity of 3mm of aluminium.[12] Adequate radiopacity facilitates visualization and enables the operator to distinguish the sealer from the surrounding tissues. The quality of obturation can thus be evaluated. It is important that root canal sealers be sufficiently radiopaque and distinguishable from adjacent anatomical structures.

TotalFill BC sealer has been shown to have good adhesion to root dentine upon setting even in the presence of minimal residual moisture content within the root canal with or without the smear layer and in the presence of residual calcium hydroxide.[26-29] Adhesion is defined as the ability to

bond to the canal dentin and to promote the binding of GP points to each other and to root dentin.

TotalFill BC™ sealer has been shown to have acceptable resistance to dissolution in water despite its hydrophilicity. Zhou[21] *et al,* showed that TotalFill BC has a solubility value of 2.9%. This was higher than MTA Fillapex (Angelus) which has a solubility of 1.1%.[21] However, these values meet ANSI/ADA recommendations of solubility not exceeding 3%.Conflicting findings were reported by Wang[30] who reported MTA Fillapex to be highly soluble namely 14.94%, more than AH Plus, which was 0.25%.[30] The differences in the findings may be attributed to variations in methods used to dry samples after having subjected them to solubility testing. ANSI/ADA recommend that solubility of a root canal sealer not exceed 3% by mass.[12]

Inadequate removal of root filling materials from within the pulp chamber caries a high risk of dentin discoloration. A root canal sealer should not stain the tooth. Ioannidis[31] et al, found that EndoSequence™ Root Repair Material putty and EndoSequence™ Root Repair Material fast set paste, (both of which have the same composition as TotalFill BC sealer) have a low potential to cause dentin discoloration.[31] This finding makes the sealer to be the material of choice where aesthetics is a high priority.

Retreatability of root canals

The main disadvantage with the use of bioceramic sealers is the challenge that is involved with removal of the root filling when the need arises. Such circumstances where removal of the root filling material is needed include post placement and retreatment when primary root canal treatment fails.[32] Residual root filling materials act as a barrier which prevents access to and complete removal of necrotic debris and bacteria that cause and sustain peri-apical lesions.[33]

In order to successfully retreat the diseased tooth, it is necessary to remove all or part of the coronal restoration as well as the obturation materials from the root canal system. This allows for cleaning and shaping to be performed, so as to eliminate the micro-organisms responsible for post-treatment endodontic disease. Studies evaluating the various mechanical and chemical techniques of removal of different root filling materials confirm that absolute complete removal is impossible.[34-37] However, a pre-requisite to successful retreatment is that, working length and apical patency must be established. All root canal filling materials, including the sealer and the core materials have to be removed.[38] In a study by Hess *et al*.[39], where Endosequence BC sealer (similar product to TotalFill BC sealer) was used as the sealer and the obturation was done to working length, apical patency was established in only 80% of the canals. When the obturation was done 2mm short of the working length, apical patency was achieved in only 30% of the teeth. These findings imply that a proper obturation needing retreatment has 20% chance of failing to regain apical patency using currently available materials and techniques. Failure to establish working length and apical patency could potentially lead to failure of the retreatment as both bacteria and their products that initiate and sustain peri-apical periodontitis remain within the root canal system.[33]

Research findings which conflict with the above findings were reported by a different group of researchers using GP as the core material and three different sealers: AH Plus, Total Fill BC and MTA Fillapex.[40] The researchers found that working length and patency was established in 100% of specimens in all groups. This group had also intentionally obturated one of their sample groups with the master cone GP 2mm short of the working length to allow evaluation of the effect of the sealer cement independently. They established that in the group where the master GP was placed 2mm short of the working length, although working length and apical patency were achieved, it took a longer time. This was in comparison to the groups that were sealed to length with GP and AH Plus as well as the group that was filled to length with gutta percha and TotalFill BC and/or MTA Fillapex. The difference in time was statistically significant. There are a number of other studies which have similar findings.[41,42]

Retreatment Protocols

As quoted by Bhagavaldas *et al.*[43], the Glossary of Endodontics defines retreatment as a procedure to remove root canal filling material from root canals, followed by cleaning, shaping and obturation of the canals.[43] Hand files, rotary instruments including Gates Glidden and patented retreatment file kits by various manufacturers, endodontic ultrasonic tips, gutta percha solvents like chloroform, tetrachloroethylene, xylene, halothane and eucalyptol, turpentine and orange oils have all been proposed and used in removal of obturation material.[32]

Gates Glidden drills mounted on electric handpieces to adequately control torque and speed are used to gain initial entry into the canals. Their use should be limited to the straight portion of the canal. They should be used with caution to avoid gouging out of dentine which could result in strip perforations and/or weakened roots which are prone to fracture.[44]

The piezo-electric ultrasonic devices with special endodontic ultrasonic tips are used to safely remove the superficial layer of GP and to create a small reservoir for the solvent. The vibrations produced by the devices' tip within the root structure is thought to weaken the adhesion of the obturation material to the canal walls facilitating its removal.[40]

Both hand files and rotary retreatment kits are used initially to grossly remove the root filling material accompanied by copious irrigation with sodium hypochlorite after each instrumentation cycle. Nickel titanium (Ni-Ti) rotary instruments have come into widespread use because of their safety, efficiency and speed in removing the GP and the sealer cement residues.[32,45]

Solvents are best used only after the gross removal of GP and sealer is complete. Their use during gross removal frequently leads to inconvenient residues of GP painted across the length of the canal walls.[32] Traditionally, chloroform has been the solvent of choice due to its ability to rapidly dissolve GP into a thin liquid. However, there has been renewed interest to find alternatives due to its potential for misuse as well as carcinogenic properties.[46] Additionally, the hepatotoxic side effect of halothane deters its use. The failure of turpentine oils to dissolve GP at room temperatures makes it impractical for chair-side application. Of the remaining solvents, tetrachloroethylene, xylene, eucalyptol, and orange oils have shown to be

the most biocompatible while also possessing useful solvency properties at 37°C.[47] The most recognizable tetrachloroethylene solvent is commercially available as Endosolv (Septodont, Saint-Maur-des-Fossés, France). Initially it was formulated as Endosolv E (E in the brand name is short form for eugenol) for use in removal of obturation materials from canals sealed with eugenol -based sealers, and Endosolv R (R in the brand name is short form for resin) for the removal of obturation materials from canals sealed using resin–based sealers. Currently, it is formulated and availed as Endosolv. According to the manufacturer, the new formulation is effective in retreatment of canals sealed with either resin- based or eugenol–based sealers. The effectiveness of this formulation in canals sealed using bioceramic sealer cements has not been established.
The solvent is delivered into the canal by using a side-vented 27-gauge needle.

The needle should be placed into the canal using a passive technique to deliver the solvent into each root canal. It is recommended that a flushing action be used. This is because repeated irrigation and aspiration creates turbulent pressures that enhance filling material removal. The deposited volume should be adequate to fill up the root canal up to the floor of the pulp chamber and the solvent is agitated with hand files. The largest size of fitting paper points should then be inserted into the canal to absorb the now dissolved root filling material.[32]

Following removal of root canal obturation materials, chemomechanical preparation using the preferred and appropriate techniques, instruments and irrigants should be completed and followed by obturation. An irrigation regime that includes a final rinse of 17% ethylenediaminetetraacetic acid (EDTA) followed by NaOCl has shown to improve resolution of peri-apical pathology in retreatment cases. This irrigation protocol removes the residual smear layer. The smear layer is known to contain infected organic and inorganic matter, solvents and filling material that is created throughout retreatment; which may be the cause of sustained peri-apical infection and inflammation.[48]

MATERIALS AND METHODS

One hundred and twenty single rooted, single canal anterior and premolar teeth were selected for this study. The teeth were obtained from the oral surgery and service rendering clinics of the Faculty of Dentistry, University of the Western Cape. The teeth collected for the purposes of this study were extracted for reasons unrelated to the objectives of this study. Prior to commencement of this study, ethical clearance was obtained from the Research Committee of the Faculty of Dentistry, University of the Western Cape (Ethics number: BM18/2/1). Every aspect of this study was conducted in accordance with the ethical and safety guidelines for handling human tissues and conducting laboratory studies, as prescribed by South African law: The Health Professions Act 56 of 1974 (Health Professions Council of South Africa, 2008).

Inclusion Criteria

1. Human single rooted, single canal anterior and premolar teeth
2. Teeth roots with mild curvature
3. Teeth with patent canals as confirmed by radiographic examination
4. Teeth with apical patency as confirmed using K-file size 10

Exclusion criteria

1. Teeth with moderate to severe root curvature at any point along the roots
2. Teeth with incompletely formed roots and open apices
3. Teeth with fractured roots
4. Teeth with canal bifurcation/trifurcation as confirmed by radiographic examination
5. Teeth with initial apical size of more than size 30
6. Teeth with sclerosed canals
7. Teeth with fusing/merging canals
8. Teeth with no apical patency

Specimen Preparation

The extracted teeth were washed under tap water and immediately immersed in 0.5% sodium hypochlorite for thirty minutes. The 0.5% sodium hypochlorite solution was prepared by mixing equal portions of distilled water and 1% hypochlorite solution -Milton's solution- (Incolabs, Parktown, South Africa). All adherent hard and soft tissues were removed from teeth using an ultrasonic scaler (Suprasson, Satelec Acteon, France), and specimens were then stored in physiological saline (B Braun Medical, Randburg, SouthAfrica). The teeth were decoronated at the cement-enamel junction using a minitome diamond disk (Struers, Randburg, South Africa) and water cooling to leave a root 12-15mm in length.

A size 10K file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the canal until its tip was visible at the apical foramen. The working length (WL) was determined by reducing 1mm from this length. Radiographs were taken using an intra-oral peri-apical machine (CS 2100, Carestream Health, Onex Corporation, Toronto, Ontario, Canada) to confirm the working length. Another set of radiographs without the files in position were done from a different angle to confirm that the teeth had single, non-furcated canals.

Canal preparation and obturation

The glide path was established using ScoutRace files (FKG Dentaire SA, Switzerland) which consist of three files ISO sizes of 10, 15 and 20 with a 2% taper.

The root canals were then prepared using iRace Ni-Ti files R1 (15/0.04), R2 (25/0.04) and R3 (30/0.04) in a Wave One (Dentsply Sirona, PA) motor with the torque 1.5Ncm and 600RPM revolution speed as recommended by the manufacturer. Additional use of R1a (20/0.02) and R1b (25/0.02) was used as required in case of difficult to negotiate canals. RC Prep cream (Medical Products Laboratories, PA, USA) which contains 10% urea peroxide and 15% Ethylenediamine tetraacetic acid (EDTA) was used to lubricate the canals and instruments.

After each instrument, the canal was irrigated with 2.5 ml of 1% solution of sodium hypochlorite in a 5ml disposable plastic syringe and a 30-G irrigating tip (HenrySchein, Melville, NY). Then, the final flush to remove the smear layer was performed with 5ml of EDTA for 30 seconds followed by 5ml of 3.5% of sodium hypochlorite and then 5ml of distilled water. The root was dried with paper points (FKG Dentaire SA, Switzerland). The apical patency was reconfirmed with a #10 K-file before filling the roots.

The teeth were first stratified into groups according to their canal lengths and then randomly allocated into four

groups 1, 2, 3 and 4 of 30 (n=30) and obturated as follows:

Group 1	TotalFill BC sealer and bioceramic nano particle–coated Gutta Percha (FKG Dentaire SA, Switzerland)	At working length
Group 2	TotalFill BC sealer and bioceramic nano particle–coated Gutta Percha (FKG Dentaire SA, Switzerland)	At working length minus 3mm
Group 3	AH Plus and regular ISO Gutta Percha (Dentsply Detrey GmbH Konstanz, Germany)	At working length
Group 4	AH Plus and regular ISO Gutta Percha (Dentsply Detrey GmbH Konstanz, Germany)	At working length minus 3mm

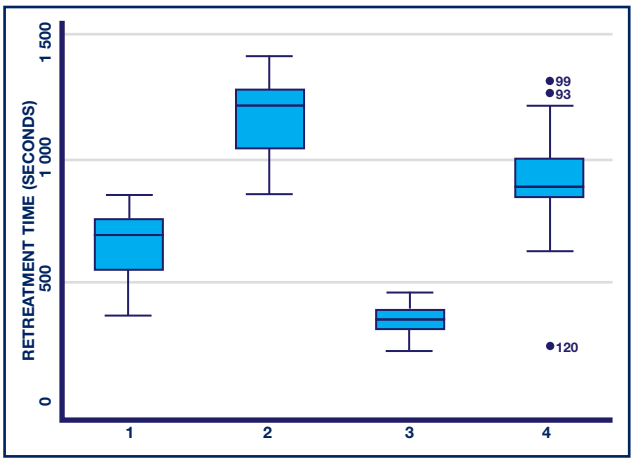
The sealers were introduced into the root canals using a #20 K-file (Flexofile, Dentsply Sirona SA) in order to coat the canal walls. The master GP cone was then coated with the sealer and slowly inserted to the appropriate length. The hydraulic condensation technique, as described by the manufacturer, where the GP is used to spread the sealer cement within the canal; and accessory GPs placed only when necessary was used for groups 1 and 2. The lateral condensation technique was used for groups 3 and 4. Digital x-rays were taken and used to assess the quality of the root filling. All the specimens were stored at 37^{0}C in 100% humidity for three weeks in a laboratory warm water bath (Labcon Laboratory Equipment, Krugersdorp, South Africa)

Retreatment procedure

A medium sized round bur (Mani, Utsunomiya, Tochigi, Japan) mounted on a high-speed handpiece (W&H, Bürmoos, Austria) was used to remove the glass ionomer cement seal. D-Race retreatment files DR1 and DR2 (FKG Dentaire SA, Switzerland) were used for the removal of obturation material.

The DR1 which has a taper of 10%, an active cutting tip of ISO size 030 and a D0-D1 length of 8mm, at 1.5Ncm torque and 1000rpm, was used to remove obturation material in the coronal third of the root. The DR2 file which has a taper of 4%, a non- cutting tip of ISO size 025 and a D0-D1 length of 16mm, at 1.5Ncm torque and 600rpm was used to remove obturation material in the apical two-thirds of the root. The retreatment file was advanced until resistance was encountered or working length was reached. If resistance was encountered before working length was reached, two drops of Endosolv solvent for root canal sealers (Saint-Maur-des-Fossés, France) were introduced into the canal and removal re-attempted after 3 minutes. If working length was not achieved using the rotary files, a further 2 drops of Endosolv was applied. Three minutes later, small Flexofiles #s 6, 8 and 10 (Dentsply Maillefer, Ballaigues, Switzerland) and Pro-Ultra Endodontic Tips (Dentsply Tulsa Dental Specialties) numbers 6 and 7 used in a pecking motion were used in an attempt to reach WL. This was repeated if the first intervention was unsuccessful. Retreatment was abandoned and considered unsuccessful if no progress was being made at this stage or the retreatment time had gone beyond 20 minutes (1200 seconds).

Fig 1. Box plot showing the retreatment times (in seconds) for each group.



RESULTS

Statistical analysis

There were 30 canals in each of the four groups 1, 2, 3 and 4. In total there were 120 specimens that were retreated. In all cases where working length was regained, apical patency was also achieved. Working length was regained and apical patency achieved in all 30 teeth in groups 1 and 3. This translates to 100% successful retreatment. However, working length was regained and apical patency achieved in only 9 out of the 30 teeth (30%) in group 2 and 25 out of 30 teeth (83%) in group 4. In total 94 out of 120 teeth were successfully retreated. (See Table 1)

Table 1

Group	No. Of Specimens	No. Of Specimens Sucessfully Retreated	Percentage Of Specimens Successfully Retreated
1	30	30	100%
2	30	9	30%
3	30	30	100%
4	30	25	83%
Total	**120**	**94**	**78.3%**

In the samples where, working length was regained and apical patency achieved, it happened much faster in Group 3 (median time = 346 seconds) followed by Group 1(median time = 577.5 seconds). Group 4 took the second longest time (median time = 872.5 seconds) while group 2 took the longest time (median time = 1218 seconds). (See Table II)

Table II

GROUP	N	P50
1	30	577.5
2	30	1219
3	30	346
4	30	872.5
TOTAL	**120**	**728**

When the time it took to retreat was considered, regardless of whether retreatment was successful or not, group 2 took the longest time while group 3 took the shortest time. The times it took to work on each specimen from each group is presented the table and box plots left.

A Kruskal-Wallis H test was run to determine if there were differences in retreatment times between four groups of the

two endodontic sealing materials, each with two different working lengths. (See Fig 1) Distributions of retreatment times were not similar for all groups, as assessed by visual inspection of the boxplot. The distributions of retreatment times were statistically significantly different between groups, $\chi2(3) = 96.280$, $p = 0.001$.

There were 94 teeth that reached apical patency. Group 2 had the least number of teeth that reached apical patency (9) and it also took the longest time to reach apical patency (median time 990 seconds. Group 3 took the shortest time to reach apical patency in all thirty teeth at a median time of 346 seconds.

DISCUSSION

The use of endodontic bioceramic based sealers have grown in popularity in recent years. The mechanism of bioceramic sealer bonding to root dentine is based on: the diffusion of the sealer particles into dentine tubules causing mechanical interlocking bonds; infiltration of the sealer mineral content into intertubular dentine causing a mineral infiltration zone; and the reaction of the phosphate with calcium silicate hydrogel and calcium hydroxide which causes the formation of hydroxyapatite along the mineral infiltration zone.[21,30] Thus; bioceramic sealers have great biocompatibility due to their similarity with biological hydroxyapatite. The biocompatibility of bioceramics aid in preventing a reaction in surrounding tissues as well as chemically bonding to tooth structure. The calcium phosphate component in bioceramic materials intensifies the setting reactions which results in a chemical configuration with a crystalline formation close to tooth and bone-apatite materials.[30]

Root filling materials act as a barrier which prevents access to and complete removal of necrotic debris and bacteria that cause and sustain peri-apical lesions.[48] This should be removed to facilitate successful retreatment.[38] Endodontic retreatment is performed to remove the root filling material (Gutta Percha), after persistent infection and root canal failure. This followed by debridement, shaping and disinfection of root pulp system for a second time.

Studies evaluating the removal of different root filling materials confirm that absolute complete removal of these materials is impossible.[34-37] However, as a pre-requisite to successful retreatment, working length and apical patency must be established.[38] Opinion on whether root canals sealed using a bioceramic sealer can successfully be retreated is divided.

This study aimed to determine the retreability of canals sealed using a bioceramic sealer. The sealing of canals in groups 2 (TotalFill BC) and 4 (AH Plus) with the gutta percha cone 3mm short of the working length allowed the study to independently test the effect of the experimental and control sealer cements on the retreatability of canals. Although this is not the correct or ideal manner to use these materials, this may happen in the clinical scenario.

The results indicated that retreatment of canals sealed using a bioceramic sealer took longer than the epoxy resin–amine-based group. Sealing the canal with the master GP cone short of the WL not only made the retreatment to take longer, but it reduced the chances of successful retreatment immensely, more so in the bioceramic sealer group. The additional time can be attributed to extra time needed to get patency and regaining working length due to the nature of the bioceramic material. A Kruskal-Wallis H test was run to determine if there were differences in retreatment times between the four groups varying endodontic sealing materials, and different working lengths. Distributions of retreatment times were not similar for all groups, as assessed by visual inspection of a boxplot. The distributions of retreatment times were statistically significantly different between groups, $\chi2(3) = 96.280$, $p = 0.001$. The retreatment times for the four groups were statistically significantly different, ($\chi2(2) = 221.05$, $p < 0.005$).

The findings of this study agree with those of Hess *et al.*[39] who found that it was significantly more difficult to retreat canals sealed using a bioceramic sealer especially where the GP cone does not extend to the working length. They noted that GP serves as a pathway for the retreatment instruments. Even though the bioceramic sealers have set, the GP remains the core material. Agrafioti *et al.*[40] found that working length and patency was established in 100% of specimens in all groups. This group had also intentionally obturated one of their sample groups with the master cone GP 2mm short of the working length to allow evaluation of the effect of the sealer cement independently. They established that in the group where the master GP was placed 2mm short of the WL, although working length and apical patency were achieved, it took a longer time. This was in comparison to the groups that were sealed to length with GP and AH Plus as well as the group that was filled to length with Gutta percha and TotalFill BC and/or MTA Fillapex. The difference in time was statistically significant. This latter finding agrees with both this study and that by Hess *et al*.[39]

The difference in these findings could be accounted for by the duration which the cements were allowed to set before retreatment as well as when the decision to stop retreatment was set at. This study set the stoppage at either when working length and apical patency was achieved or when no progress was being made by the retreatment instruments apically beyond the 20-minute mark. In the Agrafioti[40] study, the time at which retreatment was to be stopped if progress wasn't being made was not stated. The time to stop in case of lack of progress was outlined in the present study because clinically extended attempts to retreat canals are prone to result in procedural errors like perforation and instrument separation. The difference in root anatomy of specimens could also contribute to the difference between the current study and that of Agrafioti *et al.*[40]

CONCLUSION

The present *in vitro* study suggests that the new calcium silicate-based sealers are negotiable, when the root canal anatomy is simple. However, these procedures may be time demanding. The current study submits that bioceramic sealers are navigable within certain constraints. However, it does require more time spent to complete the procedures. Since the fully extended GP will guarantee a passage for retreatment instruments to the apical area of the canal should a need to retreat arise, the sealer and GP application technique during obturation should allow for full extension of the GP within the canal. Improper use of bioceramic sealers diminishes the chances of successful retreatment. The use of bioceramic sealers to seal successfully retreated canals should be considered.

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Oral antibiotic prescription patterns for dental conditions at two public sector hospitals in Pietermaritzburg, KwaZulu-Natal

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ABSTRACT

Introduction

Antibiotic resistance is a growing public health concern. Yet, there is a paucity of published data in KwaZulu-Natal on antibiotic prescription trends and patterns related to dental use.

Study Objectives

The objectives of this study were to identify the range of dental conditions for which oral antibiotics are prescribed at two public health settings (Institution A and B) in the Pietermaritzburg Complex, KwaZulu-Natal and to explore practitioner understanding of the indications for antibiotic prescription for dental conditions.

Methods

The study used a two-phased approach and collected a combination of qualitative and quantitative data. Phase 1 comprised a retrospective clinical chart review (n=720), while phase 2 comprised a focus-group discussion with purposively selected health care practitioners at each institution.

Results

The results of the retrospective clinical chart review indicated that dental abscesses were the most common dental infections requiring oral antibiotic therapy (n= 479; 66%), followed by acute alveolar osteitis (dry socket) (n=110; 15%), dental impactions (n=78; 11%) and dental extractions (n=62; 9%). At Institution A, antibiotic therapy was prescribed for conditions such as trismus (n=13; 6%), soft palate swelling of unspecified origin (n=9; 4%), fibrous epulis (n=6; 3%) and acute herpes simplex (n=2; 1%). Interestingly, antibiotics were not prescribed at Institution B for the same dental conditions. Antibiotic therapy was also prescribed for eruption pain (n=4; 1%) and for cases when patients did not bring their inhaler for asthma treatment (pump) (n=3; 1%). The findings from the focus-group discussions suggested that there is a need to improve practitioner understanding of the indications for antibiotic prescriptions for dental conditions.

Conclusion

This study showed some differences in antibiotic therapy prescription patterns at the two public health institutions, especially for dental conditions that did not require such management. This suggests a need for consensus-building among health professionals and the provision of more dedicated guidance for antibiotic prescription in the management of dental conditions.

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INTRODUCTION

Antimicrobial resistance is a global threat, it is estimated that 700 000 people die annually as a result of antimicrobial resistance.[1] By 2050, this figure is set to escalate to 10 million.[2] The reported indiscriminate or inappropriate use of antibiotics for dental conditions requires a review, specifically in light of the proliferation of resistant bacterial strains that could lead to antibiotic resistance.[3] There is an unclear picture of antimicrobial consumption rates as well as discrepancies in antibiotic prescriptions across different countries.[4] Despite adequate knowledge of appropriate antibiotic use, health care practitioners in Australia still over-prescribe, while dentists in Switzerland are cautious and unsure about prescribing antibiotics.[5]

From a South African perspective, Mthethwa *et al.* reported that oral health care practitioners lack adequate knowledge of the available treatment guidelines and best practices related to prescribing antibiotic prophylaxis.[6] A more recent study reported that antibiotic prescribing patterns by dentists following tooth extraction did not appear to follow a consistent or coherent set of guidelines for antibiotic use.[3] Despite the availability of several clinical practice guidelines on the use of systemic antibiotics to treat pulpal and peri-apical infections [7], there is very little published evidence on antibiotic- prescribing practices of dentists in South Africa.[8]

The South African Antibiotic Stewardship Programme was developed in 2012 in response to the general identified gap in antibiotic prescription trends and patterns in health care. Its purpose is to implement antibiotic stewardship programmes in hospitals and primary health care facilities.[9] The aim of this programme is to 'strengthen the antimicrobial surveillance, ensure uninterrupted access to quality essential medicines, to enhance infection prevention and control and to stimulate further research innovations'.[4] Antimicrobial prescribing practices in the public sector in South Africa are also guided by the Standard Treatment Guidelines and the Essential Medicines List 2020.[10] These documents are available electronically (http://www.kznhealth.gov.za/

pharmacy/PHC-STG-2020.pdf) and is a valuable resource to guide practitioners on antibiotic prescriptions.[4,11,12] A properly developed antibiotic surveillance programme coupled with clearly defined protocols for the judicious prescription of antibiotics can collectively contribute to delays in the emergence of resistant bacteria.[1] Adherence to the Standard Treatment Guidelines and the South African Antibiotic Stewardship Programme can also contribute to the reduction of inappropriate antibiotic prescribing that could in turn result in improved prescribing practices in dentistry. Yet, it is unclear to what extent health practitioners use these guidelines for the prescription of antibiotics for dental clinical conditions.

Given this unclear picture of oral antibiotic prescription patterns for dental conditions, this study aimed to determine antibiotic prescription trends and patterns for dental use in the public health care sector in Pietermaritzburg, in order to have a better understanding of the current management of dental conditions.

METHODOLOGY

This was an exploratory study, using a combination of qualitative and quantitative data. The research sites comprised two purposively selected hospitals (Institution A and Institution B) in the Pietermaritzburg Complex, given that these two institutions offer both basic oral health services such as management of dental caries and periodontal disease as well as more advanced services related to trauma and various types of pathology. Two phases were used in this study. The first phase comprised a retrospective clinical chart review for the period March 2012 to July 2018 (n=720). The second phase comprised two focus-group discussions (FDGs) with purposively selected health practitioners (one FGD at each institution). The study selection criteria included all health care professionals who prescribed and dispensed antibiotics for dental use. The study excluded dental and medical managers, and practitioners not involved in the clinical management and prescription of antibiotics for dental use. Ethical clearance was obtained from the Biomedical Research Ethics Committee, University of KwaZulu-Natal (Reference number. BE026/190) while permission to conduct the study was obtained from the KwaZulu-Natal Department of Health (Reference number. NHRD Ref: KZ_201902_018).

For the retrospective clinical record review, managers for each admissions department in the respective research site selected and retrieved the clinical records based on the criteria set by the researcher. The rationale for this approach was to minimize potential researcher bias in the selection of clinical records for review. The inclusion criteria included patients aged 6 to 80 years; evidence of documented antibiotic prescription for dental conditions; antibiotic prophylaxis for systemic conditions such as infective endocarditis in a patient who suffered from rheumatic heart fever; or oral antibiotic cover prior to dental surgery and/or after dental treatment. A data capturing sheet was used to document the patients' age, gender, dental history, main complaint, symptoms, differential diagnosis, laboratory reports, prescribed treatment, number of prescribed medications, drug dosage, frequency and route of administration. An antibiotic therapy worksheet[12,13] was used to gather information related to the appropriateness of the antibiotic regimen, therapeutic duplication and adverse reactions, and comparisons were made with the Standard Treatment Guidelines and the Essential Medicines List (2020). This worksheet has been validated in previous studies.[12,13]

Phase 2 comprised FGDs with health care practitioners (dental and medical practitioners) and pharmacists, involved in prescribing and dispensing antibiotics for dental purposes. Purposive sampling was used to set up the two FGDs comprising six volunteers per group at each research site. The inclusion criteria entailed practitioner eligibility to prescribe or dispense antibiotics for dental use; and registration with the Health Professionals Council of South Africa or the Pharmacy Council of South Africa (in the case of pharmacists). A semi-structured focus group schedule was used to collect data.

The focus group schedule comprised open-ended questions that explored participants' perspectives on the National Strategic Framework, Essential Medicines Lists, Standard Treatment Guidelines, The South African Antibiotic Stewardship Programme, antibiotic prescription patterns for dental conditions, adverse events related to antibiotic prescription and trends and perceptions of antibiotic prescription practices from a multi-disciplinary approach. Other questions included perceived barriers, challenges and opportunities to access oral health care, patient compliance, and the value of a multi-disciplinary team approach in combating antibiotic resistance. Written informed consent was obtained from all participants and ethical considerations such as confidentiality and anonymity were upheld. All participants were informed that they had the right to withdraw from the study at any stage without any negative consequences.

The FGDs were audio recorded and the recordings were transcribed verbatim and then cleaned. The information was transcribed onto a Microsoft Word document. A research consultant assisted with the data analysis process. Data coding was done independently by the researcher and the research consultant to identify significant features of the data and to sort out the data, thereby allowing for the emergence of sub-themes and themes from the participants' responses, as part of the thematic analysis.[14-16] The data was then compared in order to identify common themes. The qualitative data was analyzed using Nvivo version.[11] The credibility of the study was achieved by establishing that the findings of the study were a true reflection of the participant's' original view.[17] Transferability was achieved by comparing the study findings with previous and current literature.[18] Conformability was achieved through the use of quotations of actual dialogues expressed by study participants.[19]

The quantitative data was analyzed using IMB SPSS (version 25R). Univariate descriptive statistics such as frequency and mean distribution were conducted for all variables. Bivariate statistics was also used to assess the outcome and thereafter, the outcome was analyzed by the explanatory variable.[20]

RESULTS

Phase 1

A total number of 220 clinical charts (30.6%) were reviewed at Institution A and 500 clinical charts (69.4%) at Institution B. The study sample across the two institutions comprised 490 females (65.3 %). Almost half of the study sample (n= 357; 49.7 %) were in the age group 40-60 years. Only 86 patients (12%) recorded were in the 6-year-old age group.

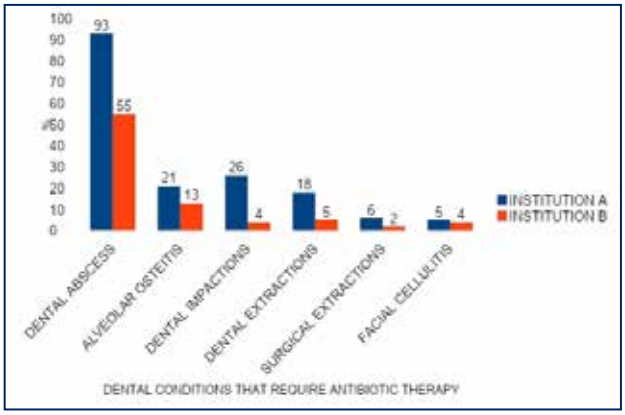
The most common dental infection requiring oral antibiotic therapy at both institutions was dental abscesses (n= 479; 66%), followed by acute alveolar osteitis (dry socket) (n=110; 15%); surgical removal of impacted third molars (n=78;

Table 1: Oral antibiotic prescriptions for dental and health related conditions

Health conditions for which antibiotics are prescribed	Institution A (n=220 files)	Institution B (n=500 files)	Total (n=720 files)
1. Other dental conditions			
Necrotizing gingivitis	8 (4%)	12 (2.4%)	20 (3%)
Facial Cellulitis	10 (5%)	21 (4%)	31(4%)
Pericoronitis	8 (4%)	5 (1%)	13 (2%)
Trismus	13 (6%)		13 (2%)
Fractured Maxilla/Mandible	6 (3%)	5 (1%)	11 (2%)
Soft palate swelling	9 (4%)		9 (1%)
Gingivitis	8 (4%)	1 (0.2%)	9 (1%)
Acute Herpes	2 (1%)		2 (0.3%)
Aphthous Ulcers	3 (1%)	4 (0.8%)	7 (1%)
Fibrous Epulis	6 (3%)		6 (1%)
2. Trauma			
Motor vehicle accidents	2 (1%)	3 (1%)	5 (1%)
Facial trauma	4 (2%)		4(1%)
Assault	16 (7%)	9 (2%)	25 (3%)
Bony spicules	3 (1%)		3 (0.4%)
3. Systemic conditions that resulted in postponement of dental treatment			
Uncontrolled Hypertension	19 (9%)	39 (8%)	48 (7%)
Uncontrolled Diabetes	3 (1%)	10 (2%)	13 (2%)
Infective endocarditis	5 (2%)	2 (0.4%)	7 (1%)
Valve replacements	1(0.4%)		1 (0.1%)
Uncontrolled Asthma		3 (1%)	3 (0.4%)
3. Miscellaneous			
Fillings	3(1%)	5 (1%)	8 (1%)
Biopsy	1(0.4%)	2 (0.4%)	3 (0.4%)
Root canal therapy	7 (3%)	2 (0.4%)	9 (1%)
Eruption Pain		4 (1%)	4 (0.5%)
Referrals to regional and tertiary hospitals for further management	5 (2%)	6 (1%)	11 (2%)
Patients undergoing dental treatment under General Anaesthesia	13 (6%)	2 (0.4%)	15 (2%)
Patient request	2 (1%)		2 (0.2%)
Uncooperative Patients	20 (9%)	4 (1%)	24 (3%)
Treatment deferred	2 (1%)	16 (3%)	18 (3%)

11%); dental extractions (n=62; 9%), and surgical extractions (n=22; 3%) (Figure 1). Allergies were recorded and alternate antibiotics were prescribed in a small number of clinical files (n=5; 3% in Institution A and n=7; 1% in Institution B). Healthcare practitioners in Institution A prescribed both Clindamycin and Azithromycin for patients allergic to Penicillin (n=5; 0.7%) while those in Institution B prescribed Erythromycin (n=2; 0.3%). According to the Standard Treatment Guidelines 2020 (STG), adult patients should receive Amoxicillin, oral, 500 mg 8 hourly for 5 days and Metronidazole, oral, 400 mg, 8 hourly for 5 days. In cases where patients have severe penicillin allergies, Azithromycin, oral, 500 mg daily can be prescribed for 3 days. The doses for the same antibiotics used in children presenting with dental abscesses, differed according to the guideline. The STG (2020) does not out outline antibiotic prescription for dental caries and dental extractions.

Figure 1: Common dental conditions requiring antibiotic therapy



At Institution A, antibiotic therapy was prescribed for conditions such as trismus (n=13; 6%), soft palate swelling (n=9; 4%), fibrous epulis (n=6; 3%), and acute herpes simplex (n=2; 1%) (Table 1). With regards to herpes simplex lesions (such as those on the lips), the STG (2020) indicates that an antiviral agent such as Acyclovir, oral, 400 mg, 8 hourly, for 7 days should be prescribed for adult patients with extensive oral herpes for 7 days. This again reflects that the STG (2020) does not highlight the need for antibiotic prescription for patients with acute herpes simplex lesions. Antibiotic

Table 2: Recommendations for improved antibiotic prescriptions

Recommendations	Quotations
Improvement of antibiotics prescription	"Strategies are implemented to combat antimicrobial resistance." (Institution A) "The last line of antibiotics prescribed now requires authorization from the consultant." (Institution B) "Diagnostic tests are recommended before prescribing antibiotics for clients." (Institution B) "Start first line antibiotics based on differential diagnosis and prescribe the definitive treatment based on confirmed diagnosis test results." (Dental practitioners from Institution A) "Antibiotic prescription was changed according to weight as instructed by the Standard Treatment Guidelines as opposed to assuming the dosage as per the age of the pediatric patient." (Institution A)
2. Reduce the adverse effect from incorrect antibiotic prescription	2. Reduce the adverse effect from incorrect antibiotic prescription "Yes, there has been one incident of an adverse effect from the incorrect antibiotic prescribed which was due to insufficient history taking and patient transparency." (Dental Practitioner from Institution A)
3. Multi-disciplinary team approach	"The pharmacists always check and approve the prescriptions recommended by medical and dental practitioners" (Institution A). "If there is an adverse effect related to antibiotic allergy, the medical practitioners always work together with the dentists to stabilize the patient." (Institution B).

prescription is also not mentioned for conditions such as trismus and fibrous epulis in the STG (2020).

Antibiotics were prescribed for necrotizing gingivitis (n=20; 3%). The STG (2020) indicates that chlorhexidine 0.2%, 15 mL as a mouthwash, should be prescribed twice daily for patients with uncomplicated gingivitis while Metronidazole, oral, 400 mg, 8 hourly, for 5 days should be prescribed for patients with necrotizing periodontitis for 5 days together with chlorhexidine 0.2%, 15 mL as a mouthwash. The STG (2020) does not mention antibiotic prescriptions for dental conditions such as gingivitis, facial cellulitis, aphthous ulcers, and fibrous epulis. However, Cefalexin, oral 500mg 6 hourly for 5 days or Flucloxacillin, oral, 500mg 6 hourly for 5 days are indicated in the case of adults presenting with cellulitis.

Antibiotic therapy was prescribed for 16 patients treated for assault (7%) at Institution A while only 9 such cases were recorded at Institution B (2%). However, it is possible that more patients requiring management for assault could have presented at Institution A, hence this can explain the skew in the prescription trends between the two institutions. Moreover, there is no indication in the STG (2020) that antibiotics should be prescribed for patients presenting with trauma. Antibiotics were prescribed for patients for whom dental treatment was complicated due to systemic conditions or the treatment was deferred (n=18; 3%). and/or when the patient was referred to other health facilities for further clinical management (n=11; 2%). The systemic condition necessitated the postponement of dental treatment but antibiotics appeared to be prescribed because the patient needed dental extractions, in most cases. Less than half of the cases with uncontrolled blood pressure (n=48; 7%) were prescribed antibiotic therapy across both institutions. Patients undergoing treatment under general anaesthesia for dental extractions involving multiple teeth, were prescribed antibiotics at both Institution A (n=13; 2%) and Institution B (n=2; 0. 4%). Institution A was much more likely (n=20; 9%) than Institution B (n=4; 1%) to prescribe antibiotics for un-cooperative patients.

Although antibiotics were prescribed for mostly the same dental conditions at both institutions, certain prescriptions made at Institution B did not appear to be prescribed at Institution A. Antibiotic therapy was prescribed for eruption pain (n=4; 1%) and in cases where patients required a dental extraction but did not have their inhaler for their asthma treatment (pump) (n=3; 1%) at Institution B (Table 1). However, there is no indication if antibiotics were prescribed because the treatment had to be postponed, in the case of a patient who did not bring his/her asthma treatment (pump) to the dental clinic, or due to the dental condition.

Phase 2

The following themes emerged from data analysis: inconsistency in antibiotic use for dental treatment needs; adherence to the standard treatment guidelines, and strategies to combat antibiotic resistance.

Theme 1: Inconsistency in antibiotic cover for dental-related treatment

Study participants indicated that medical practitioners are not primarily involved in the prescription of antibiotics for common dental conditions and instead refer patients to the dental department.

"Antibiotics were prescribed for dental abscesses, patients with multiple carious teeth presenting for general anesthesia, prophylaxis for rheumatic heart fever [Prophylaxis for infective endocarditis in a patient who suffered from rheumatic heart fever] and cases of open wound fractures and trauma" (Institution A). On the other hand, antibiotic coverage was prescribed for dental abscess, open wound fractures, cellulitis, dry socket, pericoronitis, and periodontitis, and antibiotic prophylaxis after tooth extraction, necrotizing ulcerative gingivitis, rheumatic heart fever and infective endocarditis at Institution B.

Theme 2: Antibiotic prescription and the adherence to the Standard Treatment Guidelines

All participants (medical and dental practitioners) confirmed that antibiotics were prescribed according to the STG, as reflected in the following quotation. "*Yes, the standard treatment guidelines are followed when prescribing antibiotics." (Institution A) "The medical and dental practitioners seem to be prescribing the correct regimen according to the Standard treatment guid*elines." *(Pharmacists from Institution A).* However, this finding is not congruent with the results of the clinical record analysis reported earlier.

Theme 3: Strategies to combat antibiotic resistance

There was no consensus among research participants on the need for diagnostic laboratory testing to improve antibiotics prescription. However, all participants agreed that there is a need to improve antibiotic prescription in their respective hospitals despite the fact that the respondents indicated earlier that the standard treatment guidelines are

followed.*"Prescribers use empirical treatment which may result in antibiotic resistance."* (Institution B).

Some recommendations to improve antibiotics prescription trends and reduce possible resistance are listed in Table 2.

DISCUSSION

The need for systemic antibiotic use in dentistry is limited given that most dental infections such as pulpitis and periapical periodontitis, require only operative procedures such as extractions, restorations or root canal therapy and that it is only by exception that antibiotics are required for dental conditions.[6] Yet, the results of this study indicate that some inconsistencies in antibiotic prescriptions for dental conditions did exist in the two identified sites. According to our study, a dental abscess (66%) was the most common dental infection requiring antibiotic therapy. Long postulates that dental abscesses larger than 5 cm, cellulitis or conditions with mixed abscess-cellulitis require antibiotics coverage.[21] Incision and drainage (especially when there is substantial inflammation and pain) with or without adjunctive antibiotic therapy are recommended for localized infections such as a periapical abscess, periodontal abscess and a localized dentoalveolar abscess. Likewise, sepsis can progress to cellulitis, and possibly to Ludwig's angina which could be life-threatening. Therefore, the prescription of antibiotics is justified in the management of dental abscesses.[22-24]

The clinical records revealed that antibiotics were prescribed for the treatment of alveolitis (dry socket) (15%), as it is done in England, Kuwait and Turkey where almost half the dentists surveyed would prescribe antibiotics for a dry socket.[23] However, a single dose of Metronidazole was not found to be effective in preventing the onset of dry socket. Similarly, most dentoalveolar surgical procedures in healthy individuals did not require antibiotic prophylaxis.[23]

This study further indicated that antibiotic prophylaxis was prescribed for impacted third molar surgery (11%). Prophylactic antibiotic therapy in third molar surgery in healthy patients is highly controversial.[25] There is no clear evidence that pre-operative antibiotic prophylaxis for routine third molar surgery is necessary for patients with no underlying medical complications.[23] A Cochrane review indicated that prophylactic antibiotics reduces the risk of infection, dry socket and pain following third molar extraction.[6] Yet, at the same time, the STG (2020) has limited information on the management of dental conditions, with no mention of antibiotic prophylaxis to be given prior to the surgical removal of impacted third molars.

Likewise, the STG (2020) does not provide guidance for all dental conditions that are managed within clinical settings in South Africa. The implications are that this guideline does not provide adequate guidance for dental clinical management. This inadvertently creates loopholes for health and dental practitioners to use their own discretion in deciding when to prescribe antibiotics. This finding is consistent with Lalloo et al. who also observed that practitioners might be using subjective measures or even personal preferences when deciding whether to prescribe antibiotics or not.[3] This highlights the need for an urgent review of the STG (2020) so that this document is able to provide more comprehensive guidance to practitioners in the country.

Antibiotics were prescribed for dental conditions such pericoronitis (2%), trismus (2%), acute herpes simplex (0.3%); aphthous ulcers (1%), fibrous epulis (1%), and eruption pain or for procedures such as (0.5%) restorations (fillings) (1%), biopsy (0.4 %) when the STG (2020) has not indicated antibiotics for these conditions and procedures. Antibiotics were also prescribed for uncooperative patients requiring dental extractions especially in Institution A (9%), or because the patient requested so (0.2%). Although these percentages are low, the implications are the wholly inappropriate use of antibiotics for dental clinical management, in respect of certain dental conditions.

The results of the qualitative data analysis further indicated that medical practitioners were more likely to refer patients to the dental department for the prescription of antibiotics for common dental conditions. At the same time all participants suggested that the prescription of antibiotics for dental use was based on the STG, yet the results of the retrospective clinical records review illustrate that antibiotics were prescribed for conditions that are not covered in the guideline. This finding is thus not consistent with the results of the clinical record analysis thereby suggesting some inconsistencies in the pattern and trends in antibiotic prescriptions for dental conditions at the two health institutions.

Antibiotics were prescribed for patients for whom treatment was complicated due to underlying systemic conditions. It is noteworthy that antibiotics were not prescribed for the systemic condition, but rather, were given because either the dental treatment could not be performed or it was deemed that the patient is at risk of infection due to the systemic condition. This finding is consistent with previous reviews which concluded that patients with low immunity may be at higher risk of infection.[26] In such cases prophylactic antibiotics could be beneficial to patients, where applicable.[26]

The results of this study showed that antibiotics were prescribed for the prevention of infective endocarditis in a patient who suffered from rheumatic heart fever (1%). This observation is consistent with the findings reported by Mthethwa et al., in that 2.2% of antibiotic prescriptions were given for this purpose. Bacterial endocarditis remains a risk following dental treatment.[27] This is supported by the British Society for Antimicrobial Chemotherapy and the American Heart Association which recommend that only high-risk patients require such cover.[28, 29] Although antibiotic prophylaxis to prevent infective endocarditis in patients who suffer from rheumatic heart fever, is widely accepted by the dental profession,[6] the effectiveness of such antibiotic prophylaxis in humans, however, remains unproven.[30, 31] The question however, remains as to whether antibiotics were prescribed judiciously in this study. Future research in this area is needed to further explore these identified issues.

Overall, the results of the study suggest that some over-prescription of antibiotics does exist. This needs to be reviewed because an increase in bacterial resistance to antibiotics and the associated costs will have an impact on care care delivery as well as resource allocations.[3] Dental practitioners have a responsibility to reduce and improve the way they prescribe antibiotics and should prescribe with the correct indications. Practitioners should not be swayed or influenced by the patient's demands for antibiotics cover.[32] Dental practitioners also have a responsibility to educate patients on the spread and consequences of antimicrobial

resistance.[32] There should be greater community awareness on the appropriate use of antibiotics.[32] and the injudicious prescription of antibiotics for the treatment of 'toothache' should be avoided.[33] Clinicians thus need to be aware of the ongoing evidence base for antibiotic prescription practices.[3] More research is required for the appropriate antibiotic prescription in the field of clinical dentistry.[34] Some participants in the FGDs also indicated that pharmacists played an important in the oversight and approval of antibiotic prescriptions recommended by medical and dental practitioners. This reiterates the value of a multidisciplinary team approach for antibiotic stewardship so as to ensure that there is oversight and accountability for antibiotic prescriptions.

Study strengths and Limitations

This study provided much needed data on antibiotic prescription patterns for dental conditions in the public health sector in Pietermaritzburg. While the value of such timely data cannot be overstated, several limitations were noted. The study findings are limited to the two participating health institutions and the reporting period (March 2012- July 2018). Poor record keeping and insufficient diagnostic data could have skewed the study findings. From a data analytical process, inferential statistics were a challenge given the nature of the data collected in the retrospective clinical chart review. A further research question could focus on practitioners' source of knowledge for antibiotic prescriptions (e.g. is it university education, continuing professional development, national guidelines, etc.). This could perhaps identify the gaps that seem to contribute to practitioners' decision-making. Despite these limitations, a clear picture has emerged on antibiotic prescription patterns at the identified health institutions.

CONCLUSION

This study showed that there were some differences in antibiotic prescription trends for dental conditions at the two public health institutions. There is a need for consensus building among health professionals and for better guidance in respect of antibiotic prescription in the management of dental conditions.

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Conflict of interest

None

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CPD questionnaire on page 109

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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Mandibular myiasis: A case report

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ABSTRACT

Myiasis is a condition characterised by the infestation of live vertebrates with dipterous larvae. Myiasis is derived from the Greek word mya, meaning fly. Dipterans, (order Diptera), are two-winged insects known as true flies. Myiasis tends to occur in cutaneous, necrotic lesions of patients who have weak immune systems, who inhabit unhygienic environments. Maggot Debridement Therapy is an uncommon treatment of debriding necrotic tissue, with some utility. A case of mandibular myiasis involving a malignant mandibular lesion that was colonised by maggots is discussed.

Key words

Myiasis, maggot, oral, facial, infection, wound

INTRODUCTION

Myiasis is a condition characterised by the infestation of live vertebrates with dipterous larvae[1]. Myiasis is derived from the Greek word mya, meaning fly. Dipterans (order Diptera) are two-winged insects known as true flies[2]. The Old Testament was the first written account of human myiasis[3]. It is more common in the tropical and sub-tropical regions of Africa, Central America and South America.

CASE REPORT

A 71-year-old male patient presented with a two-month history of ulceration on the dorsum of the tongue. Three weeks prior to presentation, infection developed, the patient lost the ability of speech and the lesion became infested by maggots. On examination, the patient was cachexic and an obvious lesion on the genium was noted with associated hyperpigmented skin and maggot infestation.

Dysmorphic, necrotic tissue was noted on the anterior aspect of the mandible extending posteriorly along the floor of the mouth. Poor hygiene and mobile teeth were salient. The lesion was debrided, a biopsy was taken, dressings were placed and the patient was prepared for admission to the hospital. Prior to being transported to the ward, the patient developed cardiac arrest. Resuscitation was attempted unsuccessfully and the patient demised. The histology confirmed a squamous cell carcinoma.

DISCUSSION

Human myiasis may be classified according to anatomical location. Cutaneous myiasis may be further classified into wound, furuncular and migratory myiasis[4]. Wound myiasis is the most common type encountered. The infestation of larvae in a necrotic lesion is considered to be wound, traumatic or opportunistic myiasis. Myiasis may be caused by a variety of fly species, with a particular species being either obligate, facultative or accidental parasites. Although different species may cause wound myiasis, generally only one species is found in a particular lesion[1]. Cutaneous lesions usually heal well, often with minimal or no scarring[1]. In a South African study by Kuria *et al*, 25 cases of wound myiasis were diagnosed over a four-year period in the Eastern Cape. The commonly encountered species leading to human myiasis are Lucilia Sericata and Lucilia Cuprina, with the latter

Figure 1: Patient presentation with a maggot-infested anterior mandible

Figure 2: Following debridement of the lesion

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The role played and the respective contribution:

1. I Abdoola: Writing article, data collection, data analysis – 50%
2. MMR Bouckaert: Corrections - 25%
3. M Ibrahim: Data analysis, researching relevant related articles – 25%

Figure 3: The debrided necrotic tissue and maggots

Figure 4: Lucilia sericata, a species used for maggot debridement therapy[6]

being the most prevalent noted[4]. Flies may deposit larvae on clothing, soil, wounds, or on mosquitos; these act as fomites and vectors in larval transmission. Incubation periods of obligate parasites vary according to species, lasting up to 12 weeks in Dermatobia Hominis (Human Botfly) (Figure 4).

Diagnosis

Wound myiasis is usually easily diagnosed on inspection. A high clinical suspicion is warranted, especially with the history of travel to endemic areas within 12 weeks. Pain, malodorous suppuration and the sensation of movement beneath the skin may be clues to the presence of larvae. Ultrasound is a useful diagnostic tool. Identification of larvae is sufficient and biopsy may not be necessary if the underlying cause of necrosis is known[1].

Risk factors

The most common predisposing factors to developing human myiasis in a South African population[4] was found to be lower limb gangrene due to peripheral vascular disease, followed by burns, cancerous ulcers and diabetic ulcers. Multiple predisposing factors exist[1,4], including poor hygiene, immunosuppression, old age, alcohol abuse, exposed wounds, suppurative lesions, necrotic tissue, malignant wounds, poor sanitation, poor garbage disposal and low socioeconomic status.

TREATMENT

Mechanical debridement is generally the basis of management[1]. Removal of necrotic tissue and larvae may be supplemented by irrigation (especially for cavities) or medication (such as Ivermectin for migratory myiasis). Debridement should be followed by meticulous wound care. Wound care and hygiene, especially of debilitated patients, should be optimal to preclude cases secondary to medical neglect.

Maggot debridement therapy (MDT)

MDT or artificially induced myiasis was commonly used in the past. MDT is the deliberate use of larvae to debride necrotic tissue, produce antimicrobial compounds and promote healing if used correctly. Use of MDT was noted in the past millennium by aborigines, Mayans and Burmese. Ambroise Pare noticed the benefit of maggots in the 1500s when a patient lost tissue equivalent to the volume of a hand through an infection involving the skull and recovered. Maggots were used during World War I to debride wounds and were noted to improve recovery.

The perceived distasteful nature of the treatment led to a period of disuse. Justified by contemporary research, a recent surge has been noted in the use of maggot debridement therapy in selected patients with long-standing wounds that persist despite attempts of conventional treatment. Contraindications include the presence of large vessels, vital structures or hollow organs near the wound. The larvae of the Green Bottle Housefly (Lucilia Sericata) are the most commonly used species in these cases[3]. Maggots effectively and selectively debride necrotic tissue and due to their photophobic nature, will debride regions where surgical access may otherwise be challenging[1]. Larvae used in MDT produce agents similar to antibiotics, alkalinize wounds by secreted ammonia, ingest bacteria and produce substances that promote wound healing[3]. Larvae must be prepared in a sterile manner for MDT use and removed after a maximum of three days[1,5].

Declaration

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Conflict of interest

No conflicts of interest

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An evidence-based guide to occlusion and articulation. *Part 2: A guide to the evolution of the teeth and joint*

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CP Owen[1]

SUMMARY AND PREAMBLE TO THE SERIES

Although this is essentially a review, it has not been written in the passive, third-person style normally associated with scientific writing, as it is intended to be thought-provoking and, hopefully, educational. It has therefore been written in more of a conversational style, and is aimed at students, dentists and dental technicians who are receptive to a slightly different view of occlusion and articulation, based on evidence.

Occlusion is a topic that has become a kind of archaic minefield of conflicting ideas, propositions, and above all, solutions, most of which are based on a complete lack of understanding of the evolution and development of teeth, and by extension, of clinically objective evidence.

That in itself is a statement of conflict (and perhaps even heretical), but it is by way of warning that this guide is not going to be much like anything you will find in standard text-books of dentistry or dental technology. It is, rather, an attempt to help you navigate through what you will read elsewhere, in the hope that eventually you will find an understanding that you can live with. It will appear as a sequential series in 7 Parts.

A guide to the evolution of the teeth and the joint

Note: *some of this material is to be found in an eBook on Lingualised Occlusion,*[1] *to be found at www.appropriatech.com.*

The evolution and development of the dentition and temporomandibular joint is a useful study in that it gives us clues as to how our present dentition functions (or rather how it is supposed to function naturally).

We are, of course, mammals, and mammals evolved from a group of "mammal-like reptiles" about 310 - 190 million years ago. Reptiles cannot bring their upper and lower teeth together and cannot chew. Their teeth can be of different shapes depending largely on their diet, and only a few reptiles (such as crocodiles) have teeth in sockets. Fig. 1 is a mammal-like reptile reconstructed from fossil remains found in the Free State (South Africa). Thrinaxodon lived about 251 million years ago.

Fig. 1. Thrinaxodon (from http://morgana249.blogspot.com/2014/08/5-ancient-mammal-like-reptiles.html)

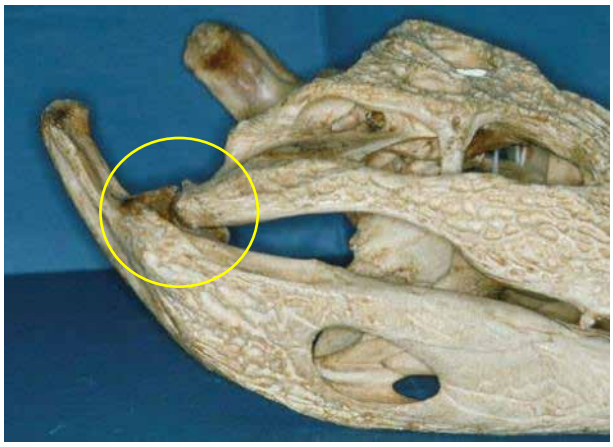

Fig. 2. The jaw joint of a crocodile

But by the time the earliest known mammal had evolved, these now had two sets of teeth, and the maxillary and mandibular teeth could be occluded. At the same time the jaw joint had to evolve from a simple joint between a bone of the mandible, as a shallow fossa-like depression and a condyle-like projection of a bone of the skull. This is what, for example, crocodiles still have (Fig. 2). It is only recently, with the discovery in China of mammal-like reptiles of about 120 million years ago, that this process of going

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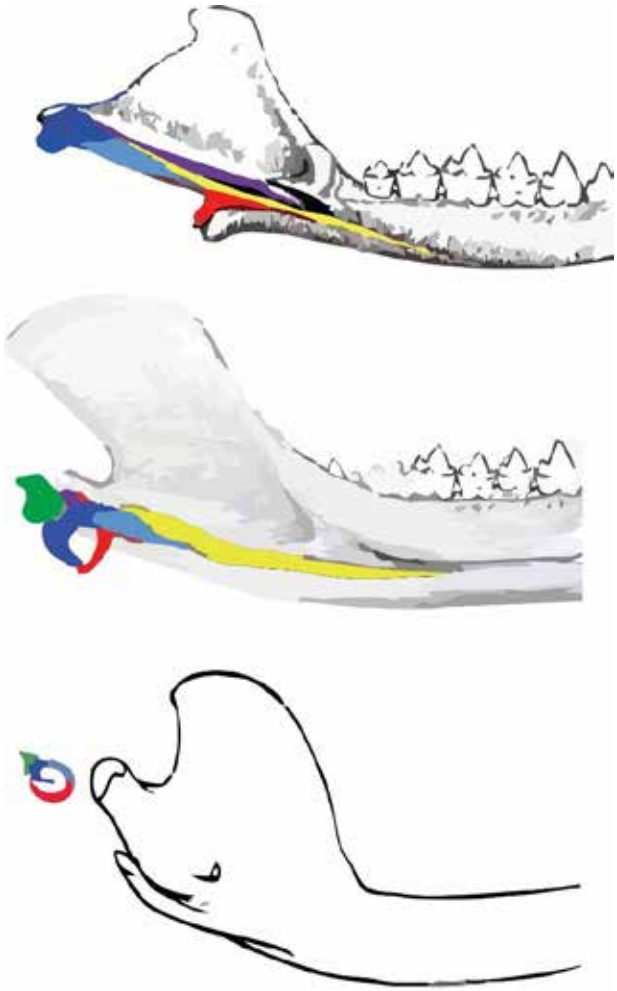

Fig. 3. Top: *Morganucodon* (about 200 million years ago). Middle: *Liaoconodon* (about 120 million years ago). Bottom: modern mammal.Yellow = Ossified Meckel's cartilage. Dark Blue = malleus (was the articular). Light blue = Stapes. Green = incus (was the quadrate). Red = ectotympanic (re-drawn from Meng et al (2011)[2])

from a reptilian joint to having a middle ear, has been better understood.[2] A middle ear is the defining characteristic of mammals, and an 'intermediate mammalian middle ear' seems to be the transitional phase. What has to happen, is that the reptilian ear has to transform so that the fossa-like part of the mandible (the articular) became the malleus of the middle ear and the condyle-like bone of the skull (the quadrate) became the incus. The other ear ossicles must also develop and it is thought this all happens by changes to the ossified Meckel's cartilage (Fig. 3).
What is extraordinary about this is that as this is happening (over millennia, don't forget), the jaw still needs to move and be used and allow movement, so that in the transitional phase, there exists what amounts to a double joint, so that the newly developed ear ossicles, external auditory meatus, tympanic bone and membrane continue to develop without interfering with jaw function, so that eventually the mammalian joint and middle ear became separate structures. Fascinating (well, I think so).

Now at the same time (sort of), the teeth were changing. Two important changes were the development of two sets of teeth (diphyodonty) and the development of the socket in which they were held. The fact that the jaw joint could now allow movements other than the up and down hinge (think crocodile again), meant that the development of a joint that could allow lateral movements, allowed the newly evolved teeth to come into a definite relationship. Which is both good and bad, because now they could grind against each other and can wear.

Probably as a result of this, the development of two dentitions became useful. A primary dentition helps to solve the problem of providing a child with an effective masticatory apparatus appropriate to their needs at that time, and consistent with the space available in the jaws, which still have to grow. But the transition to a permanent dentition could be a problem; this is minimised by a really clever sequence of events: when the central incisors are lost, the primary lateral incisors and canines can be used to incise food; loss of the primary molars does not prevent crushing and grinding food because the first permanent molars are already in place before they are lost.

Now if you think of the unworn teeth with their steep cusps, it is difficult for them to fit together as they erupt, and this was solved by the development of a tooth socket that became a dynamic, changeable one, called a gomphosis, which means a ligament type attachment. This allows for movement within the bone (as those of you who have had orthodontic treatment will know), which importantly, allows the position of each tooth to be adjusted after eruption, in response to forces produced during chewing, and guided by the cusps, so that each tooth normally ends up in the most efficient position.

The development of the mammalian dentition and chewing apparatus is a great example of the wonder of evolution. But when reading this, I have presumed you are thinking of your own, human (I hope) teeth. Anatomically modern humans haven't been around for that long on the evolutionary scale of things, and whilst we were evolving so were other animals and they also had needs to eat and to at least tear off food and to chew it to a greater or lesser extent. Eating means having to pierce, crush, cut, shred, and grind food, depending on the food, and sometimes all of those things.

So once again, we come back to the issue of function, and to better understand how teeth with an inert outer layer on top of a living, organic layer are supposed to function, we need to take a short tour of the animal kingdom (at least those with teeth, mainly).

Different strokes for different folks: us and the rest of the mammalian animal kingdom

Herbivores

By which I don't mean human vegetarians, or vegans or whatever. Herbivores are animals who only eat plant food and have to extract as much as possible of what really amounts to very little nutrient material in each plant cell.

Plant cell walls are mainly cellulose, which we have great difficulty in digesting, but herbivores have a physiology and gut bacteria that can breakdown cellulose to produce energy. To release the cellulose, you have to really grind that material up; and to do that, you need teeth that are really rough. But mammalian teeth are enamel on dentine, held

in a ligament by cementum, as you know. So to evolve a rough surface, it makes sense to take advantage of the fact that each of these materials wear down at a different rate. So when they wear, some will wear more than others, and it further makes sense to make lots of cusps that can wear. Fig. 4 is an example. It is the just erupted last molar of a porcupine, and next to it is one that has erupted, the cusps of which have worn down. Fig. 5 is another example, of the 4 molars of a beaver, with the last one recently erupted and showing early wear.

Fig. 4. A worn and unworn molar of a herbivore (in this case a porcupine)

Fig. 5. The molars of a beaver

The beaver's teeth are a good example of how the harder-wearing enamel remains as a sharp edge next to the softer and more rapidly wearing dentine and the cementum in between the multiple cusps. This is enlarged in Fig. 6. Note that the dentine, a living material and the calcified portion of the pulp, has reparative powers, and forms secondary dentine to block off the dentinal tubules. Otherwise this rapid wear would be very painful.

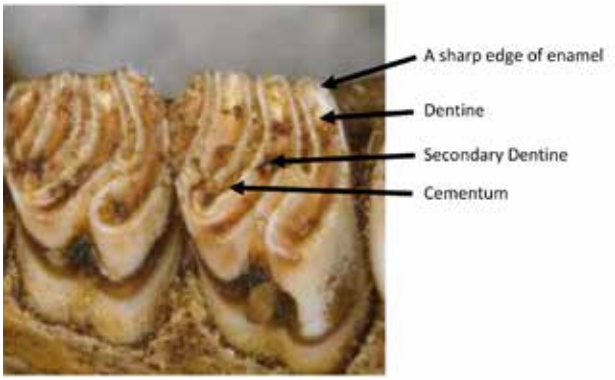

Fig. 6. The differential wear of the tooth materials creates an ideal rough surface for breaking down tough plant material.

So this differential wear creates an ideal surface for grinding plant material to extract the maximum nutrients from it. In one animal, which does not suckle its young, babies have to eat straight away. This is the guinea pig, the original bruxers – the teeth erupt in utero, and the foetus grinds its teeth in utero so that by the time it is born, the cusps are worn into surfaces that can grind the food. Which makes one wonder why many of us with post-industrial revolution teeth, grind them …

But (there's always a But) what happens when you have worn all your teeth down? The sad answer is you can no longer feed yourself and you die. The largest and longest-living herbivore is the elephant who has just 7 molars, but at any one time has the whole of one in the front and part of its replacement behind, until the front one is replaced, and so on until the last one is left, which erupts at about the age of 30 years, and will last another 30 years or so. Sad, but that's the life (and death) of a herbivore.

Fig. 7. Dentition of a shrew showing specialised incisors.

Fig. 8. The posterior teeth retain sharp cusps for piercing but also have a surface for crushing.

Insectivores

Animals that eat mainly grubs and insects really only need to pierce and crush the food, and so their dentition, like the herbivores, reflects this. A good example is the shrew, which has specialised incisors: the uppers are hooked, and the lowers contact them behind the tips, so that together they are used like forceps to pierce and grab prey (Fig. 7). The posterior teeth remain sharp but with surfaces that can crush (Fig. 8). But if these surfaces are used for grinding, the cusps would wear down, which is no use if you need cusps to remain sharp to pierce your food. So the system is set up to avoid this – insectivores have joints that do not allow for grinding, so the cusps do not wear, because there is no chewing in the sense of shredding and grinding. This action is more pronounced in the carnivores.

Carnivores

Carnivores of course, eat only meat and cannot digest plant material, which is why you should not feed your pet dog veggies. Dogs and cats are carnivores.

Carnivores are not that plentiful in the animal kingdom, mainly because they have to catch and eat many other animals over

their lifetime. So unlike herbivores this limits their life: not their teeth, but their ability to catch food. Unless of course they are domesticated, when they have trained humans to provide their food.

So now you need an entirely different dentition. You need teeth to help you bite and hold on to your prey, and you need teeth which will act like scissors to cut the chunks of meat up, and you need strong teeth and jaw muscles, to break up the bones. What you don't need to do, is chew anything, because your physiology will do the rest, just as herbivores' physiology sorts out their diet.

Fig. 9 is the joint of a herbivore on the left (a Rock Hyrax, or Dassie), and of a carnivore on the right (a Lynx). Note the complete freedom the herbivore's joint allows for free movement of the mandible, especially sideways, and contrast this with the restriction of the carnivore's joint to a purely hinge movement by virtue of the flanges on both the condyle and the fossa. No chewing is possible, which makes them messy eaters but efficient ones.

Fig. 9. An herbivore joint on the left, and a carnivore joint on the right.

Fig. 10. The teeth of a carnivore (a Lynx).

And the teeth, not surprisingly do all the things we said they need to do (Fig. 10). There are canines for piercing and holding and choking, and carnassial (from French carnassier 'carnivorous', based on Latin caro, carn- 'flesh') teeth for shearing, and to help break bones. The mandible has a large ramus to accommodate the strong masseter muscles needed to hold on to prey and break bones. The most efficient at the latter, being the Spotted Hyena (Fig. 11).

Omnivores: the Primates and Us

So if you want to get to the top of the food chain, then you need to be able to eat everything! Omnivore is derived from the Latin omnis, meaning 'all or everything' and vorare, meaning 'to devour or eat'. So now you need a physiology that can cope with plants and meat, and you need teeth

Fig. 11. Spotted Hyena

Fig. 12. The posterior teeth of a chimpanzee

Fig. 13. The maxillary arch of a chimpanzee

Fig. 14. The mandibular teeth of a an adult Baboon

that can bite, cut, and chew. And depending on how easy or not it is to get the meat, you may still need pretty good canines, unless you can evolve intelligently enough to use tools to do the job of hunting and catching, in which case you may not need them. The latter is us, the former is the primates, our close cousins. So while our posterior teeth may look the same, our canines certainly don't! Fig. 12 shows the posterior teeth of chimpanzee. Look familiar? But if you look

at the entire dentition, the canines are, well, different (Fig. 13). These are the teeth of a young chimpanzee, whose posterior teeth are not fully erupted and still have all their cusps. They look remarkably like modern human teeth, and in fact they are no different. But now look at the teeth of an adult primate, this time a Baboon (Fig. 14).

They look a little different, but still familiar. They illustrate that in a natural environment, with a natural dentition, the food is quite tough to chew, so as an omnivore, you need a system that allows you to chew both meat and plants, fruits, nuts and so on, because the physiology of your digestive system needs to start working in the mouth. Now compare these teeth with those of a herbivore and you will see the same principle: a sharp rim of enamel remains, and the dentine shows secondary or reparative dentine as darker patches. The result is a great surface for chewing, without any annoying cusps getting in the way and interfering with jaw movement. And the joint of course, needs to allow for that movement as well. Which of course, it does.

This pattern is in all primates. It used to be in us as well, before we learnt to refine foods. We can thank (not really) the Industrial Revolution for that, and we can thank (really) that for the need for the dental profession. Because since we started refining foods they got easier to chew, and our teeth no longer wear down, as they were meant to. Fig. 15 is from a 21-year old who lived about 10,000 years ago on the south-east coast of South Africa. The first molar, the first permanent posterior tooth to erupt, has lost its cusps. The premolars and second molar are showing signs of wear, and the third molar has only recently erupted.

Fig. 15. The posterior teeth from a mandible of a young man who lived about 10,000 years ago.

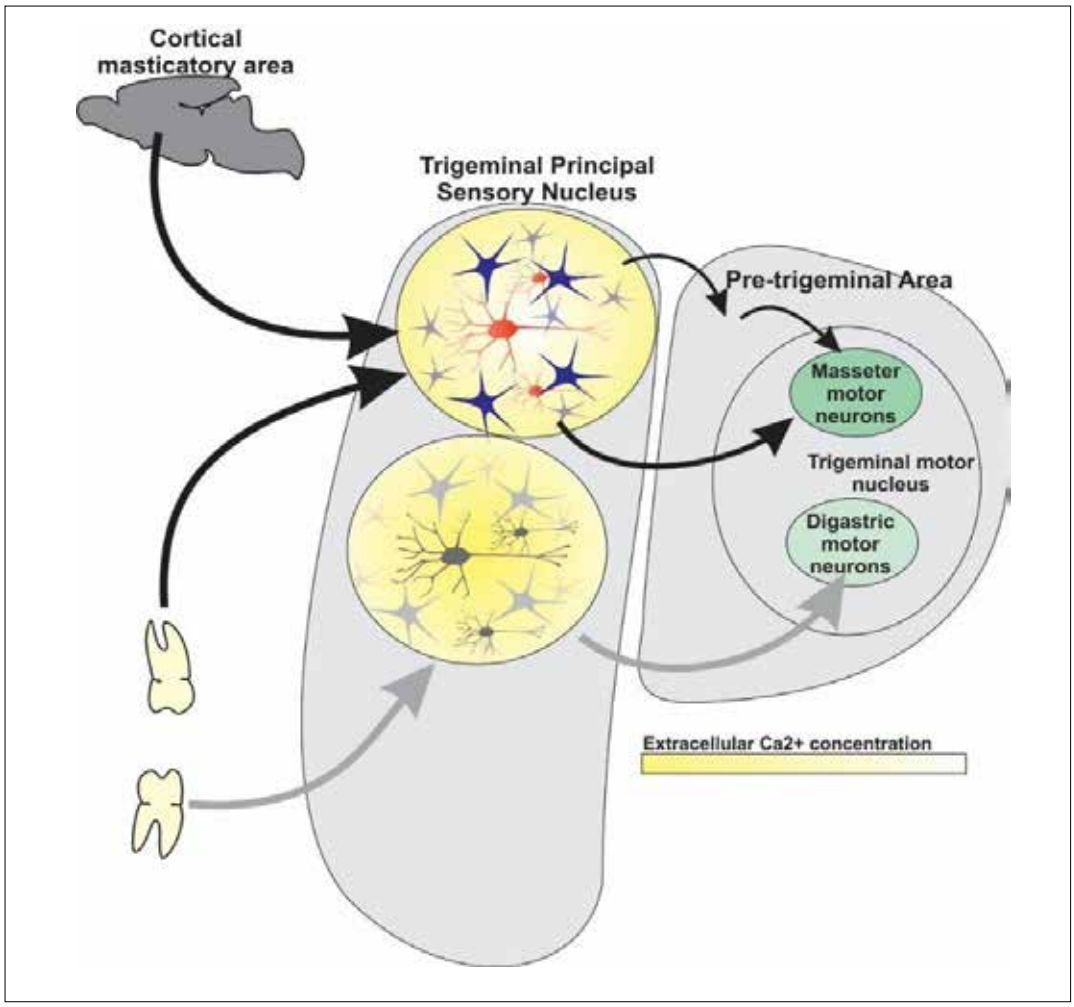

Fig. 16. Model of the masticatory Central Pattern Generator, re-drawn from Morquette et al 2012.[4] Populations of neurons in the dorsal half of the principal nucleus of the trigeminal nerve are segregated in functional domains (yellow circles). Neurons are shown in red and black and astrocytes in blue and grey. In domains receiving weak afferent input (lower circle), the sodium current is poorly activated. In domains receiving greater inputs (upper circle), activation decreases the extracellular calcium and favours activation of the sodium current. This, combined with the common incoming input would synchronise the neurons and create a rhythm generator driving the motor neurons directly.

If you didn't know the origin of this mandible, from what we have discussed, you would (I hope) conclude that this is the dentition of an omnivore, eating a natural and quite abrasive diet. And as a coastal dweller and hunter-gatherer, this is logical, as the diet would certainly be an abrasive and of course, unrefined one.

In summary, then, Herbivores need teeth that can shred and grind, and so need lots of jaw movement to do so. Shredding needs sharp edges, grinding needs a surface, and circular jaw movements. Insectivores need teeth that need only to pierce and crush, and so need limited jaw movements. Carnivores need to cut and slice, and again only vertical movements are needed. Omnivores need to do everything, cut, pierce, crush, shred and grind and so need different types of teeth and a combination of movements.

So I hope this brief foray into the teeth and jaws of some representatives of the mammalian animal kingdom will help you to understand that we need to look at our teeth and our joints somewhat differently from the static and mechanistic view that seems to dominate most of the text-books on occlusion. I once suggested 3 that cusps are the cause of most of our problems in light of the Industrial Revolution, because refined foods increased the frequency of sugar intake, and this combined with the retention of cusps and fissures to retain plaque bacteria created a huge increase in caries, and the ease with which food could be chewed reduced the size of the jaws whilst the teeth stayed the same size and so third molars got impacted, teeth couldn't find a harmonious place, the joint found it hard to adapt because chewing patterns stayed the same and so maybe we should just whack off all the cusps soon after the teeth erupted! And all of that in one breath.

But seriously, the lack of physiological tooth wear is a problem, especially when we have to replace occlusal surfaces of teeth artificially. If replacing all of them, it could be less of a problem because we can then control those occlusal surfaces and produce shallow cusps and fissures. But when we need to replace a few, and the rest have cusps which have never shown any signs of wear, then we need to understand just how teeth with cusps can function within the system without causing problems with normal masticatory movements. Chewing after all, is natural and automatic. You don't have to volitionally make your mandible move to chew food, whether it is soft or hard. This is because chewing is under the control of the masticatory central pattern generator (CPG). This CPG is a network of what are referred to as rhythmogenic neurons in the trigeminal sensory nucleus. 4 Fig. 16 shows a model of the CPG. Because it is centrally generated, interference in the form of the teeth or an abnormality in the jaws, can upset the whole system and possibly give rise to often vague oro-facial pain often classified under the gamut of what have become known as Temporo-Mandibular Disorders, or Cranio-Facial Disorders.

So the next paper in the series will look at the relationships between the teeth and the joints to better understand why the teeth are where they are.

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

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1. The influence of physical activity on periodontal health in patients with type 2 diabetes mellitus.

Type 2 diabetes mellitus (T2DM) is the most common chronic disease in the Western world and developing countries have also shown an explosion in the incidence and prevalence of this disease.

Exercise therapy is essential for the management of diabetes. The American College of Sports Medicine and the American Diabetes Association have recommended at least 150 min/week of moderate (50%-70% of an individual's maximum heart rate) to vigorous (> 70% of an individual's maximum heart rate) physical activity for patients with type 2 diabetes (T2DM). Studies including lifestyle and health interventions have shown that they have a positive health effect on patients with T2DM. For example, physical activity has been shown to improve the metabolic condition of T2DM patients, reduce HbA1c levels and cardiovascular mortality, and improve the quality of life, lipid levels, and blood pressure.

Diabetes has been identified as an important risk factor for periodontitis. The risk of developing periodontitis and peri-implantitis is significantly increased in patients with diabetes compared to healthy control groups.[1]

Wernicke and colleagues (2021)[1] reported on a trial that sought to test the hypothesis that physical activity is a health-promoting measure with significant positive effects on periodontal health and HbA1c concentrations.

METHODS

Participants >18 years old with non-insulin-dependent type 2 diabetes mellitus were recruited by information sessions in a gymnastic hall and advertisements at regional doctors in a medium-sized town in Germany. The study aimed for the inclusion of a representative sample with respect to sex, age, and ethnicity. Informed oral and written consent was obtained from each participant.

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Inclusion criteria were non-insulin-dependent T2DM and the willingness to participate in a baseline and follow-up dental examination. Exclusion criteria were unstable coronary artery disease, any serious medical condition that prevented adherence to the study protocol, or the ability to exercise safely, advanced retinopathy, and current insulin therapy. Furthermore, patients with preexisting physical activity of ≥ 60 min per week were not eligible.

This was a 26-week, single center, randomized, controlled trial with a parallel group design. Previously inactive persons with type 2 diabetes were randomly assigned to 1 of 4 groups: aerobic exercise, resistance training, combined aerobic and resistance training, or a control group that reverted to pre-study exercise levels.

Altogether, 126 patients with type 2 diabetes were willing to participate. They were randomly assigned and matched 1:1 to the four study groups. After exclusion of 16 patients as screening failure, 110 patients remained. Thirty patients were assigned to the aerobic exercise group (group AE), 27 to the resistance-training group (RE), 25 to the combined training group (CE), and 28 patients to the control group (CG).

All participants were provided with a 6-month membership at an exercise facility. The membership fees were covered by the study funding to remove economic barriers to participation. Individual exercise supervision was provided with a fitness coach twice a week throughout the study. Attendance was verified through direct observation, exercise logs, and individual smart card controllers. Participants with >10% missed trainings were excluded.

The exercise was carried out twice a week for 6 months. Each exercise unit was preceded by a 10-min warm up period. The training duration and intensity gradually progressed after four and 13 weeks, respectively. The intervention groups exercised according to the study protocol of the assigned group. All participants in the intervention group took regularly part in the training.

The training method was structured as follows: Intervention group 1 (strength endurance) completed a

strength-endurance training after a general warm up and stretching in a group setting, followed by two passes of a strength-endurance circuit. The strength-endurance training consisted of eight machine-supported exercises that included all major muscle groups (leg abduction, leg adduction, back extension (lower back), dips, vertical row, vertical traction, leg press, abdominal crunch) and were performed for 1 min each. During the initial training session, a maximum force test with three attempts was performed. The best of the three tests was scored and used to define the exercise intensity at about 60% of the participant's maximum force for the first 2 weeks of training. For the subsequent weeks, the load was increased by 10% and again by 5% for the last 4 weeks. Intervention group 2 (endurance) completed a progressive endurance training 2 times a week. After a general warm up and stretching in a group setting a 30-min training on a treadmill (technogym run 500/technogym run 600) or a bicycle ergometer with or without backrest (lifefitness-lifecycle 9500 HR) was performed. Intervention group 3 (combination intervention) completed a training combining both programs: one time a week an endurance and one time a week a strength endurance training was performed. All participants of the intervention groups regularly participated in the training. Participation, correct exercise performance and execution, and the compliance of the participants were supervised by professional trainers under supervision of a sport scientist with doctors' degree.

All participants were advised not to change eating habits or to start diets during the study. Additionally, steps were taken to minimize medication co-interventions by sending letters to participants' physicians to inform about the study. The control group did not receive a sports program or any other lifestyle intervention.

A qualified dentist interviewed the participants on pre-existing periodontal diseases and habits including smoking and frequencies of dental check-ups. Body mass index (BMI) and weight in kilograms were recorded at baseline and after 6 months. Furthermore, any history of periodontitis was recorded. For each patient, periodontal probing depth (PPD), bleeding on probing (BOP), and plaque scores were measured. PPD measurements were done at 6 sites per tooth (mesio-buccal, buccal, disto-buccal, mesio-oral, oral, and disto-oral) and BOP were recorded at 4 sites (mesio-buccal, disto-buccal, buccal, and oral). Furthermore, a periodontal anamnesis collected data on history of periodontitis. Full-mouth plaque index (API) was measured in percentage scores.

In addition to the dental examination, blood samples of each patient were collected in the morning after fasting and hsCRP and HbA1c levels were measured in mg/L or % at baseline and after 6 months.

RESULTS

A total number of 108 participants (women n=65, men n=43, age range 46 to 73 years) met the inclusion criteria and were randomized to the physical exercise or control groups. Thirty-one patients were excluded after the start of the study because patients did have no teeth (n=5) or refused a dental examination (n=26) leaving 77 at the baseline assessment. Thirty-seven participants were available for the final assessment with 20 participants of the physical activity group and 17 patients of the control group. The mean HbA1c for all participants was 6.7% with a range between 5.6 and 9%. A mean BMI of 32.2 with a range between 21.9 and 46.1 was calculated. The mean hsCRP concentration was 0.86 mg/L with a range between 0.1 and 6.1 mg/L at baseline.

No significant differences between the intervention and control group for changes between baseline and final assessment were found for weight (P= 0.103), BMI (P= 0.144), and plaque index (P= 0.06). Significant differences were found for HbA1c concentration (P= 0.011), hs CRP concentration (P= 0.040), BOP (P= 0.002), PPD (P= <0.001), and periodontal staging (P= <0.001). HbA1c levels, BOP, PPD, and periodontal staging significantly improved in the intervention compared to the control group. The hsCRP concentrations increased significantly in the control compared to the intervention group. A multivariate regression analyses with HbA1c as the outcome variable showed that HbA1c improved significantly in study participants who participated in a sports intervention (p = 0.037) compared to control.

CONCLUSIONS

the researchers concluded that physical activity is an oral health-promoting measure in patients with T2DM and physical activity significantly reduces HbA1c concentrations.

Implications for practice: The link between general health and its impact on improved oral health outcomes was clearly shown in this trial.

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2. Can implants be successfully placed in patients with uncontrolled diabetes mellitus type 2?

Type 2 diabetes mellitus (T2DM) is a widespread disease affecting both rich and poor countries. It is described as a group of metabolic disorders which is characterized by high serum glycemic levels either due to insufficient insulin levels, defective function or both.[1] Hyperglycemia, being seen in uncontrolled T2DM, may be a potentially important factor in the development of biologic complications in dental implants. Prospective data on implant performance in diabetes patients are scarce. Most studies evaluating the effects of diabetes on implant success have studied patients with well-controlled diabetes.[1]

Recent studies indicated that dental implants may show a poorer outcome in high glycemic level patients with regard to probing pocket depth (PPD) and marginal bone loss (MBL) as compared with systemically healthy individuals.[1] Narrow diameter implants were developed for sites with diminished ridge dimensions which result from numerous clinical reasons. The use of titanium-zirconium (TiZr) alloy implants for narrow implants has significantly increased biomechanical resistance, widening the indication range and making the use of narrow diameter implants in the posterior possible.[1] Friedmann and colleagues (2021)[1] reported on a trial that sought to compare clinical parameters and marginal bone level changes at narrow diameter implants placed in the posterior maxillary and mandibular zones and loaded by fixed prosthesis in uncontrolled T2DM and normo-glycemic patients.

METHODS

Thirty-two patients aging between 53 and 82, with a mean age of 67, participated in this prospective clinical study. Sixteen patients known to suffer from T2DM and diagnosed with an HbA1C > 6.5% were considered as "uncontrolled" hyperglycemic and assigned for the test group, whereas 16 non-diabetic patients (HbA1C ≤ 6.0%) were allocated as controls. HbA1C was assessed by the patient's general practitioner, who submitted the results to our clinic. The exclusion criteria were as follows: Immobility; Periodontal surgery and/or antibiotic therapy within the last 6 months prior to baseline; Pregnancy and lactation period; Full Mouth Plaque Score (FMPS) > 25%; Untreated periodontitis; Smoking > 10 cigarettes/day; Insufficient crestal width which affords an augmentation procedure even in the case of NDI; Previously performed ridge augmentation procedure for a staged implant placement; Permanent medication affecting blood perfusion rate and bone metabolism.

Each patient received one to maximum two Narrow Diameter Implant (NDI) at an edentulous posterior region of either maxilla or mandible. Exclusively narrow diameter (3.3-mm) tissue level titanium-zirconium alloy implants (Roxolid®) with the SLActive® surface characteristic were used (Institut Straumann). All implants were placed by two experienced periodontists, according to the instructions of the manufacturer regarding the osteotomy. The surgical approach was standardized. The implants were planned to restore the site by either a single crown or a fixed partial denture (FPD). The screw or cementum retention was unrestricted by the protocol; however, all restorations used either SynOcta® or Variobase® abutments (Straumann®, Institut Straumann). If two implants were placed, the most posterior one served as the study implant for this patient. Completing the surgery, all implants were radiographically documented using the parallel technique for periapical X-rays.

The post-op regimen included the patient's instruction to abstain from mechanical plaque control in the treated area for 1 week and to use chlorhexidine mouth rinse (0.2%) twice a day instead. The administration of systemic antibiotics was restricted to individual needs. There was no prescribing policy by protocol, and analgesic medication (Ibuprofen 600 mg/3× daily) on demand was recommended. A follow-up visit after 3 days was scheduled, and sutures were removed after 7–10 days. After 12 weeks, the next follow-up was to evaluate the osseointegration before starting the reconstruction. At 1 year (Visit 7), the reported measurements were obtained. Chipping of the porcelain coating, screw loosening, de-cementation, fracture of any component or other maintenance requirements were considered technical complications and recorded during the observation period.

The peri-implant PD, CAL and recession were estimated by gentle probing with a PCP-11 probe (Hu-Friedy) at 4 sites per implant. Additionally, the PPD of the adjacent tooth at 4 sites of the tooth was assessed, representing a native reference for each study implant. The measurements were carried out immediately after loading (visit 3) and 12 months after implant surgery (visit 7) on both the integrated implants and teeth. Furthermore, the bleeding on probing (BOP) and papilla bleeding index (PBI) on the buccal aspect were investigated at visit 7. The digital radiograph from immediately after implantation ("initial") and 1 year later ("12 months") was also assessed.

RESULTS

In 32 patients, a total of 48 osseointegrated implants qualified for the prosthetic loading at the 3-month pre-load analysis. Some patients discontinued treatment after this inspection unintentionally; thus, the T2DM group experienced a decline by 3 patient dropouts with a total of 4 implants, respectively. Thus, 13 NDI study implants from the T2DM group remained to compare to 16 NDI study implants from the normo-glycemic group after completing the restorative phase. Accounting for the dropouts, the mean statistical HbA1c value was calculated with 7.34% for the diabetic group.

All restored implants were under functional load after 12 months, resulting in an overall survival rate of 100% for both groups, respectively. Three single crowns in two patients were screw retained; all other crowns or bridge frameworks were cemented using glass-ionomer luting cementum (Ketac Cem). There were no complaints; no biological or technical complications or adverse events

related to the implant treatment were reported by the patients after 1 year of function regardless the glycemic status.

The mean peri-implant probing depth (PD) at 3 months was measured at 2.6 ± 0.8 mm for the normo-glycemic group, whereas the T2DM group exhibited a mean PD of 2.7 ± 0.5 mm before loading. After 12 months, the mean values changed towards 2.4 ± 0.5 mm and 2.6 ± 0.4 mm in the groups, respectively. Thus, the mean values for the clinical parameters assessed at 3 and 12-month visit revealed statistically non-significant differences ($p = 0.6$ and $p = 0.29$, respectively). The BOP index, however, appeared slightly increased in the T2DM compared to the control group (63% to 54%) at visit 7, whereas the papilla bleeding index (PBI) remained indifferent ($p = 0.351$) in both groups.
The radiographic analysis revealed a non-significant change of the marginal bone level (MBL) for both study groups.

CONCLUSION

In terms of short-term implant success and implant survival, there were statistically non-significant differences between normo-glycemic and diabetic patients after a minimal invasive surgery was applied for implant placement.

Implications for practice: uncontrolled diabetics could potentially be considered for implant treatment. The management of these patients will be key to determining treatment success.

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Can you afford to smile? The Economic disparities in oral health care provision

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ABSTRACT

Tooth loss can have a negative impact on a patient's quality of life. However, many patients cannot afford the treatment necessary to restore their dentition optimally. Their final choice may be dictated by what they can afford rather than consideration of the advantages, disadvantages or biological sacrifices associated with proposed options. At the same time, clinicians often express feelings of helplessness and stress when confronted with having to decide on, and provide treatment that is within the patient's financial means, rather than according to what they deem to be "best practice". This paper uses a patient case to illustrate how the four-principle approach proposed by Beauchamps and Childress (1983) can be used during treatment planning, and to justify the final decision making process.

BACKGROUND

While the loss of teeth may not be considered a life threatening condition, it can certainly have a negative impact on a patient's quality of life in more aspects than just oral function. These include psychosocial perspectives, dietary choices, and even employment opportunities. Related to this is poor self-esteem, a less future-orientated outlook and a more pessimistic view of health matters in general, including reduced interest in maintaining good oral health behaviours.[1,2] Furthermore, in a low income society, people generally place higher priorities on food and medical expenses rather than their dental needs. This paper will present a case of a 36 year old lady who had lost her central incisor in a motor vehicle accident, but had only sought dental treatment five years later when she had managed to find a job. Following an evaluation of the patient's presenting oral condition, her desires and a detailed clinical examination, a number of treatment options were presented to her. Her final choice, however, was not dictated by her consideration of the advantages, disadvantages or biological sacrifices that had been explained, but rather on what she could afford. This paper will explore the ethical principles and stress that clinicians may be confronted with in the decision-making process towards arriving at a suitable treatment option when the patient's financial status, rather than "best practice" is a limiting factor. It also considers the anxiety that that dealing with such disparities in distributive justice can place on a compassionate, morally driven clinician. This actual patient case was selected as it helps illustrate how the four-principle approach proposed by Beauchamps and Childress (1983) can be used during treatment planning, and to justify the final decision making process. The four principles include: respect for patient autonomy; beneficence; non-maleficence and justice.[5,6] When considering beneficence and non-maleficence, it is important to remember that this does not only refer to the "good or damage" associated with the physical treatment, but includes psycho-social benefits, and financial and biological costs.

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1. Leanne M Sykes: Primary author: 60%;
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CASE PRESENTATION

A 36-year old lady presented to the dental clinic requesting to have her missing central incisor replaced. She reported that during a motor vehicle accident she had sustained trauma to her face five years previously resulting in loss of her front tooth. She had not been able to afford dental treatment, resulting in her having spent the intervening time being very self-conscious of her appearance. She had developed a habit of hiding her smile behind her hands and pursing her lips when speaking in an attempt to conceal her missing anterior tooth. She also reported that she had always been self-conscious about the other front tooth being "skew", and this additional anomaly made her appearance that much worse. She had just managed to find employment and wanted to have her teeth fixed before commencing working. A thorough intra-oral examination revealed the patient to have a full complement of teeth in all four quadrants, apart from the missing 11 (Figure 1). All of her teeth were caries free, periodontally sound, and her oral hygiene status was excellent. All her maxillary teeth were well aligned in a class I occlusal relationship with the exception of the 12, which was in a cross bite. The mandibular incisors showed mild crowding, with slight over-eruption of the 41. There was also evidence of alveolar bone loss apical to the missing central incisor (11). The remaining maxillary incisors (13,12 and 21) were all virgin teeth. The treatment options were presented sequentially based on their associated costs. (There was no consideration or treatment proposals for the mandibular teeth other than minor occlusal adjustment of the 41).

Figure 1. Anterior view showing missing 11 and 12 in cross bite

Figure 2. Anterior view showing mild crowding of mandibular teeth, over-eruption of 41, missing 11, and 12 in cross bite

Treatment options and implications:

The following options were presented to the patient: (there may be various others, which clinicians could debate in a similar manner)

1. Maintain the dentition in its present state and provide a single tooth removable partial denture replacing the 11. The edentulous space would be restored and the patient's smile greatly improved, however the 12 would still be in cross-bite which she had indicated to be an aesthetic concern. This option was the most beneficial financially and time wise, minimally invasive on her dentition, and would restore her speech and smile adequately. The burdens/disadvantages of this option were associated with discomfort of having to wear a removable prosthesis, with a large amount of mucosal coverage when only one tooth was being replaced, as well as the psychological concerns and possible embarrassment of wearing a denture. From a biological perspective, this may be considered to be the least maleficent option as it would not sacrifice or damage any of her teeth, and is relatively cost effective (the price will vary depending on whether an acrylic resin or chrome cobalt base is used).
2. Extract the 12 and provide a two-toothed partial denture replacing the 12 and the 11. This choice has all of the benefits and burdens of option 1, with the exception that it offers a chance to improve her smile, - at the biological cost of sacrificing a healthy sound tooth. This would also add to the alveolar bone loss in that anterior region.
3. Fabricate a removable Hawley-type appliance incorporating a bite plane posteriorly to open up her bite, a Z-spring behind the 12 to try and procline it out of a cross- bite, and an acrylic resin tooth replacing the 11. This could be replaced with a permanent single-tooth removable partial denture if and when the 12 had been brought into alignment. This option was much like option 1, but prolonged treatment time and had additional financial implications. The latter could be justified in terms of the potential to improve her smile substantially. An additional risk factor was that a removable appliance would be used to execute the planned tooth movement, and could result in loosening of the 12, or bodily tilting leading to loss of the supporting buccal bone. At the same time, the clinician would have to seek advice from a specialist orthodontist before commencing with this plan to mitigate potential iatrogenic harm.
4. This was the same as option 3, but involved first referring the patient to a specialist orthodontist to carry out the planned alignment of the 12. This had almost the same benefits and burdens as option 3, except that it will be more costly and lengthy in time for the patient. It is also a more beneficent route for the clinician to follow especially if they are not confident of their own orthodontics skills and experience.
5. Extract the 12 and construct a three-unit fixed bridge from 13 to 21. This was one of the most invasive and destructive choices in that it involved sacrificing a sound tooth (12) as well as cutting two virgin teeth (13 and 21). It was also more expensive, and involved a degree of pain and discomfort during tooth preparation. This procedure could only be considered if her smile line was low enough to conceal the bony defect in the 11 region. If not, there may be a need for bone augmentation which would add to the time, costs and patient discomfort. The main benefits are psychological in that she will not have to wear a removable prosthesis as well as improved masticatory function and general comfort. Many clinicians would not consider it biologically beneficent to damage two virgin teeth in order to replace one / two missing teeth, especially anteriorly, and in younger patients.
6. Carry out orthodontic alignment of the 12 and then use it as an abutment for a three-unit fixed bridge from 12 to 21. This entails the same considerations as for option 5, but has added time and financial implications associated with the orthodontic procedure. Certain advantages could be bone preservation, a slight cost saving in that the definitive bridge will now be only three units, and the shorter span could make it more stable. However, the 12 is a weaker abutment due to its size in comparison to the 13 (and may lose some alveolar bone support during the alignment process). A further advantage in this plan is that the bridge could act as a retainer and stabilising splint for the 12, helping maintain it in the new position.
7. Either extract or align the 12, then carry out bone augmentation above the 11 (+- 12) followed by placement of 1 (2) implants. This is the most expensive and lengthy option, but will spare the virgin teeth from any potential damage. This could be seen as the most beneficent procedure for the clinician to carry out, and for the patient psychosocially, functionally and biologically. However, it is expensive. In a society where funds are limited, can it be considered distributive justice to provide this service to one patient, when the same amount

of money spent on this treatment cost could be used to address the more basic dental needs of - many more patients?

DISCUSSION AND CONCLUSION

There has been a steady decline in edentulism in developed countries, yet tooth loss remains high in poorer third world communities.[7] Tooth loss not only leads to functional and aesthetic disabilities, but also has a negative psychosocial impact on patients' lives.[7] Studies have shown that those with less than 20 natural teeth have worse oral health-related quality of life (OHRQoL) scores than those with more. This is further influenced by the number and position of the missing teeth.[7] The oral functional disabilities associated with tooth loss relate to mastication, speech and communication. However, there may be further systemic consequences as tooth loss could lead to altered dietary choices and intake, resulting in malnutrition and subsequent debilitating conditions such as diabetes and cardiovascular diseases.[8] Many countries have developed health models to address the dental care needs of the majority, with a strong emphasis on prevention rather than rehabilitation. To this end, disease prevention is a multi-stage process that must be addressed on three levels: "Primary prevention protects individuals against disease by placing barriers between the agent and the host. Secondary prevention limits the impact of disease so that health can be restored. Tertiary prevention is aimed at rehabilitation after disease has resulted in functional limitation or disability".[3]

This case scenario illustrates the myriad of clinical considerations, ethical dilemmas and treatment decisions a dentist may have to debate on a daily basis. The difficulties are compounded by the need to fully inform patients of the advantages, disadvantages, risks and benefits of each option in order for them to be able to make educated, informed and autonomous decisions about their own bodies. Sadly, even after careful and considered deliberation, the final treatment is too often dictated by cash and not by choice. This is the harsh reality of providing health service in a country where there are large disparities in health care affordability and provision. Clinicians often have to set aside their desire to provide complex treatment for a single patient in order to comply with principles of distributive justice – i.e. the fair distribution of the limited resources to many.[6] In effect, adhering to ethical principles can be stressful to an ethical, caring and dedicated clinician who has to provide medical and dental services in keeping with available finances rather than according to their "ideal" training and clinical reasoning. A recent survey amongst dentists working under conditions where there were limited resources for dental treatment confirmed that some of the major personal stressors arose from their ethical concerns of being faced with working in a "survival culture" where they were compelled to deliver in terms of patient numbers. They perceived this as a lack of control and reduced professional fulfilment especially in situations where they were unable to deliver the quality of care they wanted to provide.[4]

There may be clinicians who feel helpless or defeated when working in an environment where there are limited resources, facilities, staff and time, yet they still have to try serve a large community of needy patients. Some may have almost given up trying to make significant changes believing that their current situation echoes the age-old biblical verse "The poor you will ALWAYS have with you.", (Deut 15:7-11). However, perhaps they can gain new inspiration from a slightly modified version of the added proviso to this statement. "Harden not your heart or shut your hand against your poor brother, but rather open wide your hand, and do your best to assist the needy and the poor in whatever manner possible, and to the best of your abilities".

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Maxillofacial Radiology 197

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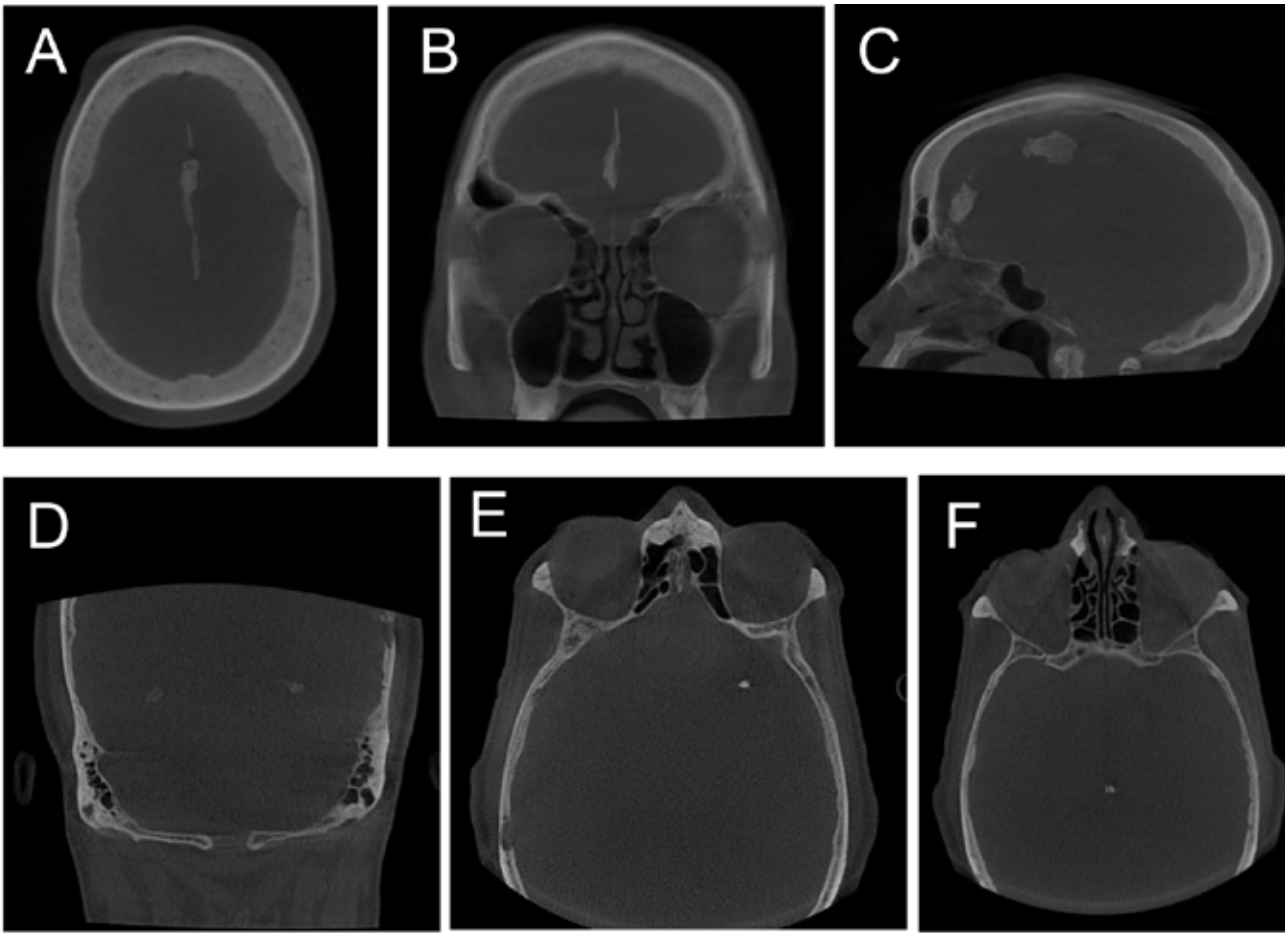
Z Yakoob[1], C Smit[2]

CBCT INCIDENTAL FINDINGS

CASE

Below are two patients that presented to our facility for dental treatment. In both of these patients' calcifications were noted as incidental findings.



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Dr Zarah Yakoob: 70%
Dr Chané Smit: 30%

INTERPRETATION

Large field of view cone beam computed tomography (CBCT) images allows the visualisation of anatomical structures outside of the teeth and jaws. These areas include the cranial vault and paranasal sinuses. Occasionally pathology, anatomical variation and various other incidental findings can be seen.[1] As the use of CBCT has become more common amongst general dentists and specialists, awareness and understanding of incidental findings are of great importance, for the patient as well as medico-legal reasons. Calcifications that are found as incidental findings on CBCT scans within the brain can be pathological or physiological in origin. Common

areas within the brain where physiological calcifications can be found include the pineal gland, choroid plexus, habenular, tentorium cerebelli, sagittal sinus, and falx cerebri. The most reported form of physiological brain calcifications is in the pineal gland and is thought to be an age-related change.[2] Pathological calcifications are less common than the physiological variants and are because of more serious diseases such as infectious diseases, endocrine disorders, metastatic lesions, and primary intracranial tumours, to name a few.[3]

Above are images of two patients that presented to our facility for reasons unrelated to the calcifications. The first patient is a 72-year-old female (Images A-C) that presents with physiological calcifications of the falx cerebri. The second patient is an 82-year-old female that presents with physiological calcifications of the choroid plexus glomus (Image D), unilateral globus pallidus calcifications (Image E) and pineal gland calcifications (Image F).

Although neither of these patients required medical intervention, a thorough medical history should always be undertaken together with a detailed evaluation of the full CBCT volume, to eliminate possible pathological calcifications.

Dentists and dental specialists should be mindful of incidental findings that may be found on CBCT scans. In cases of uncertainty a dentist trained in maxillofacial radiology and pathology should be consulted as negligence of this nature can result in medico-legal implications.

AUTHORS DECLARATION

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethics approval: This study was approved by the University of Pretoria, Faculty of Health Sciences Research Ethics Committee (Reference no.: 478/2021). All procedures followed the ethical standards of the Helsinki Declaration of 1975, as revised in 2008.

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CPD questionnaire

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GENERAL

Comparison of capsule-mixed versus hand-mixed glass ionomer cements, Part 1: compressive strength and surface hardness

1. Select the INCORRECT answer. The following are advantages of glass ionomer cements, except:
   A. Chemical bonding
   B. Fluoride release
   C. Co-efficient of thermal expansion twice as much as tooth structure
   D. Self-curing

2. Select the CORRECT option. Which factor influences the hand mixing of glass ionomer cements?
   A. Environmental humidity and temperature
   B. Air bubbles present in the liquid
   C. The angle at which the liquid bottle is held
   D. All of the above

3. Choose the CORRECT answer. Using higher volume of powder to liquid ratio will result in:
   A. Longer working and setting time
   B. Decreased compressive strength
   C. Increased compressive strength
   D. Increased susceptibility to acid erosion

4. Which of the following statements is CORRECT. Increasing the mixing time of capsulated glass ionomers up to 12 seconds will:
   A. Decrease the viscosity
   B. Increase the working and setting time
   C. Decrease the modulus of elasticity
   D. Increase the compressive strength

Comparison of capsule-mixed versus hand-mixed glass ionomer cements, Part 2: Porosity

5. Select the INCORRECT indication. Which one of the following is NOT an indication for conventional glass ionomer cements
   A. The Sandwich-technique
   B. Class II permanent restorations on primary teeth
   C. Class II permanent restorations on permanent teeth
   D. The Art-technique

6. Choose the CORRECT answer. The advantages of capsulated glass ionomer cements includes
   A. User friendliness and time efficiency
   B. Standardised mixing technique and times
   C. Pre-proportioned powder:liquid ratio
   D. All of the above

7. Select the CORRECT answer. According to Fleming and Zala, where do cracks/fractures result form in set, hand-mixed glass ionomer cements:
   A. The restoration/tooth interface
   B. The polyacid component
   C. The powder clumps formed
   D. High spatulation force

8. Choose the CORRECT statement. Why does Coldebella *et al*. advocate the use of ultrasonic excitation during mixing of glass ionomer cements?
   A. It collapses the voids during the mixing process
   B. It improves the setting reaction between the glass particles and the polyacid
   C. It breaks up the powder particle clusters formed
   D. All of the above

Retreatability of root canals obturated using a bioceramic sealer and gutta percha

9. Select the CORRECT answer. The following final rinse irrigation regimen is recommended to aid in the resolution of periapical pathology in retreatment cases:
   A. 17% EDTA followed by NaOCl
   B. 3,5% NaOCl followed by 0,2 % Chlorhexidine gluconate
   C. 10% EDTA followed by NaOCl
   D. 10% EDTA followed by 0,2% Chlorhexidine gluconate

10. Choose the CORRECT answer. Which component of bioceramic sealers improves its handling technology:
    A. Calcium hydroxide
    B. Nanoparticles
    C. Methacrylate resin
    D. Mineral trioxide aggregate
    E. Epoxy resin

11. Which of the following is CORRECT. The entry of endodontic sealers into accessory and lateral canals are facilitated by:
    A. Radiopacity f 3.83 units of aluminium
    B. Good adhesion to root canal dentine
    C. Increased dissolution in water
    D. Increased flow properties

12. Select the CORRECT option. Which of the following properties contributes to the antibacterial activity of bioceramic sealers:
    A. Low pH and the release of hydroxyl ions
    B. High temperature and release of calcium ions
    C. High pH and release of calcium ions
    D. Solubility of 2.9%

An evidence-based guide to occlusion and articulation. Part 2: A guide to the evolution of the teeth and joint

13. Select the CORRECT answer. The articular of the reptilian jaw joint becomes
    A. The malleus of the mammalian inner ear
    B. The incus of the mammalian inner ear
    C. The stapes of the mammalian inner ear
    D. The tympanic membrane

14. Select the CORRECT statement. When the primary molars are lost, chewing is possible becauseA lack of DNA reference samples
A. The incisors are in place
   B. It is not necessary at that stage
   C. The premolars have already erupted
   D. The first molar is present beforehand

15. Which of the following statements is CORRECT. Amongst other things, carnivores' teeth need to
   A. Slide over each other to break up food
   B. Cut large chunks of meat into smaller ones
   C. Have incisors to grip their prey
   D. Remain in pristine condition

Mandibular myiasis: A case report

16. Which of the following is INCORRECT. Which of these factors is NOT considered a common predisposing factor to developing human myiasis
   A. Poor hygiene
   B. Exposed wounds
   C. Necrotic tissue
   D. Poor sanitation
   E. Ankyloglossia

17. Select the CORRECT statement. What forms the basis of treatment?
   A. Mechanical debridement followed by meticulous wound care and hygiene
   B. Pre-emptive intubation
   C. Laparoscopic cholecystectomy
   D. Maxillectomy

Evidence based dentistry

18. Select the CORRECT answer. In the Wernicke *et al* trial, no significant differences between the intervention and control group for changes between baseline and final assessment were found for:
   A. Weight
   B. Height
   C. Caries status
   D. Probing depth

19. Which of the following is INCORRECT. In the Wernicke et al trial, significant differences were found for all of the following variables, except:
   A. HbA1c concentration,
   B. hs CRP concentration
   C. BOP
   D. BMI

20. Which percentage is CORRECT. In the Friedmann *et al* trial, the implant survival rate in both groups was:
   A. 95%
   B. 88%
   C. 100%
   D. 98%

ETHICS: Can you afford to smile? The Economic disparities in oral health care provision.

21. Choose the CORRECT option: With regards to distributive justice, a dentist working in a community where resources should
   A. Carry out procedures they like doing so as to speed up service provision
   B. Carry out emergency services, infection control and pain relief only
   C. Not waste time or funds on oral hygiene instruction and prophylaxis
   D. Carry out the services that will address the needs of the majority
   E. Not tell patients about possibilities of complex procedures in case they then ask for these
   E. All of the above

22. Which of the following is CORRECT: Beneficence and non-maleficence in dentistry
   A. Refers to assessment of treatment provided
   B. Includes consideration of time and financial issues
   C. Refers to consideration of psychosocial issues
   D. All of the above are correct
   E. Only A) and C) above are correct

23. Select the CORRECT answer: Autonomy entails that:
   A. Patients know about all possible treatment options
   B. Dentists decide on the best treatment based on their clinical judgement
   C. Patients sign consent allowing the dentist to decide on the final treatment
   D. Dentists discuss patient treatment with their assistants to get a second opinion
   E. Options A), B) and C) are correct

24. Choose the CORRECT option: Survival culture
   A. Can lead to demotivation and lack of professional fulfilment for the clinician
   B. Can hamper a clinicians ideals to provide "best practice" dentistry
   C. May lead to a compromised treatment option based on individual affordability
   D. Supports the principle of distributive justice
   E. All of the above

25. Which of the following statements is CORRECT: Tooth loss that could have been prevented
   A. Can be caused by poor socioeconomic conditions
   B. Can be exacerbated by poor economic conditions
   C. Can lead to systemic diseases associated with poor nutrition
   D. options A) and B) only
   E. All of the above

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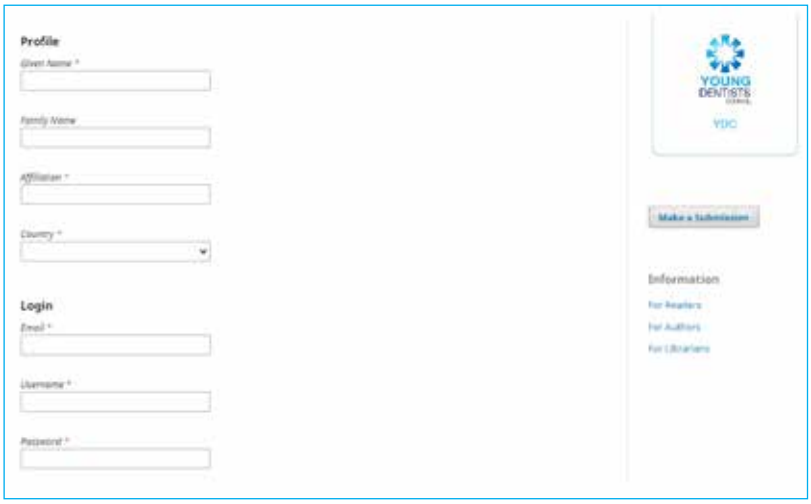

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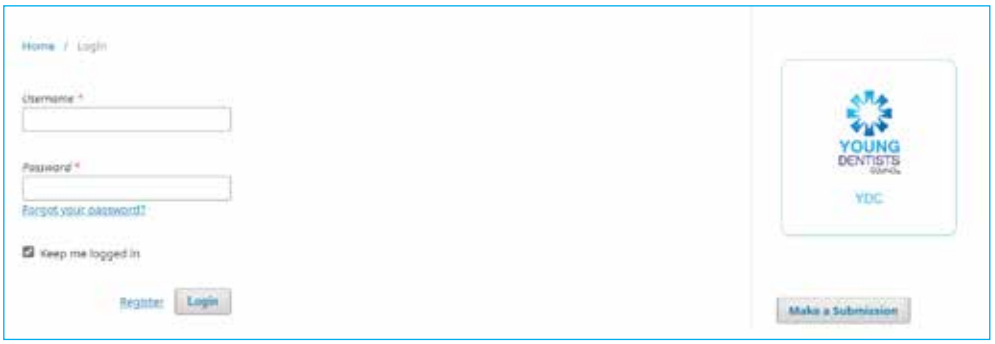

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