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IIUM Journal of Orofacial and Health Sciences (IJOHS) is a peer reviewed biannual international journal dedicated to publish high quality of scientific research in the field of orofacial sciences, health sciences and interdisciplinary fields, including basic, applied and clinical research. The journal welcomes review articles, original research, case reports and letters to the editor. Areas that are covered include but are not limited to dental sciences, oral microbiology and immunology, oral maxillofacial and craniofacial surgery and imaging, dental stem cells and regenerative medicine, dental biomaterial, oral maxillofacial genetic and craniofacial deformities.

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EDITORIAL Open Access

Halal aspect of dental materials

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Introduction

With the world being more globalized, *halal* aspect is rapidly becoming a major concern amongst Muslims worldwide. Previous concerns focusing on the halal status of meat-based products has now expanded to include personal care and cosmetic products, as well as pharmaceuticals and medical/dental consumables. 20% of Muslims are reported to be concerned about the halal status of their daily products (Hunter, 2012). The advent of technology, innovation, development and globalization has made it very likely for the Muslim individual's product to contain ingredients originated from prohibited (*haram*) sources. In Malaysia; a Muslim-majority country, 40% of the population use *halal* pharmaceuticals (Ting *et al.,* 2019).

Islamic principles outline the following for Muslim consumption: that all things are permitted (*halal*), with few exceptions that are not permissible (*haram*). *Halal* encompasses that the source of the ingredient /product should be permissible in nature and the method of slaughter must follow Islamic laws. Failure to comply with these basic requirements renders the product as *haram* (Cai *et al.,* 2012).

The Department of Standards Malaysia issues a standard *halal* logo for labeling of products authenticated as *halal* in the Malaysian market. Due to the stringent requirements for issuance and use of this logo, it provides *halal* assurance to consumers in the Malaysian and global markets. The logo serves as a trusted and credible symbol for consumers seeking *halal* products as per Shariah law requirements. Despite major progress being made in *halal* labeling and authentication in the food industry, the same cannot be said for pharmaceuticals. The ingredients and processes involved in pharmaceuticals manufacturing remain a grey area in *halal* authentication. Afifi *et al.* (2014) found that a majority of pharmaceutical products in the market did not fulfill standard *halal* requirements. Additionally, medicines have not undergone the same scrutiny as food when it comes to *halal* authentication and remains under-explored in practitioners and studies of medicine (Saha *et al.,* 2019).

Dental materials are another category of products that forego strict *halal* scrutiny. Most dental materials in Malaysia are imported and may contain ingredients with doubtful or *haram* sources, such as pig (Nadia *et al.,* 2016). Most dental materials only label active ingredients while leaving out important information on the excipient

content of the materials. This includes colourings, thickeners, diluents and flavorings. As the dental materials come into direct contact with patient's saliva and blood during various dental procedure, the *halal* aspect of these dental materials should not be taken lightly (Irfanita *et al.,* 2017).

An example of excipient in dental materials is alcohol which is forbidden in Islam. However, the prohibition of alcohol is due to its ability to intoxicate. Hence, non-intoxicating alcohols such as sterile alcohol are permissible for use, while intoxicating alcohols such as ethyl alcohol and methylated spirits and ethanol are prohibited. Furthermore, Islam makes allowances for use of prohibited materials if the ingredient is absolutely necessity to the function of the material and cannot be substituted with another ingredient (Muzakarah Jawatankuasa Fatwa Majlis Kebangsaan, 2011). Besides alcohol, another doubtful ingredient found in medical/dental/pharmaceutical products is gelatine, that derives from porcine sources. As a general rule, it is necessary for Muslims to seek the source of the gelatine before use. However, in dire cases, use of such products become permissible to preserve the life of the patient (Muzakarah Jawatankuasa Fatwa Majlis Kebangsaan, 1984.

The Malaysia Standard aims to fill in this *halal* gap by outlining Hazard Analysis and Critical Control Points (HACCP) and Good Manufacturing Practice (GMP) requirements that are Sharia-compliant to the food and pharmaceutical industries. The guidelines cover manufacturing, preparation, management and storage of products that have been labeled halal in accordance with government requirements. This certificate issue is especially critical when exporting Malaysian products for the world (Habibah *et al.,* 2008).

Efforts to educate doctors and patients with regards to the ingredients in dental materials needs to be enhanced. This is especially true for Muslims to protect their religious rights and beliefs and to protect the Ummah at large. While ongoing efforts have focused on social media posts, this information can be inaccurate and unreliable, as regulation of information on social media is non-existent. Wrong/false information not only deviates one from the correct practice of Islam, but can also divide the *Ummah*. Thereafter, it is crucial that the *halal/haram* information obtained is disseminated in a cautious manner to prevent misunderstandings and divide in the Muslim community.

In conclusion, development of dental materials needs to fall under the scrutiny of *halal* authentication in order to protect the consumers' religious beliefs and health issues. Thus, there should be a conjoint effort especially among the Muslims to develop reliable and accurate methods towards achieving this objective.

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REVIEW ARTICLE Open Access

Endodontic-orthodontic interrelationship: a review

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Abstract

The endodontic-orthodontic interface is not well understood due to the limited scientific literature on the topic. This article aims to provide an overview of the orthodontic treatment and the risk of root resorption, the effects of orthodontic tooth movement on dental pulp and endodontically treated teeth, the role of orthodontics in endodontic-restorative treatment planning, and interdisciplinary patient management. Articles published in English from 1982 to 2021 were searched manually from google scholar using keywords 'endodontic-orthodontic interface' and 'endodontic-orthodontic interrelationship'. Another search engine was MEDLINE/PubMed database using keywords 'endodontics AND orthodontics', 'orthodontic tooth movement AND dental pulp', 'orthodontic tooth movement AND endodontic treatment' and 'orthodontics AND dental trauma'. Other relevant articles were obtained from the references of the selected papers. Alterations to the dental pulp following orthodontic tooth movement can be histologic and/or cell biological reactions as well as the increased response threshold to pulp sensibility tests. However, the occurrence of root resorption is complex and multifactorial, and can be linked to individual variation, genetic predisposition and orthodontic treatment-related factors. Endodontically treated teeth can move as readily and respond similarly to orthodontic forces as vital teeth, however with inadequate endodontic treatment, the risk of apical inflammation and bone destruction following orthodontic tooth movement is increased. Dental treatment that involves endodontic and orthodontic specialities should be carefully planned according to the individual case, taking into consideration the skills and experience of the clinicians while applying interdisciplinary patient management and available scientific data.

Keywords: *endodontic, orthodontic tooth movement, endo-ortho interface, pulpal changes, tooth resorption*

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Introduction

The endodontic-orthodontic interface is not well understood due to the limited scientific evidence on the topic. To date, there is a lack of uniformity in the study protocols reported in the literature, reflecting the disparities in this subject. Therefore, the interpretation of results should be made with great caution owing to the differences in study methodology and variations in data reporting. Without thorough understanding on the subject, application of general treatment procedure is not possible, and an effective treatment plan is difficult to be executed.

When planning for patient management involving combined treatment modalities, treatment must consider the possible adverse reactions to the patients, skills and experience of the clinicians, patient-related factors and available scientific evidence supporting treatment, although at present the reported data is sparse. In certain clinical cases, the need for orthodontic tooth movement prior to endodontic and/or restorative treatment is necessary to optimise the aesthetics and functional aspects of dental treatment. Adequate communication and planning between the restorative dentist, orthodontist and other clinicians before the implementation of any treatment is crucial so that the duration of time needed to fulfill the treatment objectives and the treatment cost can be discussed thoroughly with patients (Alfallaj, 2020).

Literature search was carried out from google scholar using keywords 'endodontic-orthodontic interface' and 'endodontic-orthodontic interrelationship'. Another search engine was MEDLINE/PubMed database using keywords 'endodontics AND orthodontics', 'orthodontic tooth movement AND dental pulp', 'orthodontic tooth movement AND endodontic treatment' and 'orthodontics AND dental trauma'. Articles published from 1982 to 2021 were reviewed independently by two evaluators in regard to the scientific contents. The reference lists of the selected articles were reviewed to identify additional studies that had not been identified earlier from the database. In general, 77 published articles were included in this review with lack of original research articles on the topic and the majority of articles are mainly on case reports, narrative reviews and other types of studies (Table 1). Due to the inadequacy in scientific quality, the understanding on the topic is lacking thus could potentially result in misdiagnosis and improper patient management.

Orthodontic treatment and risk of root resorption

It has been suggested that orthodontic tooth movement can cause neurovascular disturbances, and the release of inflammatory mediators can impair blood flow and cellular metabolism, resulting in apical root remodeling or resorption during tooth movement (Hamilton & Gutmann, 1999). However, the incidence and severity of these changes may be influenced by previous or ongoing insults to the dental pulp such as dental trauma (Hamilton & Gutmann, 1999; Yang *et al.,* 2016).

To date, the mechanism of how orthodontic treatment influences root resorption is not clearly understood. The causative factors are complex and may include individual variation, genetic predisposition and/or orthodontic treatment-related factors (Weltman *et al.,* 2010). Possible aetiologies of root resorption that are associated with orthodontic treatment include; magnitude of applied force, direction of tooth movement, duration of the orthodontic treatment, amount of apical displacement, method of force application (continuous vs intermittent) and/or type of appliance. Meanwhile, patient-related factors include; previous history of dental trauma, existing root resorption, individual susceptibility, and/or genetic predisposition (Lopatiene & Dumbravaite, 2008; Aydin & Er, 2016).

A traumatised tooth can be moved orthodontically with minimal risk of root resorption provided that the dental pulp is not infected. However, if the dental pulp is compromised, appropriate endodontic

treatment is essential prior to orthodontic tooth movement (Hamilton & Gutmann, 1999; Yang *et al.,* 2016).

Additionally, when the apical root of the traumatised tooth shows signs of root resorption before orthodontic tooth movement, the possibility of progression of the root resorption during orthodontic treatment is high (Yang et al., 2016).

Table 1. Descriptions of the included studies

Type of study	Number	Area of studies
Meta-analysis/ systematic review	9	• Orthodontic-induced root resorption. • Influence of orthodontics on dental pulp.
Prospective study	7	• Influence of orthodontics on dental pulp. • Influence of orthodontics on vitality of dental pulp in teeth with a previous history of dental trauma.
Retrospective study	4	• Influence of orthodontics and quality of endodontic treatment on periapical inflammation. • Roles of orthodontics prior to implant placement. • Influence of orthodontics on apical root resorption in endodontically treated teeth and vital teeth. • Influence of orthodontics on dental pulp.
Laboratory study including animal study	12	• Molecular markers of dental pulp tissue, microvasculature of dental pulp and other histological changes following orthodontics.
Case report/series	24	• Interdisciplinary patient management. • Dental pulp responses during orthodontics. • Roles of orthodontics prior to implant placement.
Cross-sectional/survey	2	• Treatment plans of traumatised teeth.
Review article	19	• Roles of orthodontics in restorative treatment planning or prior to implant placement. • Effects of orthodontics on dental pulp, dental hard tissues, and periapical region. • Interdisciplinary patient management. • Relative merits of case reports. • Influence of dental trauma on the management of orthodontic treatment.

Even though this was highlighted in the systematic review, it should be carefully interpreted owing to the methodological variations in the included studies such as number of subjects, age differences, duration of orthodontic treatment, standardisation of pre-treatment and post-treatment radiographs, study method of external root resorption and type of teeth included for analysis (Yang *et al.,* 2016)

In a survey conducted recently, dental practitioners (general dentists, paediatric dentists and orthodontic specialists) were tested for their knowledge on the possible complications of traumatised teeth that are moved orthodontically and the researchers found that there were varying levels of knowledge on the topic (Van Gorp *et al.,* 2020). Orthodontic specialists were more confident in providing orthodontic treatment to the traumatised teeth because the history of dental trauma were not considered as an absolute contraindication, rather than an aspect that is premeditated since the treatment planning stage (Van Gorp *et al.,* 2020). The skills and experience of the orthodontic specialists could possibly lead to this decision, not only they focus on the active orthodontic treatment but also periodic follow-up of the traumatised teeth. When the signs and symptoms of root resorption are evident, early intervention can be undertaken to minimise the progression.

Effects of orthodontic treatment on dental pulp

Orthodontic tooth movement can cause biological reactions in human dental pulp and periodontal ligament. The reactions include; neurovascular disturbances, trigger of inflammatory responses, degenerative changes, increased neural activity and/or altered sensation (von Böhl *et al.,* 2012; Gulabivala & Naini, 2014; Aydin & Er, 2016; Yang *et al.,* 2016) as well as reduced pulpal blood flow, when measured using Laser Doppler flowmetry (Ersahan & Sabuncuoglu, 2018). Besides causing biological changes, molecular changes have also been reported including reduced alkaline phosphatase (ALP) activity, increased aspartate aminotransferase (AST) activity, increased number and diameter of microvessels, release of angiogenic and vascular endothelial growth factors (von Böhl *et al.,* 2012), altered gene expression (Abdul Wahab *et al.,* 2012), as well as expression of neurotransmitters (Chavarría-Bolaños *et al.,* 2014) and inflammatory mediators (Yamaguchi *et al.,* 2004). The expression of neuropeptides such as substance P and calcitonin gene-related peptide indicate the role of neurotransmitters in early pulpal inflammation response (Chavarría-Bolaños *et al.,* 2014), could be attributed to the stimulation of inflammatory mediators (interleukin-1β, interleukin-6, and tumour necrosis factor-α) in the dental pulp (Yamaguchi *et al.,* 2004). Furthermore, gene expression analysis via GeneFishing technique indicates the presence of specific genes that has potential as biomarkers to monitor the progression of orthodontic treatment (Abdul Wahab *et al.,* 2012).

Physiological changes in the dental pulp interfere with neural activity by increasing the response thresholds to electrical stimulus (Veberiene *et al.,* 2010; Alomari *et al.,* 2011; Modaresi *et al.,* 2015). A previous study reported lower response thresholds after 1-month application of orthodontic force, but values remained higher than the baseline records (Modaresi *et al.,* 2015). However, this report contradicted results from another study whereby the authors observed an increased response thresholds after 1-month application of orthodontic force (Hall & Freer, 1998). Increased response thresholds occur as a result of compression or tension on the apical nerve fibers, resulting in a compromised response to the electric pulp test (Modaresi *et al.,* 2015). Threshold values depend on the degree and the duration of the application of orthodontic forces (Briseño-Marroquín *et al.,* 2021). This situation should be taken into consideration when assessing the status of dental pulp in patients undergoing orthodontic treatment (Modaresi *et al.,* 2015). The dental pulp should not be regarded as non-vital without apparent clinical signs and symptoms such as spontaneous pain, swelling, pain to

percussion and/or palpation, pus discharged through sinus tract and periapical radiolucency. Changes in physiology of the dental pulp is caused by various factors including orthodontic treatment related factors, maturity of the apical root and/or age of patients (Gulabivala & Naini, 2014). Teeth with immature root apices are less likely to be affected due to a richer, thicker and larger supply of neurovascular bundle to the tooth (Gulabivala & Naini, 2014; Aydin & Er, 2016).

The application of appropriate or light orthodontic force enables sufficient tooth movement, limits the damage in the dental pulp and allows for the repair of any damage that is developed during orthodontic treatment (Aydin & Er, 2016). This was demonstrated in a recent in vivo study involving human dental pulp where no irreversible iatrogenic changes were observed in the dental pulp following application of appropriate orthodontic forces for tooth movement (Vermiglio *et al.,* 2020). Orthodontic tooth movement is not a direct cause of pulpal necrosis (Consolaro & Consolaro, 2018; Weissheimer *et al.,* 2021) and obliteration of the dental pulp, but when these are observed following orthodontic tooth movement, a previous history of dental trauma could possibly be the aetiological factor (Javed *et al.,* 2015; Yang *et al.,* 2016; Consolaro & Consolaro, 2018). This might explain a higher frequency of pulpal necrosis in teeth with severe periodontal tissue injuries that underwent orthodontic treatment, mainly was attributable to the previous history of dental trauma (Bauss *et al.,* 2008; Bauss *et al.,* 2010). The frequency of pulpal necrosis in traumatised teeth was reported to be 9.1% (Bauss *et al.,* 2010) and 10.4% (Bauss *et al.,* 2008) compared to 0.3% (Bauss *et al.,* 2008) and 0.5% (Bauss *et al.,* 2010) in teeth without dental trauma.

In animal studies, changes in dental pulp tissue following orthodontic-induced tooth movement are limited to hemodynamic (microvasculature) aspects with no irreversible degeneration of the dental pulp (Grünheid *et al.,* 2007; Abi-Ramia *et al.,* 2010; Cuoghi *et al.,* 2018). This could be due to the increased expression of inflammatory mediators (interleukin-1β, and tumour necrosis factor-α) in dental pulp tissue (Bletsa *et al.,* 2006). Often the changes are temporary, has an excellent capacity for adaptation (Santamaria Jr *et al.,* 2006) and are able to return to normal healthy status when the stimulus is halted (Santamaria Jr *et al.,* 2007). In teeth subjected to orthodontic force, higher vascular volume density was observed in the coronal dental pulp compared to the teeth not subjected to orthodontic force (Santamaria Jr *et al.,* 2006). Vascular volume density at 6 hours, was high but fell after 24 and 72 hours, almost similar to the values in the dental pulp not subjected to orthodontic force (Santamaria Jr *et al.,* 2006). The findings observed in the experimental rats were also mirrored in human cell experiments using haematoxylin-eosin staining (Lazzaretti *et al.,* 2014) and/or immunofluorescence (Vermiglio *et al.,* 2020) analyses. In a clinical study, orthodontic force was applied to the teeth of younger and older subjects via fixed orthodontic appliance, and pulpal blood flow was measured using Laser Doppler flowmetry. The results showed initial reduction in the pulpal blood flow values in both subjects (Ersahan & Sabuncuoglu, 2018). Even though a recovery process followed after completion of the experiment, pulpal blood flow values in the latter remained low and did not return to the baseline levels (Ersahan & Sabuncuoglu, 2018). The authors concluded that, the ability of dental pulp to return to its initial state may depend on the age of the patients. However, this needs to be interpreted with caution as the subject samples were small and the duration of observation was only one month. To date, studies on the effects of longer periods of orthodontic tooth movement in older subjects has not been conducted, therefore the reversible nature of changes in pulpal blood flow remain unclear.

Effects of orthodontic treatment on endodontically treated teeth

In dental practice, there is often the need to move teeth whether the teeth are vital, have been endodontically treated or undergoing

endodontic treatment (Aydin & Er, 2016). Orthodontic movement of endodontically treated teeth was not commonly practiced for many years and clinicians tend to avoid applying orthodontic forces to these teeth because of the general belief that orthodontic tooth movement increases the risk of root resorption (Aydin & Er, 2016). However, improved understanding of treatment outcomes and techniques, supported by the scientific data in current practice has increased clinicians' confidence to provide such treatment. The clinical importance of pulpal alterations after orthodontic treatment depends on whether or not it will endanger long-term vitality of the teeth (von Böhl *et al.,* 2012; Gulabivala & Naini, 2014; Aydin & Er, 2016).

There is controversy in the literature concerning the risk of root resorption in endodontically treated teeth because of the susceptibility to root resorption (Aydin & Er, 2016). However, endodontically treated teeth without signs of root resorption can be moved orthodontically without extensive root resorption (Malmgren & Malmgren, 2007) provided that the endodontic treatment procedures are effective with no coronal leakage and allow no access for bacterial invasion (Walker *et al.,* 2013; Aydin & Er, 2016; Yang *et al.,* 2016; Esteves *et al.,* 2007). This might clarify the reported data in a meta-analysis (Alhadainy *et al.,* 2019) and two systematic reviews (Walker *et al.,* 2013; Yang *et al.,* 2016) that showed no statistically significant differences in the amount and severity of root resorption between endodontically treated teeth and vital teeth when equal amounts of orthodontic force is applied, and a high success rate of tooth retained in the occlusion was also observed (Medeiros & Mucha, 2009).

There is limited data in the literature reporting orthodontic tooth movement in teeth with apical lesions or apical periodontitis following root canal treatment, and in teeth with a history of periradicular surgery (Hamilton & Gutmann, 1999; Walker *et al.,* 2013; Aydin & Er, 2016; Yang *et al.,* 2016). It is also unclear pertaining to the ability of teeth that have undergone periradicular surgery to move successfully following orthodontic treatment. The reported data on the combined treatment modalities of periradicular surgery and orthodontics was published by limited numbers of researchers (Pedullà *et al.,* 2015; Singh *et al.,* 2018; Bi *et al.,* 2020). In a case report with interdisciplinary patient management, the orthodontic-surgical extrusion of the impacted maxillary canine and periaradicular surgery of the deviated root of an adjacent premolar showed successful treatment outcomes (Pedullà *et al.,* 2015). Periradicular surgery to remove the dilacerated root of the right maxillary incisor that performed after orthodontic traction resulted in successful outcomes; having good periodontal and orthodontic stability (Singh *et al.,* 2018). Another case reporting a combination of orthodontic tooth movement and periradicular surgery resulted in a resolution of periapical inflammation and no progression of root resorption after a two-year follow-up (Bi *et al.,* 2020). Although case reports could provide some guidance to the clinicians, the interpretation of the results must be carefully made due to the limitations including publication and recall biases, does not represent the population hence the findings could not be generalised (Nissen & Wynn 2014).

Regarding the regenerative endodontic procedures and orthodontic tooth movement, although there is limited scientific evidence, the outcomes have been highlighted in the previous case reports (Al-Tammami & Al-Nazhan, 2017; Chaniotis, 2018; Natera & Mukherjee, 2018). It is an essential prerequisite to provide an effective endodontic treatment for successful orthodontic tooth movement (Hamilton & Gutmann, 1999; Walker *et al.,* 2013; Aydin & Er, 2016; Yang *et al.,* 2016) because the risk of apical lesions and bone destruction following orthodontic tooth movement was significantly increased in endodontically treated teeth with inadequate endodontic treatment (Alqerban *et al.,* 2019). This might explain the absence of statistically significant differences in the incidence of root resorption between endodontically treated teeth and vital teeth as highlighted in

the previous studies (Walker *et al.,* 2013; Yang *et al.,* 2016; Alhadainy *et al.,* 2019).

Role of orthodontics in endodontic-restorative treatment planning

Orthodontic treatment could recreate a space for future prosthetic restoration such as dental bridge or dental implant (Chalala, 2012). It could aid in tooth alignment by distributing the space in the arch adequately, thus the clinicians could plan for the restorative treatment effectively, for instance in hypodontia cases. Another aspect that is advantageous is that, the orthodontic extrusion of a severely compromised tooth followed by restorative treatment was useful in patient who had a medical history of bisphosphonate and irradiation treatments to avoid the occurrence of medication-related osteonecrosis of the jaw or osteoradionecrosis (Morita *et al.,* 2017).

In dental trauma, crown-root fractures account for 5% of all injuries and the successful management are compromised by a fracture below the gingival margin and/or bone (Sharma *et al.,* 2011). Complicated crown-root fractures are considered challenging because 46% of general dentists find themselves unable to treat the cases and require referral to orthodontic and periodontal specialists (De Castro *et al.,* 2010). In certain clinical cases, orthodontic tooth movement is a feasible approach to align the affected tooth/teeth prior to endodontic treatment as highlighted in the previous case reports (Singh *et al.,* 2018; Bi *et al.,* 2020; Sonoda *et al.,* 2018). Leaving dental pulp untreated after severe dental trauma can lead to complications such as pulp necrosis, apical periodontitis, and root resorption (Scholtes *et al.,* 2018). This could possibly explain the reason of providing endodontic treatment on the affected tooth/teeth before orthodontic extrusion, and the restorative treatment were carried out when the tooth/teeth were successfully repositioned in the arch (Kocadereli *et al.,* 1998; Casaponsa *et al.,* 2020). However, there was reported case in which the initial endodontic procedure and temporary intracanal dressing were carried out prior to orthodontic extrusion, then the endodontic procedure and restorative treatment were performed later when the tooth were extruded to the desired position in the arch (Agarwal *et al.,* 2020).

Patient with inadequate restorative margin may require crown lengthening, which can be achieved either surgically or orthodontically. When comparing two techniques, the latter provides a more favorable crown to root ratio, eliminates the risk of compromising the alveolar bone support of the adjacent teeth, and does not compromise the aesthetics of affected tooth/teeth (Potashnick & Rosenberg, 1982). Various extrusion techniques are available, depending on the clinical conditions encountered and both fixed and removable orthodontic appliances can be used to achieve orthodontic extrusion (Chole *et al.,* 2016). The primary objective of orthodontic extrusion in trauma patients is to provide a sound tissue margin for ultimate restoration and to create a periodontal environment that will be easy to maintain (Calasans-Maia *et al.,* 2003). The amount of force necessary to slowly extrude a tooth depends on the amount of bone on the tooth to be extruded. Orthodontic brackets are placed on the tooth to be extruded and the adjacent teeth sufficient to control the extrusive movement, with no movement of the teeth used for anchorage (Brindis & Block, 2009). When deciding on orthodontic extrusion and restoration with prosthetic rehabilitation, some confounding factors must be considered, such as crown-root ratio, root abnormities, fracture type and location, interocclusal space, and risk of exposure of furcation of a multi-rooted tooth (Bach *et al.,* 2004; Dede *et al.,* 2017). The major limitation of this approach is that it increases the duration of treatment and requires a longer retention period (Kocadereli *et al.,* 1998).

Orthodontics can also be beneficial prior to implant surgery because this approach could preserve the alveolar bone for future implant placement and/or prosthetic restoration (Medeiros & Mucha, 2009), and is a useful alternative to conventional surgical augmentative procedures (Chalala,

2012) because the alveolar bone is advanced coronally to improve vertical bone height at the future implant site (Ovaydi-Mandel *et al.,* 2013; de Avila *et al.,* 2014). During the implant site development procedure, alveolus preservation is a procedure to prepare and maintain an adequate bone volume for implant placement and stabilisation (Irinakis, 2006). After a tooth is extracted, the alveolar bone and soft tissues remodel with a resulting reduction in the horizontal and vertical dimensions of the future implant site (Schropp *et al.,* 2003; de Molon *et al.,* 2013). Bone defects can be treated by different surgical procedures, such as guided bone regeneration and bone grafts depending on the characteristics of the defect itself. Several techniques are available today by using resorbable and non-resorbable devices. These are invasive techniques with a high degree of morbidity and a risk of failure (Conserva *et al.,* 2020). The immediate implant procedure in the aesthetic zone is to furnish a peri-implant tissue architecture that facilitates the establishment of close-to-nature functional and esthetic outcomes. Orthodontic extrusion is also considered as one of the proposed approaches for pre-implant procedures. (Alsahhaf & Att, 2016). Orthodontic forces used during extrusion ranged from 15 g to >80 g; the lowest values are normally used for the anterior teeth or single-rooted teeth, whereas the highest values were for posterior teeth (Conserva *et al.,* 2020). On the other hand, the extrusion speed (mm/month) found was between 0 and 2 mm per month (Conserva *et al.,* 2020). After the tooth has been extruded, it should be stabilised for 6 to 12 weeks to allow for tooth stabilisation and bone consolidation. Overcorrection is also recommended to compensate for the possible loss of bone and gingiva that may occur because of the implant placement surgical procedure. Using orthodontic extrusion for implant site development often involves prior root canal treatment and vertical crown height reduction of the tooth that are to be extruded, to eliminate creating a traumatic bite (Kim *et al.,* 2011; Rasner, 2011). It is important to keep in mind the importance of planning before attempting to extract any tooth. Once the tooth has been removed, the ability to use nature's capacity to grow soft tissue and bone through tooth eruption no longer exist (Brindis & Block, 2009). Teeth that are hopeless and planned for extraction can still be used for physiologic benefit to impart orthodontic augmentation, or site development (Celenza, 2012). Another important role of orthodontic tooth movement is to correct the angulation of teeth adjacent to a potential implant site (Malmgren & Malmgren, 2007; Addy *et al.,* 2009; Gulabivala & Naini, 2014).

Interdisciplinary patient management

Performing root canal treatment during orthodontic treatment poses a number of difficulties such as pulpal/periaradicular pain that is counfounded by discomfort due to tooth movement, the clinicians face challenges of achieving effective tooth isolation for endodontic treatment procedure, presence of apical root resorption might compromise the determination of working length, the dilemma of whether to complete endodontic treatment during orthodontic or after completion of orthodontic treatment, and presence of carious lesion and/or defective restoration that require effective restoration (Gulabivala & Naini, 2014). There are limited number of studies reporting the appropriate timing for orthodontic treatment following the completion of endodontic procedure. In a case report, the orthodontic treatment was provided after 10 months follow-up when there was an evident of periapical healing (Er *et al.,* 2011). In another case report, the orthodontic treatment was started after 42 months follow-up when the size of abscess had decreased (Chaniotis, 2018). The approach was clearly different when starting orthodontic treatment involving the traumatised teeth as orthodontic extrusion was initiated one week after the endodontic procedure (Mittal *et al.,* 2013; Choudhary *et al.,* 2017). The difference in the time frame could be due to the absence of periapical lesion on the traumatised teeth and aesthetic region that requires restoration (Mittal *et al.,* 2013; Choudhary *et al.,* 2017). However, the observation periods following endodontic

treatment prior to orthodontic tooth movement vary based on individual case, ranged from immediate commencement of orthodontic tooth movement to approximately 6-12 months depending on the healing status of periapical inflammation (Kindelan *et al.,* 2008).

Some important aspects to consider during clinical management of teeth requiring integrated endodontic and orthodontic treatment includes the effects of orthodontic tooth movement on the dental pulp and potential root resorption (Hamilton & Gutmann, 1999). Interdisciplinary patient management has been documented in previous case reports with evidence of success such as better aesthetics, asymptomatic, improved function and no evidence of periapical pathology (Mittal *et al.,* 2013; Pedullà *et al.,* 2015; Choudhary *et al.,* 2017; Al-Tammami & Al-Nazhan, 2017; Chaniotis, 2018; Natera & Mukherjee, 2018; Singh *et al.,* 2018; Sonoda *et al.,* 2018; Agarwal *et al.,* 2020; Bi *et al.,* 2020). This includes in special need patients with previous history of dental trauma (Chaushu *et al.,* 2004). The success rate of orthodontic extrusion of traumatised teeth was reported to be 95.45% and only 4.54% teeth failed due to rapid progression of root resorption (Medeiros & Mucha, 2009). The majority of traumatised teeth underwent endodontic treatment due to pulpal involvement and a small number of teeth did not require endodontic treatment due to a vital pulp (Medeiros & Mucha, 2009). Treatment plans that involve various dental specialties must be based on a realistic evaluation of the orthodontic treatment options and optimal treatment procedures to achieve the desired outcomes (Malmgren & Malmgren, 2007).

Nevertheless, the orthodontic treatment is not without endodontic complications, particularly when it is related to the use of temporary anchorage devices (miniscrews) that are placed in the maxillary bone in close proximity to the roots and can result in pulpal necrosis and/or apical periodontitis (Rossi-Fedele *et al.,* 2020). This situation is reported in the previous study where a combination of non-surgical and surgical endodontic procedures were carried out to treat the endodontic complications (Lim *et al.,* 2013). In another study, a non-surgical endodontic procedure was successful in treating the endodontic complications due to placement of minicrews (Er *et al.,* 2011). Meticulous treatment planning involving endodontic and orthodontic aspects may prevent similar cases from repeating, minimising the need for future complex treatment procedures to correct the iatrogenic damages. In addition to this, interdisciplinary approach could improve overall treatment outcomes (Pedullà *et al.,* 2015; Al-Tammami & Al-Nazhan, 2017; Chaniotis, 2018; Natera & Mukherjee, 2018; Singh *et al.,* 2018; Bi *et al.,* 2020) as well as the quality of life of the patient (Singh *et al.,* 2018). Therefore, it is essential that treatment is planned on a case-by-case basis, taking into consideration several factors including the risks and benefits of treatment, patient factors as well as the experience of clinicians in conducting complex and lengthy treatment procedures.

Conclusion

Dental treatment that involves endodontic and orthodontic specialities should be carefully planned according to the individual case, skills and experience of the clinicians, incorporating integrated patient management with guidance from available scientific evidence. Sound knowledge and thorough understanding of the endodontic-orthodontic interface could help clinicians to provide effective treatment and eventually improve the outcomes and patient well-being.

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ORIGINAL ARTICLE Open Access

The effect of locally delivered Tualang honey on healing of periodontal tissues during non-surgical periodontal therapy

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Abstract

Honey is a sweet, viscous natural substance made from flower nectar by bees. Honey has been used not only as a nutritional source but also for wound healing and to reduce tissue inflammation. Nevertheless, the use of honey in the treatment of periodontitis is not well established. This study aimed to evaluate the effect of locally delivered Tualang honey on periodontal tissue healing by a randomized controlled split-mouth clinical trial involving 20 chronic periodontitis patients with a periodontal pocket depth of ≥ 5 mm. Each site was randomly treated either by scaling and root debridement alone (Control Group) or scaling and root debridement with locally delivered Tualang honey (Test Group). Assessment of probing pocket depth (PPD) and clinical attachment level (CAL) was recorded at baseline and after 6 weeks interval. Gingival crevicular fluid samples were collected from treated pockets at baseline and along with periodontal reassessment to evaluate the level of Matrix Metalloproteinase 8 (MMP-8) and Osteoprotegerin (OPG). Data were analysed by using Wilcoxon Signed Rank Test and Paired Sample t-Test. PPD and CAL were significantly improved after the 6 weeks review (P=0.001) in both groups. However, there was no significant difference in the changes of the PPD, CAL, MMP-8 and OPG levels after the 6 weeks review and in between the groups. In conclusion, within the limitations of this study, the effect of locally delivered Tualang honey on periodontal tissue healing is not evident. Nevertheless, all pockets achieved good periodontal healing.

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Introduction

Honey is a natural substance and food produced by bees from flower nectar. It has been widely known since ancient times, not only for its nutritional value, but also for its ability to heal many kinds of ailments. For example, in pre-ancient Egyptian times, honey was used topically to treat wounds. The ancient Greeks viewed honey not only as important food, but also as healing medicine. It is also recognized in Islam as a good medication for many kinds of diseases and medical disorders such as burns, sleeplessness, nasal congestion, wounds, fatigue, poor digestion, sore throats, and anaemia. According to Khan and Rauf

(2007), honey will never spoil if being stored correctly thus it does not have the expiry date. It can be stored at room temperature without losing its properties. Honey is one of the oldest foods in existence found in the tomb of King Tut which is still edible. It also has a prominent level of fructose thus sweeter than the table sugar.

Previous studies have shown that besides having a good source of nutrition, honey also has superior healing and antimicrobial properties. The antimicrobial activity of honey is one of the most important findings that was first reported in 1892 by Van Ketel. Honey has been reported to have an inhibitory effect on around 60 species of bacteria including aerobes and anaerobes, gram-positive and gram-negative (Olaitan *et al.,* 2007). Besides its antimicrobial properties, honey can clear the infection in several ways, including by boosting the immune system, having anti-inflammatory, and antioxidant activities and via stimulation of cell growth (Tan *et al.,* 2009). All types of honey have high sugar content but the low water content and its acidity prevent microbial growth. Honey can inhibit the growth of a wide range of bacteria, fungi, protozoa, and viruses (Tan *et al.,* 2009). Medical grade manuka honey was reported to have high concentrations of methylglyoxal which were believed to play significant role in its antimicrobial activity (Mavric *et al.*, 2008) includes towards oral bacteria (Safii et al., 2017, Badet and Quero, 2011). Manuka honey was also reported to have many similarities with Malaysian Tualang honey (Kishore et al., 2011, Ahmed & Othman, 2013). Tualang honey is a wild polyfloral honey produced by wild bees known as *Apis dorsata*. This honey is collected from the beehive which is normally found on the Tualang tree (*Koompassia excels)*, in the Malaysian rainforest. Tualang honey is used commonly as a medicinal product and as a food supplement in Malaysia. It was found that Tualang honey had high antibacterial properties derived from total and non-peroxide activities (Zainol *et al.,* 2013).

Very few studies have been conducted to demonstrate the beneficial effect of honey in the medical and dental fields. The ability of honey to reduce inflammation and improve wound healing has led to the introduction of honey impregnated pads that can act as non-adhesive tissue dressings (Al-Waili, 2005). This approach leads to the stimulation of the healing process and rapidly clears the infection. In dentistry, a study by Atwa *et al.* (2014) demonstrated that the topical application of honey can modify the pH, reduce bacterial counts, and inhibit bacterial growth. Based on this finding, topical application/chewing of honey might help prevent gingivitis and caries in patients undergoing complex dental treatment.

Periodontitis is considered one of the most common oral diseases in the world. The pathogenic bacteria that reside in the subgingival area are widely recognized as the primary etiologic factor for the disease (Shifrovitch *et al.,* 2009). It is a lifelong inflammatory disease that is characterized by loss of periodontal ligament and alveolar bone. According to National Health and Nutrition Examination Survey 2012, 46% of adults in United States of America had periodontitis, with 8.9% having severe periodontitis (Eke et al., 2015). In Malaysia, the National Oral Health Survey for Adult (NOHSA, 2010) showed that the prevalence of periodontal disease in all levels of severity is increasing from 90.2% in the year 2000 up to 94% in 2010.

The clinical treatment of chronic periodontitis is initiated by non-surgical periodontal therapy (NSPT); patient motivation and oral hygiene instructions, followed by removal of plaque and calculus to achieve a clean root surface by scaling and root surface debridement (SRD). It is widely accepted that effective periodontal therapy for plaque-related disease requires the elimination of inflammation by establishing a biologically acceptable 'clean' root surface (Dentino *et al.,* 2013). However, the success of periodontal therapy may not be achieved by NSPT alone. Hirschfeld and Wasserman (1978) found out that about 20%–30% of all chronic periodontitis cases do not respond favourably to conventional periodontal treatment. Local antimicrobial delivery such as minocycline gel, chlorhexidine chip, and doxycycline gel have been used as an adjunct

to SRD which were demonstrated to provide additional benefit over SRD alone (Hanes and Purvis, 2003). But the use of antimicrobial agent particularly antibiotics is not appropriate for long term used. As honey was known to provide various beneficial effects in curing diseases, it is anticipated to possess similar action in treating periodontal disease. Therefore, this study was conducted to investigate the effect of locally applied Tualang honey on the healing of periodontal tissues as an adjunct to SRD.

Materials and Methods

Study design and sampling

This was a randomized controlled split-mouth clinical trial on chronic periodontitis patients with a follow-up period of 6 weeks. Each patient represents both experimental and control subjects with either right or left side of jaw as the experimental site determined by randomization. Chronic periodontitis patients attending Dental Clinic, Hospital USM, Kelantan was chosen as our source population. Sample size was calculated by using PS software version 3.1.2 by Dupont and Plummer (2009). A total of 20 subjects were included in this study after fulfilled the inclusion and exclusion criteria. The split-mouth design was used in this study, whereby the teeth with a pocket depth of 5 mm or more in the right and left quadrants in each patient were assigned into either control group or experimental group by using an opaque sealed envelope contained a piece of paper which determined whether a patient receives honey on either left or right quadrant. The envelope was chosen by the patient. Those who were diagnosed with chronic periodontitis (Armitage, 1999) with minimum periodontal pocket depth (PPD) of 5 mm on at least 3 sites on each quadrant, aged between 20 to 65 years old, and maintained optimum oral hygiene were included. Chronic periodontitis is either localized (≤ 30% of periodontal sites with PPD greater than 3 mm) or generalized (≥ 30% of periodontal sites with PPD greater than 3mm) with evidence of alveolar bone loss equal to or greater than 3 mm in the radiograph. In this study, only sites with minimum of 5 mm PPD were selected as these sites possess difficulty for patient to clean that required root debridement. Patients taking antibiotics 3 months prior to the study, having uncontrolled systemic disease, smokers, taking medications that affect the gingiva, have known allergy towards honey and taking honey regularly were excluded from this study.

The conduct of this study was fully conformed to the local practices, laws, and regulations. Ethical clearance was obtained from the Human Research and Ethics Committee, Universiti Sains Malaysia, protocol code USM/JEPeM/15090301 on 4th January 2016. Written informed consent was obtained from each subject prior to participation.

Clinical procedures

Patients were briefed about the study procedures and the informed written consent was taken. Patients' information including patient particulars, intraoral examination, orthopantomogram radiograph, and periodontal charting were recorded in a Data Collection Form. Periodontal parameters such as Plaque Index (PI) (O'Leary, 1972), Gingival Index (GI) (Ainamo, 1975), PPD, and Clinical Attachment Level (CAL) were recorded at baseline and 6 weeks after scaling and root debridement. Calibration of the clinical measurement for periodontal parameters was conducted prior to the data collection. Inter and intra examiner agreements were achieved.

The gingival crevicular fluid (GCF) was collected from PPD ≥ 5 mm in control and experimental sides for each subject from two buccal sites of two different teeth GCF was collected by using Periopaper (Oraflow Inc) strip before scaling at baseline and after 6 weeks at the same sites during the review visit. The collection method was adapted from Guentsch *et al.* (2011). Samples were collected in the morning, between 9 am to 12.30 pm. Prior to GCF collection, the

supragingival plaque and calculus were carefully removed by using a hand scaler. Subjects were instructed to rinse their mouth with distilled water to wash out food debris and exfoliated cells. The sites to be sampled were isolated with cotton rolls and gently air-dried to prevent saliva contamination. Periopaper strip was gently inserted for 30 seconds into the periodontal pocket until a minimum of resistance felt. The paper strip that absorbed blood from the pocket was discarded and sampling was repeated after 90 seconds. Paper strips from each group were removed and placed in a test tube containing 500 µl bidistilled water which were eluted at 4°C overnight. After being centrifuged at 400 g for 4 minutes, the paper points/strips were removed; the supernatants were kept frozen at −20°C until assayed.

All subjects received a course of NSPT consisting of motivation, oral hygiene instructions (emphasizing proper tooth brushing technique, flossing, interdental brush, and mouthwash usage), scaling, polishing and root debridement with an ultrasonic scaler and Gracey curettes (Schwert, Germany) done by a periodontal registrar (MAMI). The control group received SRD with normal saline irrigation on sites with PPD ≥ 5 mm. The experimental group received SRD with normal saline irrigation and locally delivered 0.5 ml non-diluted Tualang honey on sites with PPD ≥ 5 mm. The Tualang honey was delivered to the sites until overflows using a syringe with plastic catheter of cannula 20 g (B Braun) attached to it. Subjects were reviewed at 6 weeks to re-evaluate the clinical periodontal parameters and for the second collection of the GCF sample using the same method. The CONSORT diagram of trial is shown in figure 1.

Biomarker analysis

For this study, the level of MMP-8 and OPG were determined to compare the healing of periodontal tissue after SRD in patients with chronic periodontitis. The concentrations of the MMP-8 and OPG, in eluted GCF were determined by commercially available Human Quantikine Enzyme-Linked Immunoabsorbent Assay (ELISA) kits by Elabscience Biotechnology Incorporation as described in the manufacturer's instruction. The ELISA kit is based on the Sandwich-ELISA method. The micro ELISA plate which was provided in the kit has been pre-coated with an antibody specific to human MMP-8 and OPG. To ensure data consistency, the clinical parameters evaluation, GCF samples collection, and laboratory works were done and recorded by one clinical researcher. During biomarker detection with ELISA kit, duplication of each sample was performed. Prior to biomarker detection assay, pre-run test was done on both MMP-8 and OPG to ensure the proteins concentration in eluted GCF is detectable within the standard range. The optical density (OD) and concentration of each well of the micro ELISA plate were determined with a microplate reader with 450nm wavelength filter (SkanIt Software 2.4.3 RE for Thermo Scientific™ Varioskan™ Flash Multimode Reader).

Statistical analysis

Data were processed and analysed using the IBM Statistical Package for Social Sciences (SPSS) Statistics Version 24 (IBM Corporation, USA). The means and standard deviations were computed for all patient's data, clinical parameters, and protein biomarkers concentration. Analysis was carried out using non-parametric two-related samples test; Wilcoxon Signed Rank Test, to compare PI, GI, and for comparison of protein biomarkers concentration between control and experimental groups from baseline and at 6 weeks. The results were expressed in median and interquartile range (IQR). Independent t-test was used to compare the mean changes of PPD and CAL between both groups and was expressed in means and standard deviations (SD). The level of significance was set at $P<0.05$ and 95% CI (Confidence Interval).

Results

Demographical data

Twenty subjects with a mean (SD) age of 46.5 (11.9) were participated and completed the trial. There were 12 (60%) males and 8 (40%) females with the total number of pockets treated were 194 and 176 sites in the control and experimental group respectively. In terms of medical background, five subjects had medical illnesses such as heart disease, hypertension, hypercholesterolemia, bronchial asthma, and heart septal defect, which were under control (Table 1). Periodontal tissue healing occurred in all subjects with no adverse effects such as pain, burning sensation, or any other uncomfortable feeling. There was also no allergic reaction towards honey reported from any of the subjects.

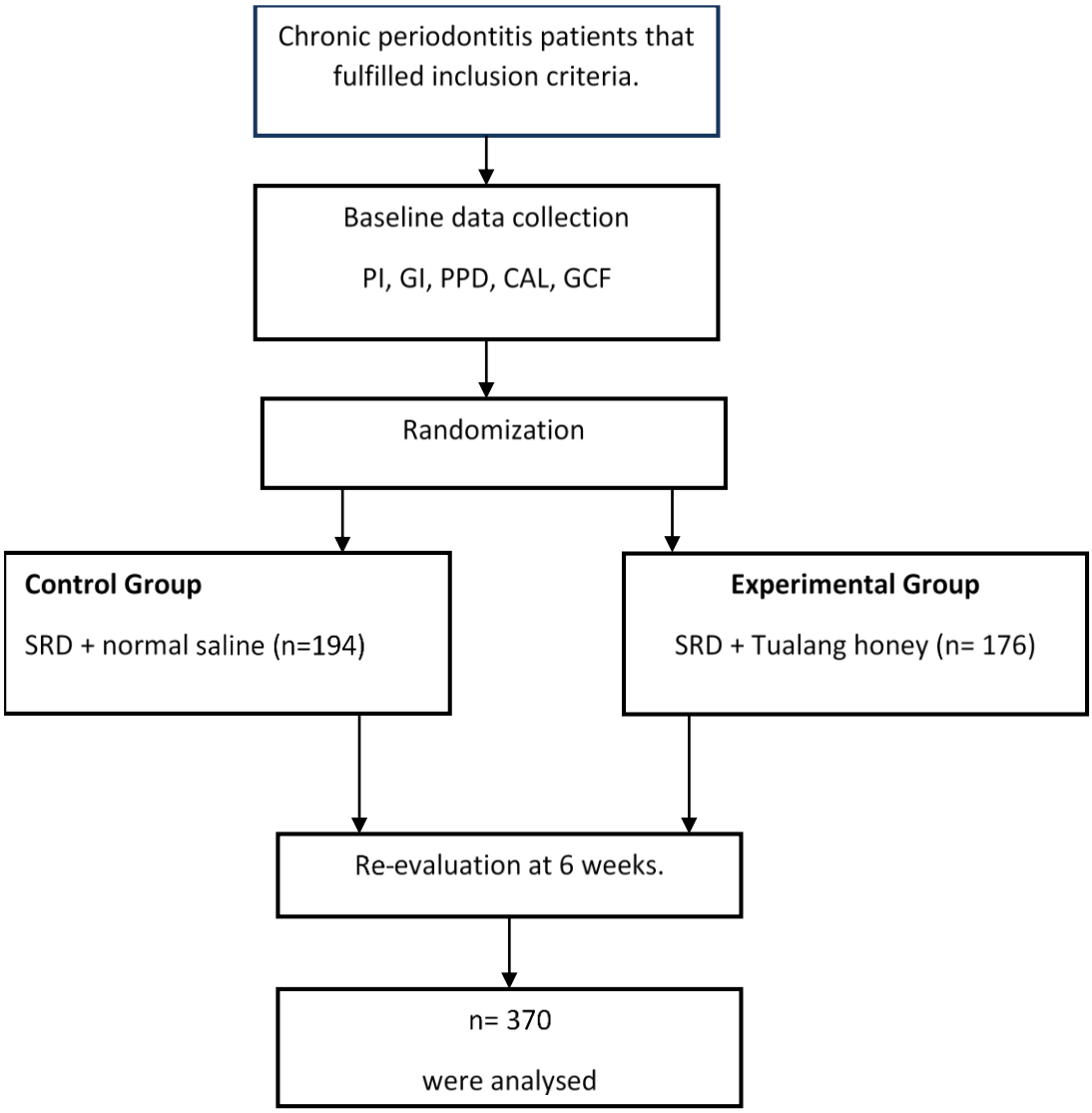

Figure 1. Flow chart of the study trial. (Plaque index = PI, Gingival index = GI, Periodontal pocket depth = PPD, Gingival crevicular fluid = GCF)

Table 1. Characteristic of the study subjects (n=20)

Variables	Mean (SD)	Frequency (%)
Age	46.50 (11.96)	-
Gender		
Male	-	12 (60.0)
Female	-	8 (40.0)
Systemic disease		
Yes	-	5 (25.0)
No	-	15 (75.0)
PPD sampled sites (mm)		
Control	5.51 (0.53)	-
Experimental	5.45 (0.46)	-

The effect of local delivery of Tualang honey as an adjunct during SRD versus SRD alone on periodontal parameter

PI and GI were maintained at a satisfactory level from baseline and after 6 weeks in which only slight reduction with no significant changes were observed for PI (P=0.668) and GI (P=0.052) (Table 2).

At baseline, the mean (SD) of CAL for control and experimental group was 6.50 (1.38) mm (min 5.12mm; max 7.88mm) and 6.14 (1.59) mm (min 4.55mm; max 7.73mm) (Table 3). Both groups showed significant PPD improvement and CAL gain after 6 weeks (P=0.001).

Table 2. Plaque Index (PI) and Gingival Index (GI) at baseline and after 6 weeks after scaling and root debridement

Variables	Baseline Median (IQR)	After 6 weeks Median (IQR)	Z statistic[a]	P value[b]
Plaque index	23.20 (8.0)	19.05 (21.3)	-0.239	0.668
Gingival index	22.50 (16.3)	19.80 (21.7)	-1.941	0.052

Notes: [a]Wilcoxon Signed Rank Test; [b]Significant level is at P<0.05; IQR = Interquartile range.

Table 3. Values of mean (SD) of periodontal pocket depth and clinical attachment level at baseline and after 6 weeks in each group

Variables	Evaluation Point	SRD only (n=194) Mean (SD)	SRD with honey (n=176) Mean (SD)
PPD (mm)	Base line	5.51 (0.53)	5.45 (0.46)
	6 weeks	3.81 (0.51)	3.84 (0.73)
	P value[a]	0.001	0.001
CAL (mm)	Base line	6.50 (1.38)	6.14 (1.59)
	6 weeks	4.95 (1.30)	4.71 (1.28)
	P value[a]	0.001	0.001

Notes: a Independent t-test; PPD = Periodontal pocket depth; CAL = Clinical attachment level; SRD = Scaling and root debridement; SD = Standard deviation.

However, no significant difference in the mean (SD) changes in both clinical parameters when compared between groups (Table 4). Both treatment modalities in this study demonstrated statistically significant improvement in the evaluated clinical parameters (PPD and CAL) after 6 weeks of review in the same group compared to baseline. Nevertheless, the difference in mean changes between both groups was not statistically significant.

The effect of local delivery of Tualang honey as an adjunct during SRD versus SRD alone on periodontal biomarker

A total number of 80 GCF samples were evaluated for the analysis of protein biomarkers. The mean (SD) concentration of GCF MMP-8 at baseline for control group was 0.105 (0.038) ng/ml, while the mean (SD) for experimental group was 0.121 (0.058) ng/ml (Table 5). After 6 weeks, no reduction of MMP-8 concentration was recorded. As for OPG concentration in GCF, the mean (SD) for the control group was 0.094 (0.005) ng/ml, which was almost similar to the experimental group mean, 0.095 (0.007) ng/ml. After 6 weeks, both groups showed a mean OPG concentration of 0.093 ng/ml. Similar to the result for clinical parameters (PPD and CAL), the magnitude of changes from baseline and after 6 weeks showed no significant difference when compared between control and honey groups (P=0.62) as shown in Table 6.

Table 4. Comparison of the changes of periodontal pocket depth and clinical attachment loss before and after treatment between experimental and control sites

Variables	SRD only (n=194) Mean (SD)	SRD with honey (n=176) Mean (SD)	Mean Differences (95% CI)	t – statistic (df)[a]	P value[b]
PPD (mm)	1.69 (0.59)	1.62 (0.71)	0.08 (-0.34,0.50)	0.373 (38)	0.503
CAL (mm)	1.54 (0.71)	1.43 (0.84)	0.16 (-0.34,0.67)	0.66 (38)	0.540

Notes: [a] Independent t-test; [b]Significant level is at P<0.05; PPD = Periodontal pocket depth; CAL = Clinical attachment level; SRD = Scaling and root debridement; SD = Standard deviation.

Table 5. Values of mean (SD) of inflammatory protein biomarkers at baseline and after 6 weeks in each group

Variables	Evaluation Point	SRD only (n=20) Mean (SD)	SRD with honey (n=20) Mean (SD)
MMP-8 (ng/ml)	Base line	0.10 (0.038)	0.121 (0.058)
	6 weeks	0.114 (0.031)	0.130 (0.048)
	P value[a]	0.21	0.54
OPG (ng/ml)	Base line	0.094 (0.005)	0.095 (0.007)
	6 weeks	0.093 (0.004)	0.093 (0.003)
	P value[a]	0.69	0.91

Notes: MMP-8 = Matrix metalloproteinase 8; OPG = Osteoprotegerin; SRD = Scaling and root debridement; SD = Standard deviation.

Table 6. Comparison of the changes of inflammatory protein biomarkers before and after treatment between experimental and control sites (n=20)

Variables	SRD only (n=20) Median (IQR)	SRD with honey (n=20) Median (IQR)	Z statistic[a]	P value[b]
MMP-8 (ng/ml)	-0.013 (0.07)	-0.002 (0.08)	-0.598	0.550
OPG (ng/ml)	0.001 (0.01)	-0.001 (0.00)	-0.392	0.696

Notes: [a]Wilcoxon Signed Rank Test; [b]Significant level is at P<0.05; MMP-8 = Matrix metalloproteinase 8; OPG = Osteoprotegerin.

Discussion

This study aimed to evaluate the effect of local delivery of Tualang honey on periodontal tissue healing as an adjunct to SRD in chronic periodontitis by a split-mouth research design. This type of design is commonly used in clinical research related to dentistry where two treatments are randomly assigned to either the right or left halves of the dentition (Lesaffre, 2009). It was introduced by Ramfjord *et al.* (1968) when they compared the efficacy of two types of periodontal therapy. This design limits the resources needed to conduct a clinical study and also removes a lot of inter-individual variability from the estimates of the treatment effect.

The first result demonstrated that scaling and root debridement (SRD), with or without adjunctive of Tualang honey, improve the periodontal clinical findings of patient with chronic periodontitis. SRD is known as a prerequisite for the success of periodontal treatment to halt disease progression and to resolve inflammation. In 2015, the Council on Scientific Affairs (CSA) of the American Dental Association (ADA) made a clinical recommendation that clinicians should consider SRD as the initial treatment of chronic periodontitis (Smiley *et al.,* 2015). SRD is considered as the reference standard and thus used as active control for periodontal trials.

The non-significant findings between the two groups could be due to the single application of honey carried out in the treatment group, in combination with a long-time interval between the baseline and the subsequent measurement, albeit pure concentration honey was used. In contrast to a study by English *et al.,* (2004) which demonstrated that there was a statistically significant reduction of clinical parameters after a 21-days trial period in the test group (Manuka honey), compared to the control group. The differences could be due to the variance in type, frequency, and method of application of honey. In their study, the subjects chewed or sucked Manuka honey products, for 10 minutes, three times a day, after each meal period. Therefore, in the future study, we suggested more frequent application of honey inside the periodontal pockets, for example, a once-daily topical honey application within the first five days of treatment might show the beneficial effect of honey on periodontal tissue healing.

In the second part of study, the presence of MMP-8 and OPG were assessed to determine the progression of chronic periodontitis after the clinical intervention was initiated. Both biomarkers which were collected from gingiva crevicular fluid (GCF) showed non-significant finding. MMP-8 is one of the enzymes that belong to the matrix metalloproteinases group. It plays a central role in periodontal ligament remodelling, both in physiological and pathological conditions (Alrowis *et al.,* 2014). OPG is the members of the TNF receptor superfamily besides RANK (receptor activator of nuclear factor κ B) and RANKL (RANK ligand). OPG is a soluble decoy receptor that has been called the "bone protector" as it protects the skeleton from excessive bone resorption (Simonet *et al.,* 1997). There are several ways on how GCF can be collected such as by intra crevicullar washing, microcapillary, and absorption technique. In this study, we

choose paper strips technique as it is the most convenient and accurate method for GCF collection (Nazar *et al.,* 2016), followed by the ELISA technique for analysis of biofluids.

Buduneli *et al.* (2009) evaluated the effects of initial periodontal treatment on GCF levels of IL-17, soluble RANKL, and OPG in smoking and non-smoking patients with chronic periodontitis. The authors reported that GCF OPG levels decreased in smokers and non-smokers after periodontal therapy that is not observe in this study, this could be due to the differences in the interval for evaluation and number of sites for GCF collection. In this study. GCF only was taken from 2 sites thus leading to a limited amount of GCF that can be collected (between 1-3 µl). Besides that, there were no intermittent GCF samples were collected between baseline and after 6 weeks review which could be too long to observe an effect. Our result was also in contrast to Shimizu *et al.* (2016) who showed significant changes of GCF levels of interleukin (IL)-1β and transforming growth factor (TGF)-β level after periodontal therapy. Their study was also similar to Buduneli *et al.,* (2009), whereby the GCF samples were collected after 4 weeks interval during the review visit. Other differences could also be due to variation in the expression of different types of cytokines in the GCF (Taso *et al.,* 2019). Additionally, the lack of changes could be due to the washout effect of the honey from the gingival sulcus, thus, limit its local effect on periodontal tissue healing. The GCF flow rate is related to the degree of inflammation and it has been reported that a flow rate of 0.05 to 0.20 µl per minute in cases of minimal inflammation. However, the flow rate of GCF can increase up to 30 times at sites of periodontitis as compared to healthy sites (Boström *et al.,* 1999).

A study done by Jaswal and colleagues (2014) utilized a periodontal pack (COE pack) to cover the sites that received clinical intervention in their split-mouth study on evaluation of 2% turmeric gel in chronic periodontitis patients. They found that the group who received 2% turmeric gel showed a significant difference in the improvement of PPD and CAL when compared to the control group ($P<0.001$). Besides avoiding the risk of spillage, the usage of the COE pack would have minimized the carry-across effect that has been reported as a major problem in a split-mouth design. Therefore, we suggested GCF sample collection could be performed together with the use of COE pack at an earlier time to observe changes in the MMP-8 and OPG level.

Conclusion

In conclusion, the present study demonstrated significant improvement of PPD and CAL in all periodontal pockets during NSPT. However, within the limitations of the study, the local delivery of Tualang honey as an adjunct, showed no superior effect over SRD alone. Further investigations by controlling any confounding factors such as frequency of Tualang honey application, the sustainability of honey in periodontal pockets, interval between measurements and choosing the appropriate group of chronic periodontitis patients, is recommended.

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ORIGINAL ARTICLE Open Access

Dental anxiety among Wisma Lincoln University College community

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Abstract

Dental anxiety is common among people of all ages, which results in delay and avoidance of dental visit and eventually deterioration of oral health. The aim of this study is to assess the dental anxiety level among the community in Wisma Lincoln University College. A cross-sectional study was carried out from April to December 2018. A total of 186 participants were included in this study. The Modified Dental Anxiety Scale (MDAS) was used to assess participants' dental anxiety level. The prevalence of participants with severe anxiety level was 16.7% (n=31), with Indian female being the highest number (n=6, 20%). Participants felt most anxious if they were to receive a local anesthetic injection, with a mean score of 2.04 for male and 3.76 for female. With regards to the aspects of dental treatment that make participants anxious, 74.7% (n=139) of the participants would feel anxious about extraction, followed by pain arising from treatment (63.4%, n=118) and fear of injury caused by dental instrument (60.8%, n=113). In conclusion, 16.7% of the community in Wisma Lincoln University College were highly anxious, with Indian female being most anxious (20%).

Keywords: *dental anxiety, dental visit, Modified Dental Anxiety Scale*

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Introduction

Dental anxiety is very common among people of all ages, which results in delay or avoidance of dental visit and eventually deterioration of oral health (Armfield, 2013; Carter *et al.*, 2014). Such people often have irregular dental attendance and only seek care in the case of an emergency (Armfield *et al.*, 2007). Dental anxiety happens due to various reasons, such as traumatic childhood experience, fear of injection or unpleasant past dental visits (Beaton *et al.*, 2014). It is not only a distressing problem for the public, but also for the dental practitioners as it can lead to increase chair time, diagnosis inaccuracy and negative dentist-patient relationship (Armfield *et al.*, 2009).

Despite of the advances of modern dentistry, dental anxiety remains a huge problem to patients and dentists. According to Hmud and Walsh (2007), restorative dentistry is the main trigger for dental anxiety due to the sight of drills and needle, sound and sensation of drilling and smell of dental chemicals. Alternatively, atraumatic restorative treatment, air abrasion, chemo-mechanical caries removal and lasers are encouraged in anxious patients (Hmud & Walsh, 2007). It is also noted that the time waiting for dental treatment is considered by many as anxiety provoking, as patients have the time to thinking about the worst

possible outcome that can happen to them (Cohen *et al.*, 2000).

Dental anxiety has been studied extensively worldwide, with a prevalence from 10 to 65% in different countries (Nicolas *et al.*, 2007; Viinikangas *et al.*, 2007; Hill *et al.*, 2013; Bell *et al.*, 2012; Kirova *et al.*, 2010). Systematic review by Silveira *et al*. (2021) on adults found that the prevalence of dental fear and anxiety was 15.3%, with 3.3% having severe dental fear and anxiety. The prevalence of dental anxiety among Malaysians has been reported to be around the same level. Study by Gunjal *et al.* (2017) among Malaysian students found that 16% of them had high level of dental anxiety, while another study among dental patients reported that 9.9% of them had high level of anxiety (Kueh, 2013). This study aims to assess the dental anxiety level among the community in Wisma Lincoln University College.

Materials and Methods

Study design

A cross-sectional study was carried out at Wisma Lincoln University College, involving staff, students, and visitors, from April to December 2018. A sample size of 186 was determined based on the prevalence of dental anxiety of 12.2-15.3% from the systematic review by Silveira *et al.* (2021) and Cianette *et al.* (2017) on adolescents and adults. Convenience sampling technique was used to select the participants for this study. An informed consent was obtained from all the participants prior to answering the questionnaire. Ethical approval was obtained from the Dental Research Ethics Committee, Lincoln University College (LUCethics/FDent/009/2018).

Research tool

The questionnaire used was the Modified Dental Anxiety Scale (MDAS) (Humphris *et al*., 2000), which has been validated and pre-tested extensively worldwide (Sitheeque *et al.*, 2015; Humphris *et al.*, 1995; Humphris *et al*., 2009). It has also been translated into the Malay version and tested among the local population (Sitheeque *et al.*, 2015). In this study, both the English and Malay language were included in the MDAS questionnaire. The first part of the questionnaire consisted of 5 questions, assessing patients' anxiety level in relation to "thinking of seeing a dentist, sitting in the waiting room, having a tooth drilled, having teeth scaled and polished, and having a local anesthetic injection". Each question had five responses, using a 5-point Likert scales, ranging from not anxious, slightly anxious, fairly anxious, very anxious to extremely anxious, scored from 1 to 5 respectively. The patients would be categorized into low anxiety (5-11), moderately anxious (12-18) and severely anxious ($\geq$ 19), based on their scores. The second part of the questionnaire included 10 possible aspects of dental treatment that would make participants anxious, and they could choose more than one answer.

Data collection and analysis

A total of 186 questionnaires were distributed randomly to the staff, students, and visitors at Wisma Lincoln University College. Explanations were given to the participants regarding the objectives of the study. All queries from the participants were clarified before they filled in the questionnaires. The questionnaires were collected back upon completion and the data were analysed by applying descriptive and inferential statistical analysis, using SPSS version 24. T-test was used to compare the mean score of each question in the MDAS between male and female.

Results

One hundred and eighty-six participants took part in this study. The demographic data of the participants is shown in Table 1. Most of the respondents were female (55.9%, n=104), Malay (53.2%, n=99) and 16 to 25 years old (59.2%, n=110). Table 2 presents the MDAS score categories of the

participants. 16.7% (n=31) of the participants had severe anxiety level (MDAS score ≥19). Table 3 shows the number of participants who obtained MDAS score of 19 and above based on race and gender. Indian female had the highest percentage (20%, n=6) of high anxiety level, compared to other groups.

When looking at the individual aspect of the MDAS, the participants felt most anxious if they were to receive a local anesthetic injection, with a mean score of 2.04 for male and 3.76 for female ($p<0.001$), as shown in Table 4.

Table 5 shows 10 aspects of dental treatment that would make the participants anxious, and participants could choose more than one answer. The result showed that 74.7% (n=139) of the participants would feel anxious about tooth extraction, followed by pain arising from treatment (63.4%, n=118) and fear of injury caused by dental instrument (60.8%, n=113).

Table 1. Demographic data of the participants

Variables	Number (n)	Percentage (%)
Gender		
Male	82	44.1
Female	104	55.9
Age		
16-25	110	59.2
26-35	32	17.2
36-45	10	5.4
46-55	17	9.1
56-65	9	4.8
More than 65	8	4.3
Race		
Malay	99	53.2
Chinese	57	30.6
Indian	30	16.1
Total	**186**	**100**

Table 2. MDAS score categories of the participants

		Anxiety Level	Number (n)	Percentage (%)
MDAS score	5-11	Low	112	60.2
	12-18	Moderate	43	23.1
	≥19	High	31	16.7
Total			**186**	**100**

Table 3. Participants having MDAS score ≥ 19, based on race and gender

	Male		Female		Total	
Race	n	%	n	%	n	%
Malay	2	2	16	16.2	18	18.2
Chinese	3	5.3	4	7	7	12.3
Indian	0	0	6	20	6	20

Table 4. Mean score for individual aspect of the MDAS for all participants based on gender

Questionnaire Item	Male Mean (SD)	Female Mean (SD)	p-value (T-test)
Thinking of seeing a dentist	1.68 (0.925)	2.6 (1.232)	<0.001
Sitting in waiting room for treatment	1.83 (0.965)	2.68 (1.284)	<0.001
About to have a tooth drilled	1.94 (1.194)	3.47 (1.251)	<0.001
About to have your teeth scaled and polished	1.76 (1.058)	2.96 (1.473)	<0.001
About to have a local anesthetic injection	2.04 (1.195)	3.76 (1.356)	<0.001

Table 5. Aspects of dental treatment that make participants anxious

Aspects of dental treatment that make participants anxious	Number (n)	Percentage (%)
Pain arising from dental treatment	118	63.4
Putting dental instrument into the mouth	90	48.4
Gagging feeling	46	24.7
Tiring jaw after prolonged mouth opening	60	32.3
Worried having a lot of dental treatment	50	26.9
Worried for the cost of dental treatment	84	45.2
Insufficient information about dental procedures	72	38.7
Fear of injury caused from dental instruments	113	60.8
Dislike the feeling of numbness from anesthesia	72	38.7
Tooth extraction	139	74.7

Discussion

The present study was conducted to investigate the dental anxiety level among Wisma Lincoln University College community, using the MDAS questionnaire. In this study, 16.7% of the participants were considered to have high dental anxiety level, with Indian female being the most anxious (20%). However, according to Schuurs and Hoogstraten (1993) higher anxiety score among women did not necessarily mean that they were more anxious, but they expressed their anxiety level more readily than men. Similar results were observed in Adult Dental Survey 2009 in the United Kingdom (Hill *et al.*, 2013), with 12% of the population having extreme dental anxiety. Studies conducted in other European countries among French and Finnish adults revealed that the prevalence of adults with severe dental anxiety were slightly lower, with the prevalence of 7.3% and 8% respectively (Nicolas *et al.*, 2007; Viinikangas *et al.*, 2007).

When compared to local studies, contrasting results are seen. Study by Sitheeque *et al.* (2015) among dental patients at Hospital Universiti Sains Malaysia found that only 3.5% of them had high level of dental anxiety, while in a similar study among patients attending dental clinic Oya, Sibu, 9.9% of them reported to have high level of dental anxiety (Kueh, 2013). The difference in the results could be attributed by patients' oral health awareness and their frequency of exposure to clinical and dental settings. Nevertheless, in a more recent study among 1024 Malaysian students using the MDAS, the percentage of students with high level of dental anxiety was 16.3% (Gunjal *et al.*, 2017).

With respect to individual question in the MDAS for all participants, the highest mean score was seen to be associated with

intraoral anesthetic injection for both male and female (2.04 and 3.76). Such finding is consistent with the literature, as needle injection is often cited as the main cause of dental anxiety (Hakim and Razak, 2014; Siddiqui *et al*., 2016; Al-Omari & Al-Omiri, 2009; Yoshida *et al.*, 2009; Gunjal *et al.*, 2017). This is most likely because injection can inflict pain, and dental anxiety often arises due to anticipation of pain during the procedure. Nevertheless, newer technology such as Computer Assisted Relaxation Learning (CARL) (Heaton *et al.*, 2013), a self-paced, computerized program based on systematic desensitization has proven to be effective in helping patients to reduce their self-reported, injection specific dental anxiety.

Finally, when asked about the aspects of dental treatment that make participants anxious, 74.4% of the participants claimed that tooth extraction would make them anxious, followed by pain arising from dental treatment (63.4%) and fear of injury caused by dental instrument (60.8%). Thus, it is important to always assess patients' level of dental anxiety prior to dental treatment, explain each step of the procedure to them clearly and adopt a supportive, gentle, and sympathetic approach to help patients to relax and adapt to the clinical settings.

Dental anxiety has become a major barrier to assessing dental care and maintenance of good oral health by many people (Krishnan *et al*., 2020; Freeman, 1999; Milgrom *et al.*, 2010; Hill *et al*., 2013). Individual with dental anxiety often find themselves being trapped in a vicious cycle of avoiding dental visit, seeking care only when there is pain and eventually needing invasive dental treatment (Armfield *et al*., 2007; Armfield, 2013). These people also report to have very bad oral health (Armfield *et al*., 2009). Thus, identifying ways in which these people can be supported is vital, to increase their utilization of dental care. For example, setting up specialized dental clinic to manage patients with dental anxiety would help to alleviate their dental anxiety level and increase their uptake of dental care.

Several limitations were present in this study. The results from the cross-sectional study did not demonstrate a causal relationship. The sample size was small and only taken from Wisma Lincoln University College. Thus, it is not representative of the whole population. Also, self-reported questionnaire was prone to recall bias and social desirability bias, where participants tend to hide their feeling of dental anxiety.

Conclusions

Based on the study, 16.7% of the community in Wisma Lincoln University College were highly anxious, with Indian female being most anxious (20%). Most participants would feel anxious if they were to have a tooth extraction (74.7%, n=139), followed by pain arising from dental treatment (63.4%, n=118). Apart from psychotherapeutic and pharmacological interventions, elimination of dental anxiety can be achieved by dental education and promoting awareness about oral health.

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ORIGINAL ARTICLE Open Access

Restoration in primary molars placed by undergraduate dental students: reasons for failures

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Abstract

Dental caries is one of the most common chronic childhood diseases and highly prevalent in the world. The commonest treatment procedure for dental caries is a dental restoration which aims to retain the tooth. The survival of restoration depends on the factors associated with restorative materials, patients or operators. Thus, this study aimed to determine the reasons for the failure of restoration in posterior primary teeth performed by undergraduate dental students. A total number of 32 patients aged from 5 to 12 years old were included in this study. Overall, 115 primary molar restorations were assessed clinically using the modified United States Public Health Service Ryge criteria. The O'Leary plaque score was used to evaluate the oral hygiene status of all patients. Then, the data was analysed using the Kaplan-Meier survival curves with log-rank test and Cox regression analysis. 43 (37.4 %) restorations failed with 62.1 % for glass ionomer cement and 36.4 % for composite restorations. Marginal adaptation (62.8 %) is the commonest cause of failure. 76.7% of failure restoration was in patients with poor oral hygiene, and it showed a significant difference compared to patients with moderate and good oral hygiene (p = 0.014). Thus, it was concluded that the type of restorative material and oral hygiene status contributed to the failure of restoration placed in primary molar restorations with failure restoration may occur 2.6 times more in poor oral hygiene patients.

Keywords: *primary molar restorations, longevity, oral hygiene, failure rate*

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Introduction

Dental caries is one of the most common chronic childhood diseases affecting 621 million children and a highly prevalent disease worldwide (Kassebaum *et al.,* 2015). Caries in children requires careful intervention whereby, if untreated, premature extraction of primary teeth may occur and lead to malocclusion in permanent dentition due to space changes since primary teeth act as a space maintainer (Tunison *et al.,* 2008, Lin *et al*., 2011).

In order to retain the tooth, dental restorations are the most expected dental intervention performed by dentists. A long survival rate of restoration depends on the factors associated with restorative materials, patients or operators (Demarco *et al.*, 2012). Several restorative materials could be used to restore carious primary molar teeth, including amalgam, stainless steel crowns, composites, glass ionomer cements, resin modified glass ionomer cements and polyacid-modified composite resins. These materials appeared to have acceptable properties; however, many failures have been reported mainly due to secondary caries, fractured restoration and marginal gaps (Damarco *et al.,* 2012; Franzon *et al*., 2015). Type of material influence on the longevity of primary tooth restoration and composite restorations have shown favourable success rates in posterior teeth (Pinto Gdos *et al.,* 2014; Chisini *et al.,* 2018). Conversely, a study by Casagrande *et al.* (2013) found that longevity of restoration was not influenced by the type of restorative material and the technique used for caries removal (Casagrande *et al.,* 2013).

Microleakage is a clinically undetectable passage between tooth surfaces and the restorative or filling material, which allow bacteria, fluids, molecules or ions to infiltrate, and if left untreated, will lead to secondary caries formation and marginal gap of restoration and cause failures of restoration (Kemoli & Van Amerongen, 2011). In primary teeth, composite resins can be used for restorations of class III, IV and V, and I and II cavities; however, they are time-consuming and more technique-sensitive procedures. Glass ionomer cements which can be placed in only one increment are occasionally a better option favouring clinical management, especially in less cooperative children because they are less technique sensitive. Patient cooperation is required to achieve optimum isolation during composite resin placement for a higher success rate, although cooperation in children can sometimes be challenging (Fayle *et al.*, 2003).

Caries risk assessment is essential prior to restorative treatment. High-risk caries patients tend to lower the success rate of the restorations two times as compared to low-risk caries patients (Opdam *et al.,* 2010). Furthermore, the failure rate increases as the DMFT value increases (Melgar *et al*., 2017). Oral hygiene and plaque occurrence also contributed to the failure of restoration in which patients with a higher amount of visible plaque experienced more failure of restorations (Kemoli & Van Amerongen, 2011; Casagrande *et al*., 2013; Melgar *et al*., 2017).

Operator skills and experience are factors that may influence the longevity of the restorations. Inexperienced dental students are often unable to do proper restorations as compared to the experienced ones; however, a study of clinical performance of posterior resin composite restorations performed by undergraduate dental students showed that the survival rate is still acceptable, but less experienced students placed restorations with a shorter lifetime compared with more experienced students. The reasons for failure were secondary caries, restoration fractures, endodontic treatments, defective margins and lack of proximal contact (Opdam *et al*., 2004). Therefore, the knowledge and experience of the operator determine the longevity in terms of the techniques used. More experienced operators showed a higher survival rate of restorations than the less experienced (Da Rosa Rodolpho *et al*. 2011; Al-Samhan *et al.,* 2010).

Data on the failure of primary tooth dental restorations placed by undergraduate

students in dental schools are still scarce. The failure in dental restorations may be because the students are less experienced or other factors involved such as oral hygiene or type of restorative material used. Thus, this study aims to determine the reasons for failure restorations placed by undergraduate dental students with a different type of restorative materials in primary molar teeth and an association with oral hygiene.

Materials and Methods

Ethical approval was obtained from IIUM Research Ethics Committee (IREC) (Project number IREC 273), and the parents/guardian provided written informed consent for their children participation before data collection.

This retrospective study was conducted at the Student Polyclinic, Kulliyyah of Dentistry, International Islamic University Malaysia. The targeted population consisted of healthy children aged between 5 to 12 years old with dental restorations placed at their posterior primary teeth by fourth-year undergraduate dental students. The procedures performed are closely supervised by Paediatric Dentistry specialist lecturers. All restorations were placed under cotton rolls isolation and saliva aspirator. All information was obtained from the patient's dental records and were used in this study after consented by parents or guardians.

Cavities were prepared with a slow-speed dental handpiece, and dentinal caries was excavated using an excavator aiming for total caries removal whenever necessary. The area close to the pulp was covered with calcium hydroxide cement in a very deep cavity. Composite restorations were placed using the acid etch and rinse adhesive system. Glass ionomer cement restorations were restored following the manufacturer's recommendations. Restorations were finished and polished before the patient was discharged. Patients were given oral hygiene instructions by the students prior to the commencement of any dental treatment. Only consented participants were called for a review visit at the polyclinic during the data collection period. Patients should have at least one review visit after the placement of restorations to be included in this study. The prefabricated stainless steel crown (SSC), self-cure glass ionomer cement (GIC), dental amalgam (AR) and light-cure resin-based composite (CR) restorations for posterior tooth were evaluated during the visit after 6 to 36 months of restoration placement using the modified United States Public Health Service (USPHS) Ryge criteria (Table 1) (Sartori *et al.*, 2013).

The restorations were evaluated according to a four-grade scale for marginal adaptation, anatomical form, and signs of secondary caries criteria. The scale of 1 and 2 are considered acceptable; likewise, 3 and 4 are considered as a failure for marginal adaptation and anatomical form criteria. As for secondary caries, scale 1 is considered acceptable, while scale 2 is considered as failure. The restoration is considered a failure if it failed one or more criteria. The date of restoration placement and review visits were recorded, and the time between the placement of restoration and review visit, either a failed or accepted restoration, was counted in weeks.

The O'Leary plaque index was used to assess the oral hygiene status (Rafatjou *et al*., 2016). Patients were asked to chew a disclosing tablet during the review visit. The dental plaque on tooth surfaces was stained, and the plaque occurrence was recorded. The index score is calculated by dividing the number of plaque-containing surfaces by the total number of available surfaces and then multiplied by 100 (percentage). The percentage of the disclosed plaque was then calculated for each patient. The percentage below 25 % is indicated as good oral hygiene, 25 to 35 % as moderate and above 35 % is poor. The association between oral hygiene status and the failure of the restorations were then compared and analysed.

Table 1. The modified United States of Public Health Services Ryge criteria

Ryge criteria	Scale			
	1	2	3	4
Marginal adaptation	Restoration adapts closely to the tooth along margins	The clinically insignificant gap between restoration and cavity margins	Poor marginal adaptation with an obvious gap with or without caries. Restoration needs replacement.	Loss of restoration
Anatomical form	Good anatomic form with optimal approximal	Clinically acceptable shape with acceptable approximal contact	Insufficient approximal contact resulting in food impaction	No approximal contact
Secondary caries	Not observed (acceptable)	Present clinically and/or radiographically (not acceptable)		

Clinical examinations and evaluations were performed by three trained and calibrated examiners. The examiners were calibrated before data collection, showed satisfactory intra-examiner and inter-examiner reliability ($\kappa > 0.8$).

Data Analysis

SPSS version 24.0 was used in this analysis. The survival rate analysis was used to analyse the data collected with the life table, Kaplan Meier and Cox regression.

The Kaplan Meier procedure is used to estimate time-to-event variables in the presence of censored cases. The assumption was made that paediatric patients who begin treatments at different times should behave similarly. To analyse the survival time for the restorative materials, the time variable used was in weeks; the status variable used was the results, which meant the failure status of the materials over time.

Cox regression procedure is used for modelling the time to a specified event, based upon the values of given covariates. The covariates used was the oral hygiene status. The central statistical output is the hazard ratio. The status variable used was the type of restorative materials, time-variable used was weeks, and covariates or the categorical variable used was oral hygiene status.

Results

In total, 115 posterior primary teeth restorations in 32 children were evaluated. CR was the restorative material most frequently used (47.8 %), whereas 25.2 % of restorations were performed using GIC, 13.9 % using SSC and 13.6 % using AR. There were 43 (37.4%) restorations that were considered as failure, and GIC showed the highest percentage of failure (62.1 %), followed by CR (36.4 %), AR (20 %) and SSC (12.5 %). The number of failures according to the type of restoration is shown in Table 2.

Table 3 summarises the cause of failures in different types of restorations. All types of restorations showed that poor marginal

adaptability (62.8 %) is the commonest cause, followed by the presence of secondary caries (23.3 %) and poor anatomical form (13.9 %). Nevertheless, poor marginal adaptability causes failures the most in composite restorations (70 %) compared to glass ionomer cement and amalgam.

Table 4, 5 and 6 summarise the data for the relationship between oral hygiene status and clinical performance of overall restorations. There were significant differences noted as the *p*-value is 0.014, which means that oral hygiene status affects the clinical performance of restorations, with the restoration failure increasing with poor oral hygiene, as illustrated in Table 7.

Figure 1 shows the survival plot for restorations in weeks. Poor oral hygiene showed the steepest decrement when compared to good and moderate oral hygiene.

Table 2. Failure restoration according to the type of restorative materials

Materials	Total number of restorations N (%)	Failure n	Percentage of failure (%)
SSC	16 (13.9)	2	12.5
GIC	29 (25.2)	18	62.1
CR	55 (47.8)	20	36.4
AR	15 (13.6)	3	20
OVERALL	115	43	37.4

Table 3. Causes of restoration failure

Materials	Failure	Percentage of failure causes		
		Margin n (%)	Anatomic n (%)	Caries n (%)
SSC	2	2 (100.0)	0	0
GIC	18	11 (61.1)	2 (11.1)	5 (27.8)
CR	20	14 (70.0)	2 (10.0)	4 (20.0)
AR	3	0	2 (66.7)	1 (33.3)
OVERALL	43	27 (62.8)	6 (13.9)	10 (23.3)

Table 4. Failure or success of restorations according to oral hygiene status

Failure/success	Percentage N (%)	Good OH n (%)	Moderate OH n (%)	Poor OH n (%)
Failure	43 (37.4)	10 (23.3)	13	20 (76.7)
Success	72 (62.6)	14 (19.4)	33	25

Table 5. Categorical Variable Codings [b]

		Frequency	(1)	(2)
OH[a]	1=Poor	45	1	0
	2=Moderate	46	0	1
	3=Good	24	0	0

a. Indicator Parameter Coding, b. Category variable: OH

Table 6. Omnibus Tests of Model Coefficients [a, b]

-2 Log Likelihood	Overall (score)			Change from Previous Step			Change from Previous Block		
	Chi-square	*df*	Sig.	Chi-square	*df*	Sig.	Chi-square	*df*	Sig.
231.459	8.499	2	.014	7.791	2	.020	7.791	2	.020

a. Beginning Block Number 0, initial Log Likelihood function: -2 Log likelihood: 239.251

Table 7. Variables in the Equation

	B	SE	Wald	*df*	Sig.	Exp(B)
OH (poor)			8.005	2	.018	
OH (moderate)	.895	.411	4.745	1	.029	2.448
OH (good)	-.053	.459	.014	1	.907	.948

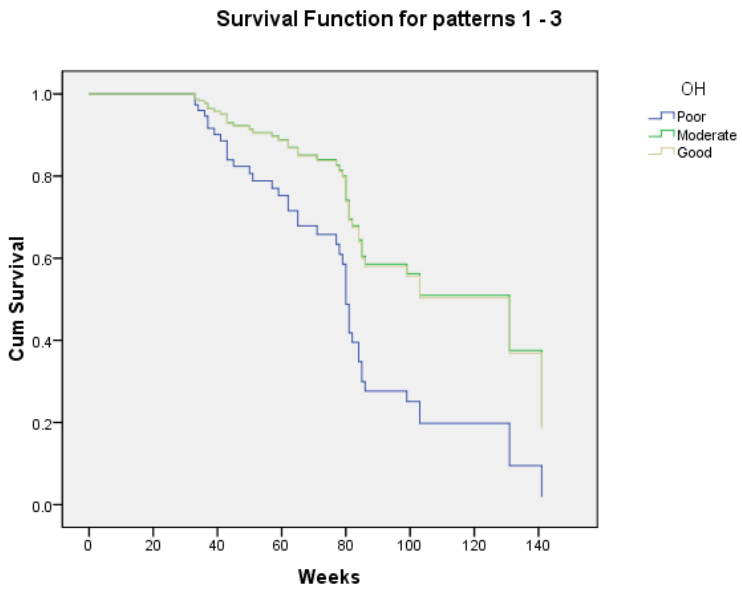

Figure 1. Survival Plot for Comparison of Oral Hygiene Status

Discussion

In this study, the failure percentage of restorations performed by undergraduate dental students was evaluated. The result showed that 37.4 % of restorations failed, and GIC showed the highest percentage of failure. The percentage of failure is considered high when compared to the reported global failure rate (12.5 %) without taking the follow-up times into consideration (Chisini *et al*., 2018). The high percentage of failure might be due to the student's lack of clinical experience. They only started treating patients in the clinical years, with all of them having only one to two years of clinical experience. Furthermore, they had a limited number of paediatric patients to perform dental restorations. Thus, dental schools must play an important role in providing adequate training to the student to develop their clinical skills throughout the course.

The longevity of restorations placed by more experienced operators is greater compared to less experienced operators (Opdam *et al.,* 2004; Ortiz-Ruiz *et al*., 2020). However, another study of undergraduate student's experience based on the years of clinical practice revealed that the operator's ability influenced the survival of restoration more than the operator's experience (McAndrew *et al*., 2011). Thus, proper training and full supervision are required to increase the student's capability in performing restorations as it will improve the reliability of the restorations (McAndrew *et al*., 2011).
The main reason for failures observed in this study for all types of restoration materials was poor marginal adaptability (62.8 %). Poor marginal adaptability causes the most failures in composite restorations (70 %) compared to other types of restorations. Good marginal adaptation is crucial for the success of restorations. If the restoration margins are not completely sealed, there will be accumulation of plaque and bacterial invasion between the restorative material and tooth surface, which will lead to secondary caries, and therefore the restoration needs to be replaced (Ferracane & Hilton, 2016). The cause of inadequate marginal adaption is closely related to polymerisation shrinkage of the material used, which is one of the disadvantages of direct composite restoration (Kaisarly & Gezawi, 2016; Han *et al*., 2017).

Isolation during the restoration procedure is necessary to reduce the amount of saliva at the treatment site and avoid contamination of microbes, which is an important factor for a successful restoration. Isolation with cotton rolls and aspiration by saliva ejector is a common practice in dental procedures to facilitate the bonding between restorative materials to the tooth surfaces for an optimum marginal adaptation. However, this technique requires frequent replacement of sodden cotton rolls. Rubber dam isolation had been introduced with numerous advantages and claimed to be optimum in preventing saliva contamination compared to cotton roll isolation; thus, the use may lower the failure rate of restorations (Heintze & Rousson, 2012; Keys & Carson, 2017). However, rubber dam placement in children can be a significant challenge because the patient needs to cooperate throughout the procedure.

Therefore, in cases where moisture control is required and in non-cooperative children, the isolation procedure can be jeopardised, and failure of restoration can be expected. In this study, all restoration procedures were performed under cotton roll isolation due to this reason. It could be one of the reasons for a higher percentage of failure and poor marginal adaptability. On the other hand, previous studies concluded that there was no solid evidence to suggest rubber dam usage will improve the survival rate of restorations compared to cotton roll isolation, and type of isolation had no influence on the success rate of restorations (Wang *et al*., 2016; Ortiz-Ruiz *et al.,* 2020).

The success of restoration is influenced by the patient risk factors, type of restorative materials, the severity of the tooth affected, and the experience and ability of the operator (van de Sande *et al*., 2013; Chisini *et al.*, 2018). Previous studies concluded that a higher risk of restoration failure is presented in patients with higher caries risk

(Opdam *et al.,* 2010; Damarco *et al.,* 2012; van de Sande *et al.,* 2013). In our study, patients with poor oral hygiene demonstrated the highest number of primary teeth restoration failures significantly, which can be concluded that oral hygiene is one factor contributing to the failure rate of primary molar restorations. This result corresponds with the previous report that poor oral hygiene status may have resulted in a lower survival rate of the restorations (Kemoli & Amerongen, 2011). It is crucial to lowering the caries risk status of patients by improving oral hygiene as caries risk play a significant role in restoration survival (Opdam *et al*., 2014).

In conclusion, our results show a high percentage of failure of restorations placed in primary molar teeth, with poor marginal adaptation as the commonest cause of the failure, and oral hygiene could also influence the failure percentage.

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ORIGINAL ARTICLE Open Access

Perceived stressors of undergraduate dental students at an Australasian dental school

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Abstract

The purpose of this study was to identify the perceived stressors of Bachelor of Dental Surgery (BDS) students at a prominent Australasian dental school using the Dental Environment Stress (DES) questionnaire. All BDS students were emailed a modified version of the DES questionnaire. The questionnaire consisted of forty questions: seven collecting demographic information, one free text question and thirty-two items related to various sources of stress, grouped into four subscales: 1) Academic 2) Clinical and patient related 3) Environmental and 4) Personal. Students were asked to rate the items on a five-point Likert-type scale ranging from not at all stressful (1) to extremely stressful (5). Of the 314 students emailed, 165 responded to the survey (52.5% response rate). The academic subscale had the highest self-reported mean stress score (3.09 ± 0.68 (SD); compared with the clinical (2.71 ± 0.77), environmental (2.40 ± 0.77) and personal (2.37 ± 0.68) subscales. There was a statistically significant difference ($p<0.05$) in self-perceived clinic related stress levels between male and female students, with female students reporting more stress. There was also a statistically significant difference in self-perceived environmental stress between second- and third-year students ($p=0.037$), and in perceived personal stress between students based on their English language status ($p=0.034$). These findings can enable identification of students who might be at higher risk of stress to ensure support is provided for them; specifically, female students and students in their third year. Results also indicate the need to develop interventions to help all students with academic stressors.

Keywords: *perceived stress, dental students, dental education, student experience, clinical education*

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Introduction

The term "stress" is now well embedded in our vocabulary, even though it only originated approximately sixty years ago (Al-Sowygh, 2013). The word has a variable meaning depending on the situation and the parties involved, however the most generic definition of stress is that it is "the nonspecific response of the body to any demand" (Fink, 2016). Dentists are reported to suffer higher amounts of stress compared with other health professionals, and the concerns of dental students mirror those of practicing dentists (Kumar *et al.,* 2009). For

example, there is a significant difference in reported stress levels between undergraduate dental students and their medical counterparts, with the dental cohort reporting greater stress levels (Al-Sowygh, 2013; Fonseca *et al.,* 2013). Research reports that dental students' levels of depression, anxiety and hostility are near the levels expected for psychiatric outpatients (Abu-Ghazaleh *et al.,* 2011; Morse & Dravo, 2007). This may be because dental education is known as one of the most difficult and stressful fields of study, (Muirhead & Locker, 2008; Polychronopoulou & Divaris, 2009) not least because dental students are required to gain and develop a myriad of clinical, academic and interpersonal skills (Polychronopoulou & Divaris, 2009). A systematic review found a correlation between medical students' perceptions of stress and their risk of future depression. Whether the stress experiences of dental students indicate their stress levels as a working dentists is not yet known, and this has been indicated as an area for future research (Pau *et al.,* 2007). Students' stress is a major concern for dental educators. Increased stress may lead to a decrease in students' performance (Kumar *et al.,* 2009) which may lead to attrition or failing. There is a significant expense involved in training healthcare professionals; therefore, attrition has a substantial financial impact as well as hindering the well-being of students (Birks *et al.,* 2009).

There are certain demographic trends that can be identified regarding dental students and their perceived stress. There is evidence of a correlation between higher levels of dental education (i.e. clinical training) and stress (Harikiran *et al.,* 2012). First choice of admission into dentistry (rather than as a fall-back option) has also been shown to have a relationship with stress levels in dental students (Pau *et al.,* 2007). Other demographic trends include correlations between students' perceived stress levels and their emotional intelligence, previous higher education and gender (Polychronopoulou & Divaris, 2009). It should be noted that gender is a controversial topic when it comes to dental education and stress, and this will be discussed in greater detail later in this paper.

Country of study is another factor that may impact on students' stress. A multi-country study of dental students' perceived sources of stress found that individual perceived stressors varied considerably amongst students from different dental schools. Greek and Spanish students appeared most stressed about their professional future, whereas Swedish and Irish students were more stressed about clinical issues such as patients being late or not showing up for appointments (Polychronopoulou & Divaris, 2009). However, it should be taken into consideration that these results may be due to differences between dental schools rather than differences between country of study.

The purpose of the current study was to identify the perceived stressors of undergraduate dental students at an Australasian dental school and identify if any groups reported more stress than others. The results of this study may help researchers and dental educators within Australasia, and perhaps internationally, better analyse the factors surrounding stressors of dental students. This will help inform management strategies to reduce burnout and to bring out the best of the students' abilities in a healthy, stress-free learning environment.

Materials and Methods

The study surveyed all undergraduate Bachelor of Dental Surgery (BDS) students from the first year of their professional course to students in their final year at a prominent Australasian dental school. The BDS programme comprised a five-year curriculum commencing with a one-year general health-science programme (or equivalent) followed by four years of professional training in general dentistry. Hence, the students' second year of their degree (BDS2) is their first year of dental education; BDS3 is their second year of dental education and so on.

The survey was a modified version of the Dental Environment Stress (DES) questionnaire (Figure 1) originally developed by Garbee *et al* (Garbee *et al.,* 1980).

Question 1: What year group are you currently enrolled in?
a) BDS2 b) BDS3 c) BDS4 d) BDS5
Question 2: What is your gender?
a) Male b) Female
Question 3: Are you a domestic or an international student?
a) Domestic b) International
Question 4: What is your ethnicity?
a) European b) Asian c) Maori d) Pacific Islander e) Other: please state
Question 5: Are you a permanent resident of the country of study?
a) Yes b) No
Question 6: What is your age range?
a) 19 or under b) 20-23 c) 24-27 d) 28-31 e) 32 or over
Question 7: Is English your first language?
a) Yes b) No
For Question 8- 39 please indicate how stressful you are finding each item this year on a scale of 1-5 (note that if an item is not applicable to you, you will mark it "not at all stressful"):
1= not at all stressful 2= somewhat stressful 3= quite stressful 4= very stressful 5= extremely stressful

Figure 1. Modified version of Dental Environment Stress (DES) questionnaire

Academic:
Question 8: Amount of assigned classwork
Question 9: Difficulty of assigned classwork
Question 10: Competition for grades
Question 11: Examinations and grades
Question 12: Completing academic course requirements
Question 13: Fear of failing course or year
Question 14: Lack of time to complete assigned school-work
Question 15: Fear of being unable to catch up if behind
Clinical and patient related:
Question 16: Completing clinical course requirements
Question 17: Difficulty learning clinical procedures
Question 18: Difficulty in learning precision manual skills required in preclinical and laboratory work
Question 19: General clinical environment
Question 20: Responsibility for providing comprehensive patient care
Question 21: Patients' co-operation in their home-care
Question 22: Patients being late or not showing up for their appointments
Question 23: Working on patients' with dirty mouths
Environmental:
Question 24: Rules and regulations of the school
Question 25: Discrimination due to race, class status, ethnic group or gender
Question 26: Inconsistency of feedback from different teachers
Question 27: Receiving criticism from teachers

Figure 1. Modified version of Dental Environment Stress (DES) questionnaire (continued)

Personal:
Question 28: Lack of confidence to be a successful dental student
Question 29: Lack of confidence to be a successful dentist
Question 30: Insecurity concerning ability to gain a job after graduation
Question 31: Considering entering some other field of work
Question 32: Financial concerns
Question 33: Personal relationship problems
Question 34: Lack of time for relaxation
Question 35: Balancing dental school with leisure time
Question 36: Balancing family with dental school commitments
Question 37: Conflict with partner or family over career decision
Question 38: Problems in living/home environment
Question 39: Personal physical health (including mental health)
Question 40: Do you have any further comments on stress at dental school:

Figure 1. Modified version of Dental Environment Stress (DES) questionnaire (continued).

The DES questionnaire wording was edited slightly to reflect the programme at the institution, and students from another professional oral health course at the same dental school, alongside two non-dental personnel, were asked to fill out the questionnaire. This pilot was undertaken to test the appropriateness and clarity of the items in the survey, and pilot respondents were asked to provide feedback. Questions that the pilot respondents found confusing or had difficulty understanding were either modified or removed from the inventory.

Subsequent to obtaining ethical approval (reference number D15/233) all undergraduate BDS students at the dental school were sent an email inviting them to complete the survey, during the second semester of 2015. The email contained a link to the anonymous electronic survey, which was hosted on the Qualtrics platform. The final modified version of the DES questionnaire consisted of 40 questions: seven collecting demographic information, one free text question, and 32 items related to various sources of stress, grouped into four broad categories/subscales: 1) Academic (eight items) 2) Clinical and patient related (eight items) 3) Environmental (four items) and 4) Personal (twelve items). Students were asked to rate each item on a five-point Likert-type scale ranging from: 1) not at all stressful 2) somewhat stressful 3) quite stressful 4) very stressful and 5) extremely stressful. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Statistical analysis

Statistical analysis was undertaken using IBM SPSS (version 22.0). Cronbach's alpha scores were calculated to determine internal consistency. The mean values for each student for each of the subscales (academic, clinical and patient responsibility, environmental and personal) as well as the overall self-reported stress values for each student were calculated. Non-parametric tests were performed to determine if there was evidence that the scores differed between the demographic variables. Mann-Whitney-U tests were performed to identify

variation in binary variables such as gender, student with English as first language or student with a non-English speaking background (NESB), international or domestic student and permanent resident or non-permanent resident. Kruskal-Wallis tests were used to calculate variation in other demographic variables such as ethnicity, BDS year group and age. Where statistically significant differences were noted, the Dunn's test was performed to see which groups differed.

Results

Demographics

The demographic distribution of all participants (total 165 participants) is outlined in Table 1. The demographic characteristics of participants was similar to the characteristics of the student body and represented an equal spread of respondents across all years of the professional programme.

Table 1. Demographic distribution of participants

Demographic variable	n (%)
Gender	
Male	43 (26.1)
Female	116 (70.3)
DNS	6 (3.6)
Domestic/International	
Domestic	129 (78.2)
International	30 (18.3)
DNS	6 (3.6)
PR status	
PR	126 (76.4)
Non-PR	32 (19.4)
DNS	7 (4.2)
English language status	
EAFL	103 (62.4)
NESB	53 (32.1)
DNS	9 (5.5)
BDS year group	
BDS2	43(26.1)
BDS3	39(23.6)
BDS4	40(24.2)
BDS5	37 (22.4)
DNS	6 (3.6)
Age	
<19	14(8.5)
20-23	125(75.8)
24-27	14(8.5)
28-31	2(1.2)
>32	1(0.6)
DNS	9(5.5)
Ethnicity	
European	51(30.9)
Asian	90(54.5)
Maori	11(6.7)
Pacific Islander	2(1.2)
Other/DNS	11(6.7)

DNS: did not state; PR: permanent resident; EAFL: English as first language; NESB: non-English speaking background; BDS: Bachelor of Dental Surgery.

The Cronbach's alpha score for the total scale (i.e. all 32 items) was 0.91 whilst the Cronbach's alpha scores for the individual subscales were 0.79 (Academic), 0.73 (Clinical), 0.68 (Environmental) and 0.83 (Personal). This established construct validity for the total scale as well as the subscales. The only exception was the Environmental subscale as it was slightly below the desired level of 0.7.

Stressors

The highest self-reported stressors for all students were in the academic subscale, as shown in Table 2. The mean reported academic stress score for BDS2 was 3.14 ± 0.72 (SD) whilst the mean reported academic stress scores for BDS3, BDS4 and BDS5 were 3.01 ± 0.68, 3.14 ± 0.67 and 3.05 ± 0.64 respectively. The subscale with the highest reported stress scores for the students overall was also the academic subscale (3.09 ± 0.68), followed by the clinical (2.71 ± 0.70), the environmental (2.40 ± 0.77) and then the personal (2.37 ± 0.68) subscales.

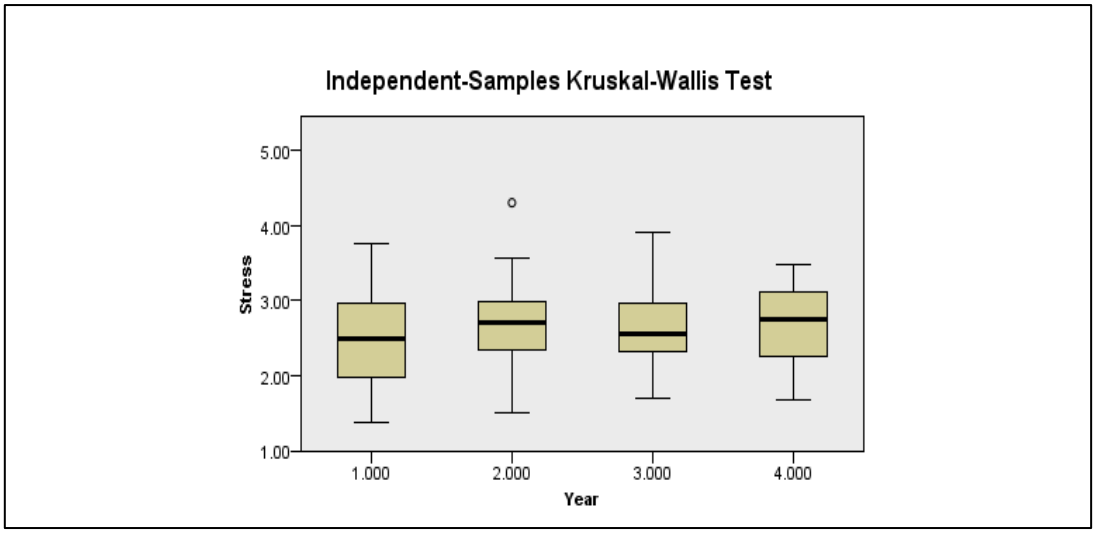
In the individual items, the highest reported stressor was "completing academic requirements" (in the academic subscale) scoring 3.54 ± 1.16; followed by "inconsistency of feedback from different teachers" (in the environmental subscale) scoring 3.46 ± 1.14 and "examinations and assessments" (also in the academic subscale) scoring 3.43 ± 0.89. The lowest scoring individual items included "conflict with partner or family over career decisions" and "discrimination due to race, class status, ethnic group or gender" scoring 1.53 ± 1.10 and 1.61 ± 0.93 respectively.

There was no significant difference (p= 0.386) in total perceived stress across the different year groups (Figure 2), the different age groups (p= 0.904) or across the different ethnicities (p= 0.769) as identified by Kruskal-Wallis tests. There was also no significant difference in total perceived stress between the two genders (p= 0.220), between permanent residents and non-permanent residents (p= 0.702), between domestic and international students (p= 0.603) or between students whose first language was English and students with a NESB (p= 0.171) as identified by Mann-Whitney-U tests. There was no significant difference in perceived stress for the above demographics in any of the subscales (academic, clinical and patient related, environmental and personal) except for: clinical stress between male and female students; environmental stress across the BDS year groups; and personal stress between students whose first language was English and students with a NESB.

The results indicate that there was a significant difference (p= 0.012) in perceived clinical stress between male and female students (Figure 3). Female students reported greater stress with a mean clinical stress score of 2.79 ± 0.73 whilst their male counterparts reported a mean clinical stress score of 2.48 ± 0.57.

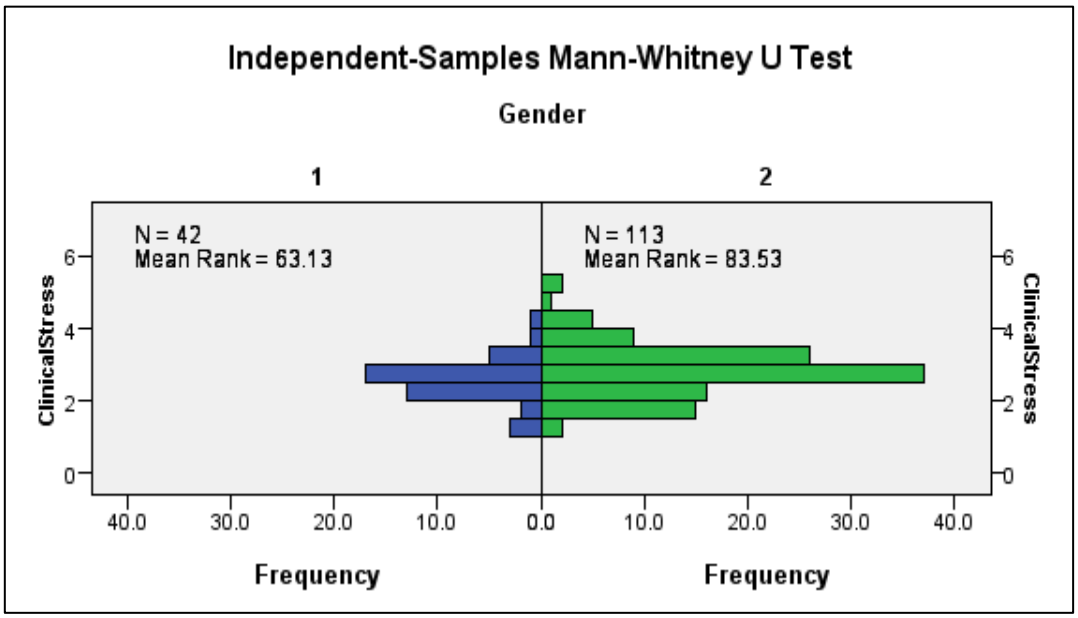
Table 2. Mean stress scores (SD) per subscale for all Bachelor of Dental Surgery (BDS) year groups

BDS year group	Mean (SD)			
	Academic	Clinical	Environmental	Personal
2	3.14 (0.72)	2.65 (0.93)	2.11 (0.68)	2.27 (0.69)
3	3.01 (0.68)	2.82 (0.73)	2.60 (0.85)	2.42 (0.69)
4	3.14 (0.67)	2.61 (0.54)	2.37 (0.72)	2.40 (0.65)
5	3.05 (0.64)	2.77 (0.51)	2.55 (0.75)	2.41 (0.73)
Total	3.09 (0.68)	2.71 (0.77)	2.40 (0.77)	2.37 (0.68)



Key: Year 1=BDS2 2=BDS3 3=BDS4 4=BDS5

Figure 2. Total stress scores for all Bachelor of Dental Surgery (BDS) year groups

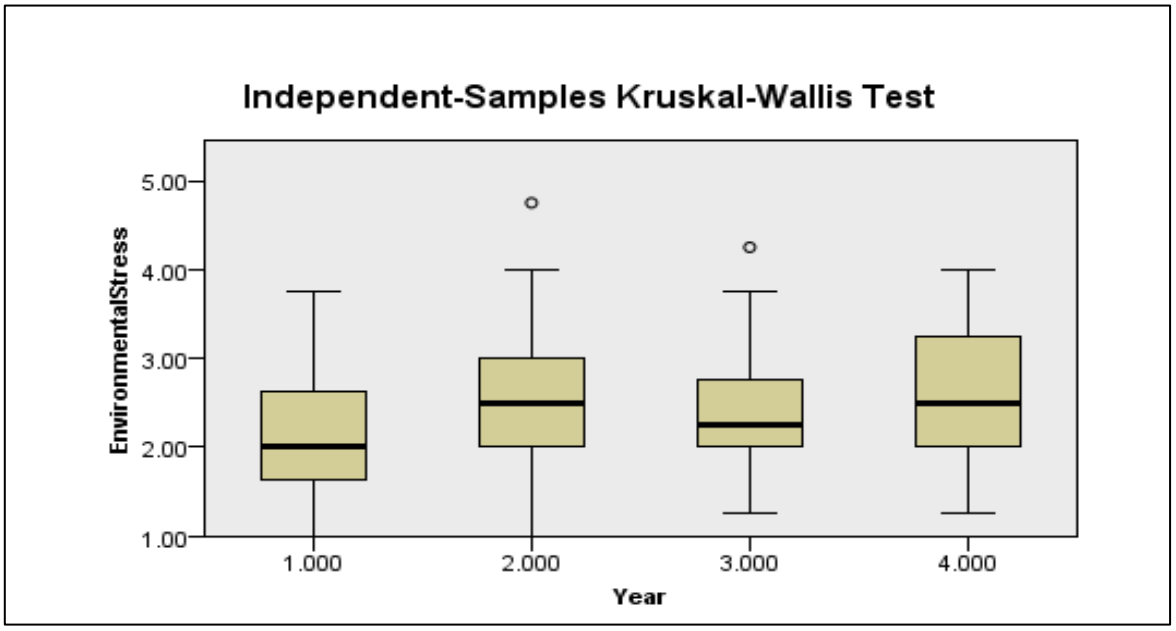


Key: 1= Male 2= Female

Figure 3. Clinical stress scores by gender

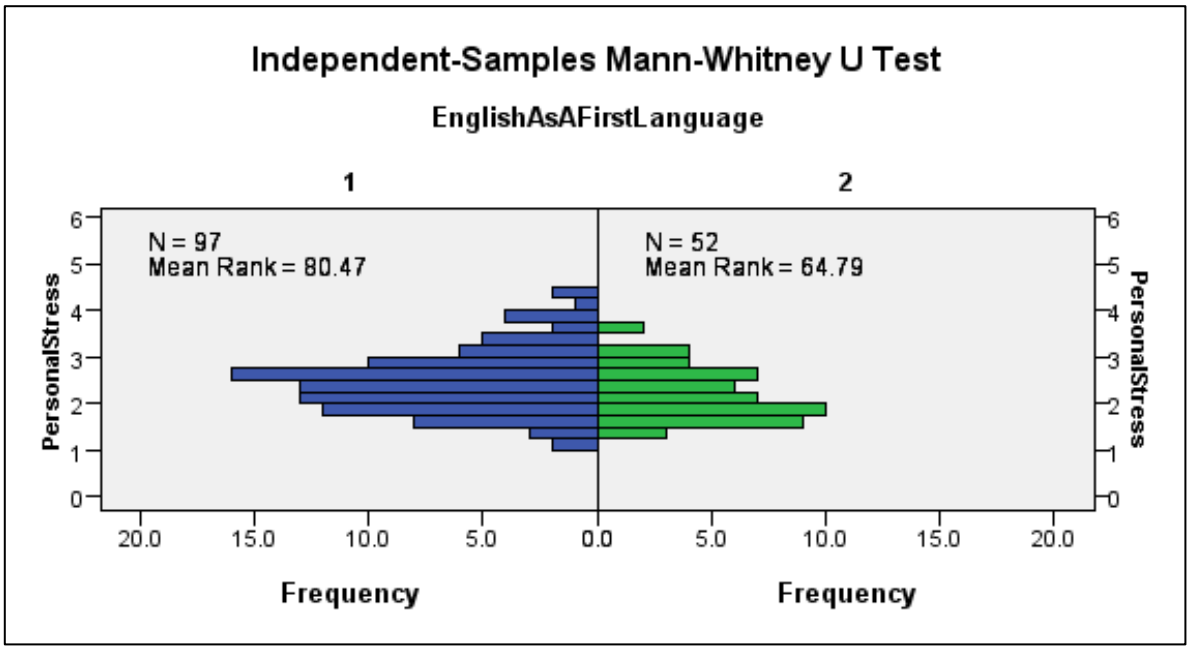
There was also a significant difference (p= 0.025) in perceived environmental stress between the different BDS year groups (Figure 4). BDS2 reported a mean environmental stress score of 2.11 ± 0.68 whilst BDS year groups 3, 4 and 5 reported mean environmental stress scores of 2.60 ± 0.85, 2.37 ± 0.72 and 2.55 ± 0.75 respectively. There was a statistically significant difference in perceived environmental stress between BDS2 and BDS3 (p= 0.037) but no statistically significant difference between any of the other year groups. There was also a large, although not statistically significant difference (p=0.073) in perceived environmental stress between BDS2 and BDS5 students.

Lastly, there was a significant difference (p= 0.034) in perceived personal stress between students whose first language was English and students with a NESB (Figure 5). Surprisingly perhaps, the students with a NESB reported lower personal stress with a mean score of 2.20 ± 0.59 compared with students whose first language was English who reported a mean score of 2.50 ± 0.71.



Key: 1=BDS2 2=BDS3 3=BDS4 4=BDS5

Figure 4. Environmental stress scores by Bachelor of Dental Surgery (BDS) year group



Key: 1= English as first language 2= non-English speaking background

Figure 5. Personal stress scores for students with English as a first language vs non-English speaking background

Discussion

In the past three decades stress amongst undergraduate dental students has been highlighted as a major concern for dental educators (Alzahem *et al.,* 2011). Student stress may hinder performance, as well as the well-being of parties involved, hence much research has been conducted to shed light on this complex issue (Birks *et al.,* 2009; Kumar *et al.,* 2009).

Numerous studies at various dental schools internationally have reported that students' highest stressors have related to academic factors including examinations and grades, and assigned workload (Abu-Ghazaleh *et al.,* 2011; Al-Sowygh, 2013; Fonseca *et al.,* 2013; Kumar *et al.,* 2009; Muirhead & Locker, 2008; Polychronopoulou & Divaris, 2009). Consistent with these findings the current study found that the subscale with the highest perceived stress score was the academic subscale. The items "completing academic requirements" and "examinations and assessments" in particular were marked as highly stressful by students. This is not surprising as assessments and academic requirements in higher education are necessarily stressful due to their high stakes nature, and dentistry is known to be a particularly challenging academic field (Fonseca *et al.,* 2013). Considering these findings, thought may need to be given regarding whether this is something that needs to be addressed.

Another item that the students marked as highly stressful was "Inconsistency of feedback from different teachers" (from the environmental subscale). This finding is also consistent with findings from a previous study which report "improper feedback from tutors" as a major stressor (Al-Sowygh, 2013). The dental education literature contains multiple references to the importance of feedback in dental education. Research at the institution at which this study was undertaken found that feedback practices in the clinical setting were central to students' learning and outcomes (Adam *et al.,* 2019; Ebbeling *et al.,* 2018). Similarly, a study by Pine and McGoldrick (Pine & McGoldrick, 2000) in the United Kingdom highlighted inconsistencies in teaching as an issue. The study found that teaching was adequate in most areas of the concerning dental school; however, there were inadequacies in clinical application of a theoretical basis. A study in Greece (Kossioni *et al.,* 2012) also reported problems with the curriculum and teaching practices, however, the authors did highlight the multiple stressors that dental educators face on a daily basis. Considering these findings, students' stress levels may be reduced if consistency of feedback in the clinical learning environment is ensured.

Differences according to gender in self-reported clinical and patient related stress levels were evident in the data analysis. The subject of gender differences in perceived stress in the dental learning environment is a controversial topic with studies reporting conflicting findings. Some studies note that females report greater levels of stress than male students (Abu-Ghazaleh *et al.,* 2011; Al-Sowygh, 2013). Some of these studies specifically indicate that females report higher levels of stress in relation to clinical factors or higher levels of stress are reported by females in clinical years of study (Pau & Croucher, 2003; Polychronopoulou & Divaris, 2005). Conversely, other studies indicate that there are no gender differences in perceived stress (Fonseca *et al.,* 2013; Kossioni *et al.,* 2012; Kumar *et al.,* 2009) and that participants' gender does not influence the likelihood of burnout (Mafla *et al.,* 2015). One explanation for these discrepancies may be that female students are more likely than male students to report their perceived stresses (Pau & Croucher, 2003).

Although students' clinic and patient related stress scores revealed statistically significant differences between male and female respondents, the current study did not find a statistically significant difference in overall reported stress between male and female students. These findings indicate that some female students may require greater support in the clinical setting than male students, however, it should be taken into account that male students may also benefit from increased support. One reason that this

may not be apparent in the data is possible under-reporting by the male cohort (Pau & Croucher, 2003).

Another notable finding in the current study was the significant difference in perceived environmental stress between BDS2 and BDS3 students. The second year of the dental education programme (BDS3) was when students were first introduced to the patient clinical environment. In BDS2, students' clinical experiences were limited to the simulation environment. It is, therefore, unsurprising that BDS3 students reported significantly more environmental stress than BDS2 students. This finding is consistent with previous studies that reported students found the transition from preclinical to clinical years stressful (Al-Sowygh, 2013; Pau & Croucher, 2003). Interestingly, in the current study there were no significant differences between BDS2 students' and BDS3 students' clinic and patient related stress, or their academic stress. This indicates that interventions designed to ease students' transition into the clinical environment could be beneficial towards reducing students' stress in relation to treating patients.

Lastly, the statistically significant difference ($p=0.034$) in perceived personal stress between students whose first language was English and students with a NESB was unexpected. Contrary to our expectations that NESB students would report higher stress, they reported less personal stress. One explanation for this may be that since these students were able to study a subject as challenging as dentistry in a language different to their native-tongue, they may have developed more resilience than their peers and were therefore better able to cope with other stresses (Wang, 2009). It should be noted however, that previous research has reported greater stress levels in students with "poor command of English" (Al-Sowygh, 2013).

As has been mentioned previously, the stresses placed on dental students have been noted in the literature for the last three decades (Fonseca *et al.,* 2013). However, ways in which dental students' stress could be reduced have not been fully explored. Furthermore, the amount of research into dental students' stress indicates a perception that stress among students is a bad thing. This perception does not take into account that stress is a broad term, there are many ways to define it and even more ways that it may be perceived (Elani *et al.,* 2014). The multi-factorial nature of stress makes its assessment difficult (Al-Sowygh, 2013), particularly with regard to determining if the stress is enabling or inhibiting performance. Hence, deciding how to proceed on the basis of students' stress is problematic.

Although too much stress can impede performance, it can also work as a driver towards success. Stress does have some positive outcomes, such as personal transformation and growth. A review by Folkman and Moskowitz (Folkman & Moskowitz, 2000) outlined three mechanisms that enable stress to bring out positive emotion: a) positive reappraisal (focusing on the good); b) problem focused coping (thoughts and behaviours to solve the source of distress); and c) creation of positive events (infusing ordinary events with a positive meaning). Keeping these ideas in mind, the issue with the dental learning environment may not necessarily be stress itself, but rather the coping mechanisms and resilience of the students involved.

Strategies suggested in the literature for the management of students' stress include increasing study groups and interactive education; changes to assessment practices (Polychronopoulou & Divaris, 2005); and establishing student advisors and councillors. Similarly, a faculty advising system has also been shown to have a positive impact on reducing students' stress (Fonseca *et al.,* 2013; Kumar *et al.,* 2009; Polychronopoulou & Divaris, 2005). The dental school where this study was undertaken has an established student support office; however, it is possible that students are not taking advantage of this. It was beyond the scope of this research to investigate what strategies students were undertaking to reduce their stress, or to find

out what the students thought the school could do to reduce their stress levels. Further research could be conducted to ascertain whether there is a link between students' reported stress levels and their use of such services.

Another concept that is popular in the literature is the relationship between emotional intelligence (EI) and perceived stress. EI may be defined in terms of four characteristics "perception, appraisal and expression of emotion; emotional facilitation of thinking; understanding, analysing and employing emotional language; and reflective regulation of emotions"(Pau & Croucher, 2003). Studies show that students with higher EI are less likely to report perceived stressors (Pau *et al.,* 2007; Pau & Croucher, 2003). There is also evidence for higher EI leading to professional competence in medical education (Pau *et al.,* 2007). These findings indicate that a possible strategy may be to introduce a more rigorous EI test for entry into the BDS professional course. A suggestion by Pau (Pau *et al.,* 2007) is to limit entry into the programme to students who already possess a higher education qualification. This was recommended on the basis that graduates are more likely to have a higher EI and would therefore be better able to cope with the stresses of dental education.

The cross-sectional nature of the current study means that the differences between years may have been pre-existing, therefore longitudinal changes cannot be determined. Secondly, bias may have been present as the questionnaire was self-administered. The response rate of 52.5%, although satisfactory, is not substantial and might be considered another limitation. However, the results of this study do add to our understanding of dental students' stress within Australasia, and possibly worldwide, and can help with designing more targeted interventions depending on the identified stressors.

Conclusion

The results of this study show that students entering their first clinical year of dental education (working on patients) report higher stressors than preclinical students or students in later stages of their programme. Students from all years of their programme reported high amounts of stress in relation to completing academic requirement. These finding indicate that interventions designed to help students manage their stress or resilience in relation to academic requirements might be beneficial, along with increased support for students entering their first year of clinical education. In addition, female students reported higher levels of stress in the clinical setting than male students reported. However, this study, consistent with other studies on stressors in dental education, did not examine whether the students' stress levels were productive or counter-productive. Determining whether the students' stress is enabling them or is acting as a barrier to their success will inform whether interventions to reduce students' stress would be beneficial.

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Conflict of interest

The authors have no financial interests or conflicts of interest to declare.

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CASE REPORT Open Access

Full mouth rehabilitation for severely worn dentition using fixed prostheses and tooth-supported partial overdenture: a case report

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Abstract

Rehabilitation of severely worn dentition represents a significant clinical challenge, especially when the restorative space is not sufficient. Creating restorations that fulfil the aesthetic, occlusal and functional parameters are essential to long-term success. This case report describes a 48-year-old male, who had severely worn dentition, which resulted in collapsed vertical dimension. The initial treatment involved careful planning, stabilization of existing dental diseases and construction of provisional prostheses at increased vertical dimension. Once the compatibility of the new vertical dimension had been confirmed, permanent reconstruction was performed. As with all full mouth prosthetic rehabilitation cases, equal-intensity centric occlusal contacts on all teeth and an anterior guidance in harmony with functional jaw movements were critically taken into account in each treatment phases.

Keywords: *full mouth rehabilitation, tooth wear, tooth-supported overdenture*

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Introduction

The progressive wear of teeth surfaces is a normal process during the lifetime of a normal adult. However, excessive wear can result in pulpal pathology, occlusal disharmony, impaired function and aesthetic disfigurement (Song *et al.*, 2010). The terms erosion, attrition, abrasion and abfraction have been used to describe different wear mechanisms but contrary to the beliefs, it is now accepted that the aetiology of pathological tooth wear is multifactorial, usually involving a variety of behavioural, medical and local factors (Djemal *et al.*, 1998, Darbar & Hemmings, 1997). Although one type of wear may predominate in a patient (Smith & Knight, 1984), in many clinical situations, combination of these conditions exist (Smith, 1989).

In many cases, the vertical dimension of occlusion (VDO) is maintained by tooth eruption and alveolar bone growth (*Song et al.*, 2010). As the progression of tooth wear is slow, the alveolar bone undergoes adaptation and compensates for the loss of tooth structure to maintain the VDO. It is recommended that VDO should not be changed in a patient without careful evaluation and approach (Jahangiri & Jang, 2002). Otherwise, there will be a severe overload on the restorations and increased risk of destruction of these restorations.

Management of severely worn dentition utilizing fixed or removable prostheses can be a daunting procedure in clinical endeavour. Loss of harmony of occlusal plane orientation and progressive reduction in anterior tooth length leads to an aesthetically compromised appearance. This condition is normally exacerbated by bruxism and sub-optimal general dental care. Eventually, a reduced VDO may develop, which complicates the future restorations.

Although full mouth reconstruction is the preferred treatment for most cases with generalised tooth wear it is not always needed. Where the coronal tissues are mildly worn or where only a few teeth need restorative intervention, a conformative occlusal approach can be used. This not only simplifies the procedures, but it also cuts down on the cost and duration of the treatment. When multiple restorations are needed, it is critical to consider whether a reorganised occlusal scheme can be used to manage the condition. In a severely worn down dentition, when there is no stable occlusal relationship, the need for reorganised approach becomes more apparent.

This case report describes the full mouth rehabilitation of a patient with severely worn down dentition by means of combination of fixed and removable prostheses.

Case report

A 48-year-old man was referred to Guy's Hospital, UK for management of his severely worn down dentition. He complained of not being able to chew his food completely and socially compromised due to his appearance. Multiple visits to different dentists could not solve his problem as the composite build-ups that were done eventually failed over the years. An initial evaluation indicated that the patient has no known medical problem and was not aware of any parafunctional habits. He was a chronic smoker for more than 15 years and had been actively smoking about 10 cigarettes per day. A weekly dietary evaluation revealed that the patient consumed acidic fruits, mainly apples and grapefruits, fruit juices and fizzy drinks, which he sipped throughout the day and took them between meal times. He also reported to consume about 10 units of wine weekly.

Extraorally the patient presented with reduced lower facial height associated with overclosure of his lips and prognatism of his mandible. On smiling, no obvious gingival tissue showing, however there was disharmony of occlusal plane orientation (Figure 1A-B).

His oral hygiene was fair and there was no periodontal problem. Clinical and radiographic examinations as well as diagnostic casts revealed generalized moderate to severe tooth wear (combination of attrition, erosion and abrasion). Most affected teeth had worn down to the gingival level with severely short clinical crown height, dentin exposure and visible pulpal outline (Figure 2A-C). Few teeth were sensitive to air blow and his tooth 13 was tender to palpation and percussion. Basic Erosive Wear Examination (BEWE) indicated score 3 for all the sextants.

Occlusal analysis showed Class III incisal relationship with cross bite of the tooth 13 was seen in intercuspal position (ICP). On lateral mandibular movement, the teeth 24 and 25 (contralateral group function) guided his right excursion, while tooth 17 guided his left excursion. Protrusive movement was guided by teeth 24 and 25.

Full mouth periapical radiographs were taken which revealed periapical radiolucencies on teeth 13, 36, 37 and 47. There were also presence of radiolucencies on tooth 37 (disto-occlusal) confirming the intraoral finding of carious lesion. The radiographs also showed generally short root morphology on most of his teeth (Figure 3). All teeth responded to electric pup test and cold test except teeth 13, 37 and 47, which indicates pulp necrosis.

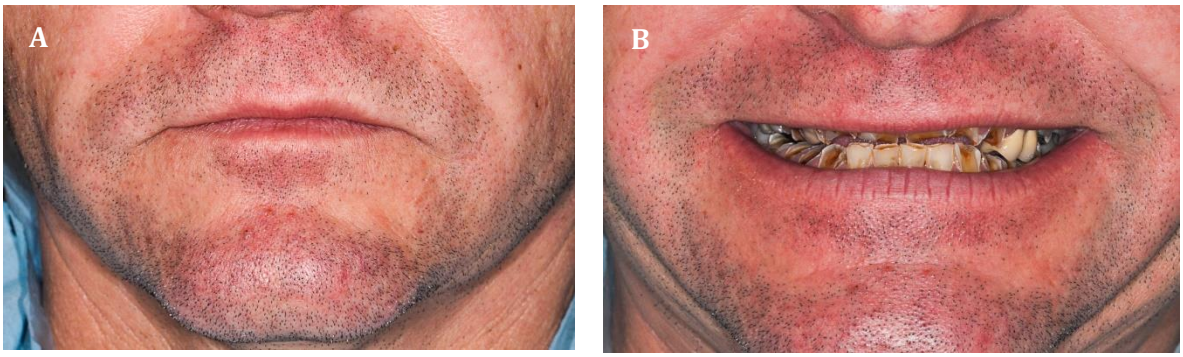

Figure 1. Frontal view. Overclosure of lips at rest (A) and on smiling (B), the occlusal disharmony was evident.

Figure 2A-C. Intraoral view. Severe tooth wear (combination of erosion, attrition and abrasion) could be seen. Dentoalveolar compensation has taken place leading to reduced interoclusal space for restorative works.

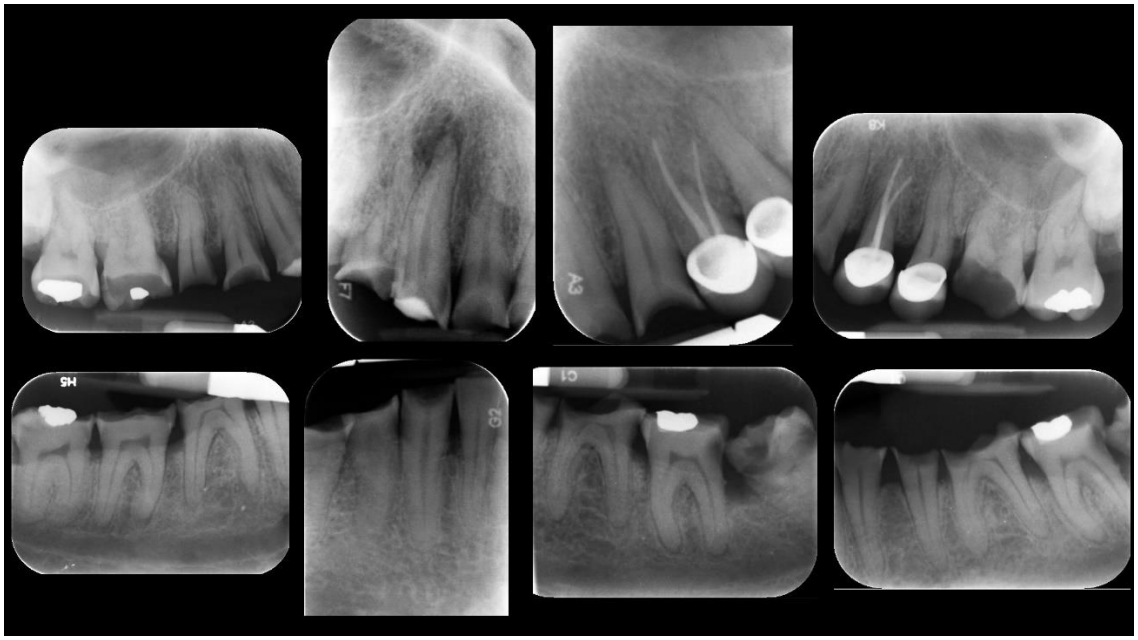

Figure 3. Full mouth periapical radiographs (pre-operative)

The prognosis for his upper anterior severely worn dentition was guarded due to their poor restorability. Most of the anterior teeth did not have adequate ferrule and their roots were short. The provision of crown lengthening and aesthetic anterior crown length for these teeth would result in unfavorable crown-to-root ratio.

The initial preventive treatment phase was first initiated and this includes oral hygiene maintenance and dietary changes as well as caries management. Endodontic treatments were carried out on teeth 13, 37 and 47. Elective endodontic treatment was also performed on 36 (Figure 4A-C).

Diagnostic wax-ups were made at an increased vertical dimension on articulated study casts using semi-adjustable articulator (Denar® Mark II, Whipmix) (Figure 5). Chairside intraoral mock-up was done with temporary bis-acrylic material (Protemp™ 4, 3M™) to assess the aesthetic and smile line of the planned final restoration (Figure 6).

Provisional upper partial tooth-supported overdenture was constructed to the desired VDO, covering teeth 15 to 25 where the abutment teeth were shaped into dome and restored with composite resin. Posteriorly, provisional resin crowns were placed on all his remaining upper molars (Figure 7A-B). The patient was reviewed every 2 weeks for the total duration of 3 months until the temporary prosthesis and composite restorations were deemed stable.

Figure 4. Post endodontic treatments on teeth 13 (A), 36, 37 (B), 47 (C)

Figure 5. Articulated diagnostic wax up

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Figure 6. Intraoral mock-up with bis-acrylic temporary crown material

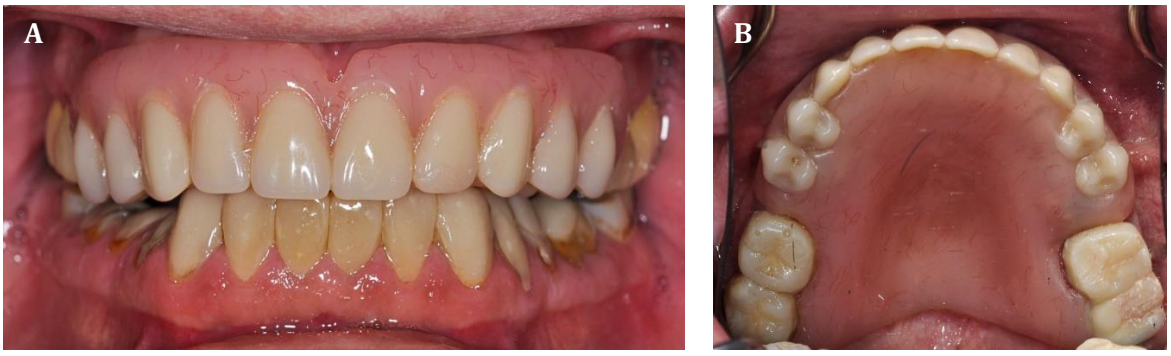

Figure 7. Provisional upper acrylic partial tooth-supported overdenture (A) and provisional crowns on upper molars (B)

After his oral condition stabilizes, master impression of the prepared molars was done for construction of milled porcelain-fused-metal (PFM) crowns. For bite registration, pattern resins crowns were used and chairside occlusal resin beading was performed to maintain the same vertical dimension, as the temporary crowns were removed one at a time (Figure 8A). Anteriorly, upper wax rim was used to stabilize the vertical dimension and reconfirm the labial support (Figure 8B).

Definitive metal ceramic crowns with milled palatal ledges were cemented with resin cement and maxillary cobalt chrome

overdenture was issued (Figure 9A-B). On the mandibular arch, composite resin build-ups were done on the four incisors, while the canines and premolars were fitted with composite crowns. Full gold crowns were issued to the molars (Figure 9C, 10A-C, 11A-C). The patient was reviewed after 1 week, followed by 3 months and 6 monthly intervals to ensure that oral hygiene is up to optimal condition.

Figure 8. Utilizing resin copings to stabilise the existing vertical dimension during jaw registration stage (A). Upper wax rim to stabilize the vertical dimension and labial support (B).

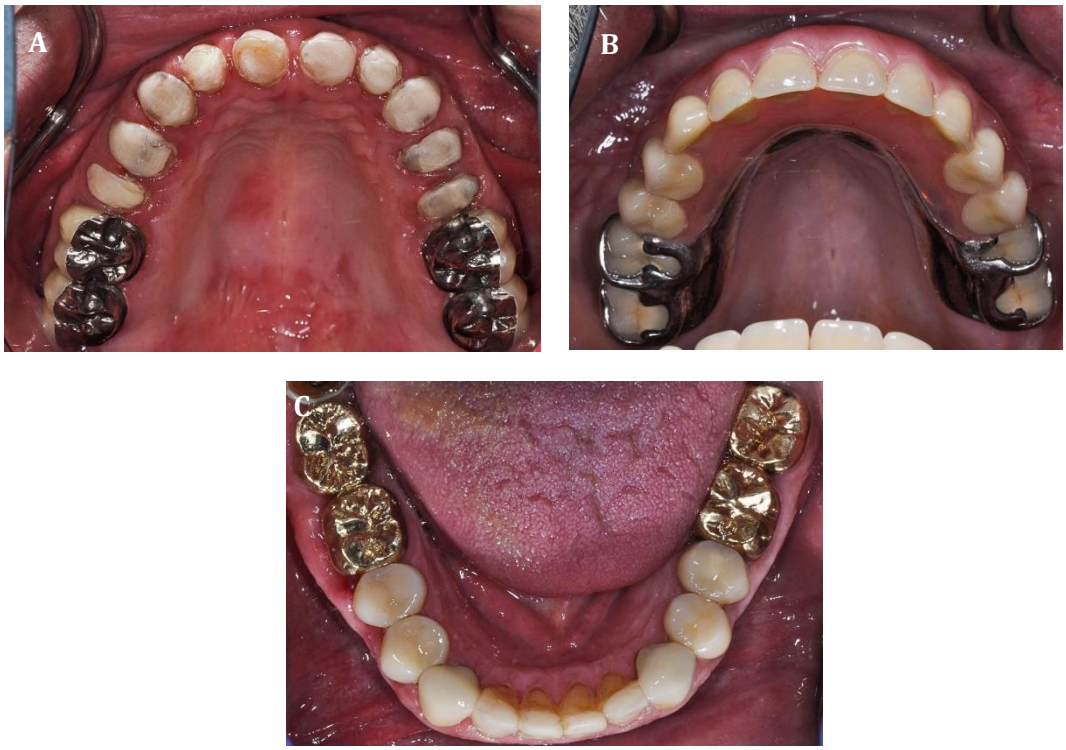

Figure 9. Maxillary molars fitted with PFM crowns with milled rest seats and palatal guideplanes (A), supporting a cobalt-chrome partial denture (B). Posterior fixed prostheses on the lower arch with composite resin build up on the anterior teeth (C).

Figure 10. Frontal view (A), right buccal view (B) and left buccal view (C) of the final treatment

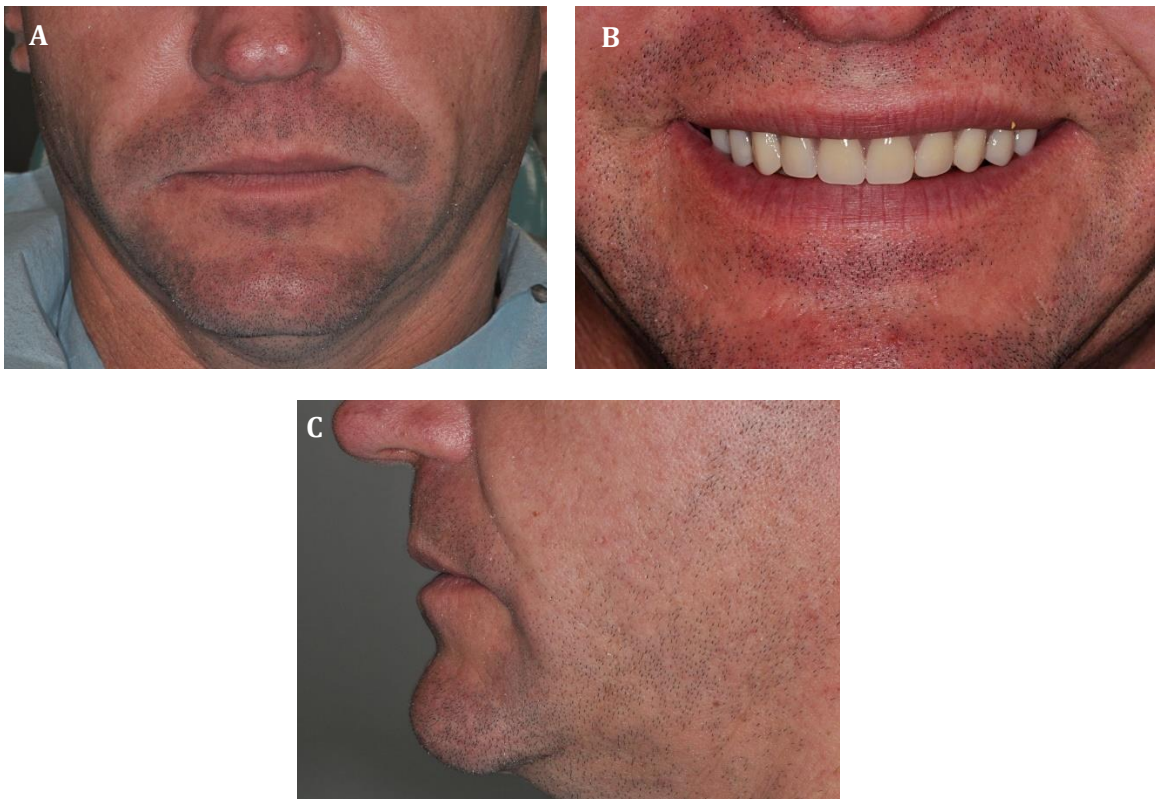

Figure 11. Post treatment frontal view at rest (A) and smiling (B), as well as the side profile view (C)

Discussion

The management of severely worn down dentition has been classified by Turner and Missirlian according to the amount of VDO loss and the available restorative space (Turner & Missirlian, 1984). His classification with the combination of the conventional treatment of raising VDO with crown lengthening procedure followed by prosthodontic intervention have been widely advocated up until today. However due to the lack of evidence in the long term clinical outcomes of this technique and the vast choice of materials have cause difficulty in clinical decision making (Johansson *et al.*, 2008). Because of these unclear guidelines, adhesive restoration which is more conservative and reversible in nature, is increasingly utilized (Darbar & Hemmings, 1997; Hemmings *et al.*, 2000; Jahangiri and Jang, 2002; Song *et al.*, 2010). Nonetheless, composite restoration was not indicated for this particular patient due to the lack of remaining tooth structures for its retention.

Increasing the occlusal vertical dimension was essential to achieve good outcome. Establishing the anterior guidance first would allow a good occlusal stability and will also affect the morphology of the posterior restoration. There has been various reports on the recommended provisionalization stage for crowns but generally 2 – 6 months are required before final restoration (Turner & Missirlian, 1984; Hemmings *et al.*, 2000; Sato, Hotta & Pedrazzi, 2000; Jahangiri & Jang, 2002) In this case, the patient was regularly monitored for 3 months to evaluate the adaptation to the provisional crowns and provisional acrylic partial overdenture. The increase of VDO was determined not by the standardized aesthetic golden proportion of anterior teeth but rather by the patient's physiologic factor such as interocclusal space, facial bony contour and speech. If the increased VDO was arbitrarily decided without close evaluation, multiple complications might arise and further management will be needed leading to a longer treatment duration. Depending on the patient's adaptability and compliance, the provisional stage can be modified accordingly and with careful evaluation and monitoring, shorter overall treatment duration may be warranted.

The use of natural teeth as overdenture abutments has become an accepted, realistic alternative to the extraction of remaining teeth since 1960s. The treatment is also affordable for many patients who requires extensive treatment for tooth wear albeit multiple dental maintenance visits are required to ensure a successful and long survival rate. Whilst several cross-sectional and longitudinal studies have shown that patients with overdenture abutments are at a higher risk of developing caries and periodontal disease, the success of overdenture therapy can be predicted with improved communication between the patient and the dentist with regard to the daily use of fluoride gel and regular recall appointments (Ettinger & Qian, 2004). In another study, the same researchers who performed follow up of up to 22 years on patients with tooth-supported overdenture had reported the rate of abutment tooth loss of 20%. They further clarified that many of these failures could have been prevented if patients had practiced a better oral hygiene. Therefore, it is suggested that if a dentist recommends overdenture therapy, the patient needs to be examined regularly to reduce the risk of experiencing caries and periodontal disease.

Traditionally, a full mouth rehabilitation based on complete crown coverage has been the recommended treatment for patients with severe tooth wear. However, with the improvement of adhesive technology, a more conservative approach such as direct or indirect composite resins may be proposed. A study conducted in a university setting has reported a 3-year survival rate of 91.6% for indirect composite resin crowns (Jongsma *et al.*, 2012). In addition, another prospective study also reported a 5-year survival rate of 86.6% for direct and indirect composite cuspal restorations (Fennis *et al.*, 2014). Several factors may affect the prognosis of a crown and may differ between composite resin crowns and metal ceramic crowns. Apart from technical and operator-

related factors, patient-related factors such as oral hygiene, dietary habits, parafunctional habits and the extent of tooth surface loss may all contribute to the survival of the crowns. In this case, due to the severe tooth surface loss of the mandibular premolars and the fact that the patient did not wish to undergo crown lengthening procedure, a less invasive treatment option of composite resin crowns was decided. In addition, the mandibular canines were also fitted with composite resin crowns to provide a canine-guided lateral excursive jaw movement. As for the remaining mandibular incisors, direct composite resins were built up to the intended mutually protected occlusal scheme. As the tooth surface loss was not severe on his mandibular incisors and the enamel layers were adequate, composite resins should provide a medium- to long-term success in this case.

Conclusions

This case report demonstrates the raising of vertical dimension of occlusion using the combination of fixed and removable prostheses which was performed after careful analysis and provisionalisation. This has shown to be successful outcome of full mouth rehabilitation in a severely worn dentition.

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CASE REPORT Open Access

Resin infiltration technique as minimal invasive approach for treatment of mild to moderate dental fluorosis in an adolescent: a case report

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Abstract

Dental fluorosis can be defined as a developmental condition that affects dental hard tissue, mainly enamel characterised with white or yellowish lesions due to excessive fluoride exposure. Fluorosis can have a major impact on the appearance, structure and shape of the tooth which posed a significant aesthetic concern to individuals having this condition. There are several treatments recommended in treating dental fluorosis depending on the severity of the disease itself ranging from tooth bleaching to prosthetic crowns in severe cases. This case report describes the use of resin infiltration technique on a patient with mild to moderate severity of dental fluorosis of the upper anterior teeth which produce an acceptable improvement of the appearance of the affected tooth. Resin infiltration technique in this case provided a conservative and inexpensive approach in treating mild to moderate dental fluorosis for the patient, improving the aesthetic without significant loss of tooth structure.

Keywords: *dental fluorosis, resin infiltration, aesthetic, minimally invasive technique*

Introduction

Dental fluorosis can be defined as a developmental condition of enamel caused by excessive absorption and repeated exposure to low doses of fluoride during all stages of tooth development (Pamela Denbesten & Li, 2011). This causes disruption in enamel development and results in hypomineralization of the enamel and giving the appearance of white or yellowish lesions on tooth surfaces (Aoba & Fejerskov, 2002). Fluoride disturbs enamel formation by reducing calcium ion concentration in the matrix which then interferes with protease activity, thus delaying or inhibiting enamel matrix protein degradation (Fejerskov *et al.*, 1990; Robinson *et al.*, 2004). The main sources of fluoride that are likely to cause dental fluorosis usually come from the caries prevention modalities such as accidental ingestion of fluoride-containing dental

products (e.g. toothpaste, varnishes, gels, fluoride supplement) and greater than 1 ppm of added or naturally occurring fluoride in drinking water (Watts & Addy, 2001). Dental fluorosis cases had been reported worldwide with Saudi Arabia reported a high overall prevalence of 46.52%, 11.3% reported from Germany and as low as 4% from India (Alshammary *et al.*, 2020). Dental fluorosis also can be seen quite regularly in Malaysia as a study show prevalence of slightly above the optimal levels of exposure at 57.8%, particularly for mild to moderate cases in fluoridated areas of Malaysia (Tan *et al.*, 2005). A recent study has shown a lower prevalence of fluorosis amongst children who lived in a place where water fluoridation has been stopped and were exposed partially to fluoride through toothpaste or foods (Karim *et al.*, 2021).

Clinically, dental fluorosis can be seen as diffuse, symmetrical, discoloured white opaque stains and striations in mild to moderate cases. However, in severe forms; porosity, pitting, and brownish areas associated with fragile enamel can often be seen on the surface of the tooth. Nevertheless, an accurate diagnosis of the disease should only be reached from proper anamnesis, as not to be confused with other types of tooth discolouration and staining that shows quite similar clinical presentation such as the hypomaturation type of Amelogenesis Imperfecta (Crawford & Aldred, 1992). The amount and duration of fluoride exposure in addition to the stages of enamel development during exposure play a role in determining the severity of the fluorosis which require different treatment measures (Bertassoni *et al.*, 2008). It also has been suggested that the direct effect of fluoride on ameloblast may have influences on the development of fluorosed enamel. It includes structural changes of early secretory ameloblasts, cell proliferation alteration, reduced protein synthesis, apoptosis, the elevation of F-actin and stress-related protein upregulation (Pamela Denbesten & Li, 2011). Fluoride also affects the cell-matrix interactions during tooth formation which also have a role in the development of fluorosis by hindering hydrolysis of amelogenin which causes a delay in final enamel matrix mineralization (Debensten *et al.,* 1985).

Based on Dean's Fluorosis Index (DFI), fluorosis can be categorized by scoring according to the clinical presentation of the lesion itself as in Table 1 (Pamela Denbesten & Li, 2011; Tirlet *et al.*, 2013). Several treatment options are available for the treatment of dental fluorosis depending on the severity and extent of the disease. For mild to moderate levels of fluorosis, dental bleaching, micro abrasion or a combination of both has been recommended and shown considerable success (Sherwood, 2010). Veneers also have been shown to result in successful outcomes in the management of moderate levels of fluorosis (Auschill *et al.*, 2015). A more invasive technique is needed in managing severe fluorosis with the prescription of prosthetic crowns, especially when there is a mottling appearance and loss of occlusal vertical dimension of the patient. This is due to the common findings of severely fluorosed enamel that easily fractured even during normal functional use (McKay, 1952).

A technique derived from the enamel infiltration procedure developed for incipient caries management has been applied in dental fluorosis treatment as well (Wang *et al.*, 2020). The resin infiltration technique which involves three-step of etching, drying and infiltrating resin into the porous enamel has shown promising outcomes in the management of mild to moderate levels of fluorosis. This procedure is more conservative in nature and conforms to the concept of minimally invasive dentistry. This technique masks the appearance of white lesions by its additional positive effect due to the similar refractive index of the resin and enamel itself (Giambro *et al.*, 1995). It has also demonstrated good clinical applicability amongst the clinicians and high acceptance by patients as reported by Kugel and colleague (Kugel *et al.*, 2009).

This case report will provide a step-by-step procedure of resin infiltration technique for a moderate level of fluorosis and the aesthetic outcome.

Table 1. Fluorosis index of H.T. Dean (1942)

Score	Criteria
Normal (0)	Normal teeth with a smooth, uniform natural coloured tooth surface
Questionable (0.5)	Teeth that have some white flecks or spots
Very mild (1)	No more than 25% of the tooth is covered with small white opaque areas
Mild (2)	Less than 50% of the tooth affected with white opaque areas
Moderate (3)	More than 50% of the tooth surface areas are affected and may be associated with brown staining
Severe (4)	Teeth that are severely mottled or pitted and often have brown staining which affects 100% of the enamel surface of the tooth

Case report

A 22-year-old male student was referred to the Department of Restorative Dentistry Specialist Clinic, International Islamic University of Malaysia (IIUM) seeking treatment to improve the aesthetic appearance of his upper front teeth. His main complaint is that his teeth exhibited white discolouration which he started to notice in high school along with the abnormal shape of the lateral incisors, and affecting his self-esteem whenever he smiles. Upon intra-oral examination and anamnesis, there was generalised fluorosis was observed, with mild to moderate severity with the score of 2 and 3 based on Dean's Fluorosis Index (DFI) on both upper and lower anterior teeth (Figure 1). It was also noted that upper and lower posterior teeth have severe fluorosis with a score of 4 from DFI. The upper front teeth also had mild spacing and peg-shaped of right and left lateral incisors (Figure 2). The patient demonstrated optimal oral hygiene level with satisfactory periodontal health and is systemically healthy. The initial treatment plan proposed and agreed to by the patient, which was to mask the mild to moderate fluorosis of upper anterior teeth with resin infiltration and followed by the placement of direct composite veneer on the peg-shaped lateral incisors. However, the patient decided to defer the composite veneer treatment due to financial constraints.

Figure 1. Intra-oral view of the patient when during the initial presentation to the clinic.

Figure 2. Mild to moderate fluorosis of upper anterior teeth span from tooth 13 to 23. Notice the peg-shaped of both the right and left lateral incisors (Tooth 12 and 22).

Prior to the commencement of the resin infiltration procedure, scaling and dental prophylaxis was carried to ensure the teeth are clean, free of plaque and calculus. Excess prophylaxis paste was then rinsed away using a water syringe. Rubber dam was placed using multiple isolations from the upper right first molar to the contralateral left molar. Floss ligatures were tied to the respective teeth to secure rubber dam inversion, therefore protecting the soft tissue and ensure a clean and dry working area (Figure 3).

Figure 3. The whitish spot of the fluorosis become accentuated due to lack of moisture from the rubber dam isolation

Following the manufacturer's instructions, resin infiltration procedure (Icon, DMG Chemisch-Pharmazeutische Fabrik GmbH, Hamburg, Germany) was initiated on the maxillary incisors (DFI = 2), canines (DFI = 2) and premolars (DFI = 3). Premolars were included in the procedure to assess the effectiveness of resin infiltration on a severe level of fluorosis lesion.

The labial enamel surface of the teeth was etched with 15% hydrochloric acid gel (ICON-Etch, DMG Chemisch-Pharmazeutische Fabrik GmbH, Hamburg, Germany) for 120 seconds (Figure 4). The etchant gel was then rinsed away for 30 seconds using water spray and gently dried. At this stage, frosty appearance will become more evident on the fluorosed area. The etching step was then repeated another two times before the application of drying agent (ICON-Dry, DMG Chemisch-Pharmazeutische Fabrik GmbH, Hamburg Germany) applied onto the tooth surface for 30 seconds to ensure desiccation of the enamel surface (Figure 5).

Figure 4. The application of etching gel on the tooth surface.


Figure 5. Tooth surfaces were completely dried using the drying agent, ICON-Infiltrant. Notice the premolars still show marked opacities even after the repeated etching cycle done on the teeth.

Before resin infiltrant was applied, the affected enamel surface was assessed, on whether the opacities decreased or disappeared, indicating the treatment effectiveness. For this patient, the authors decided to repeat the etching cycle on premolars to see the effect of the additional etching cycle showed an improvement of the severe opacities which however were still quite visible afterwards. The drying agent also serves as a preview of the aesthetic outcome that can be expected after the infiltration. Subsequently, resin infiltrant agent containing tetramethylene glycol dimethacrylate (TEGDMA) (ICON-Infiltrant, DMG Chemisch-Pharmazeutische Fabrik GmbH, Hamburg, Germany) was applied on the treated surface and allowed to penetrate for three minutes. This was deemed adequate in ensuring the maximal infiltration process (Figure 6). Excess resin infiltrant was removed using a cotton roll and dental floss for interproximal areas, followed by light-curing on each tooth for 40 seconds.

The rubber dam was then removed and the surface was polished using flexible diamond-impregnated spirals (EVE Diacomp Plus Twist, EVE Ernst Vetter GmbH; Pforzheim, Germany) to ensure a smooth and aesthetically acceptable glossy surface finish (Figures 7, 8, 9, and 10). The patient was satisfied with the final outcome of the treatment. There was a marked improvement in the appearance of the concerned tooth as white opacities managed to be masked following the treatment. The final shade of the teeth also in the authors' opinion will be much simpler to be followed in the subsequent direct composite veneer procedure as it eliminates the need to use white stain to mimic the fluorosis.

Figure 6. Immediate view after the application of resin infiltrant.

Figure 7. Clinical aspect after rubber dam removal and polishing was done.

Figure 8. A close-up view of the resin infiltrated maxillary incisors.

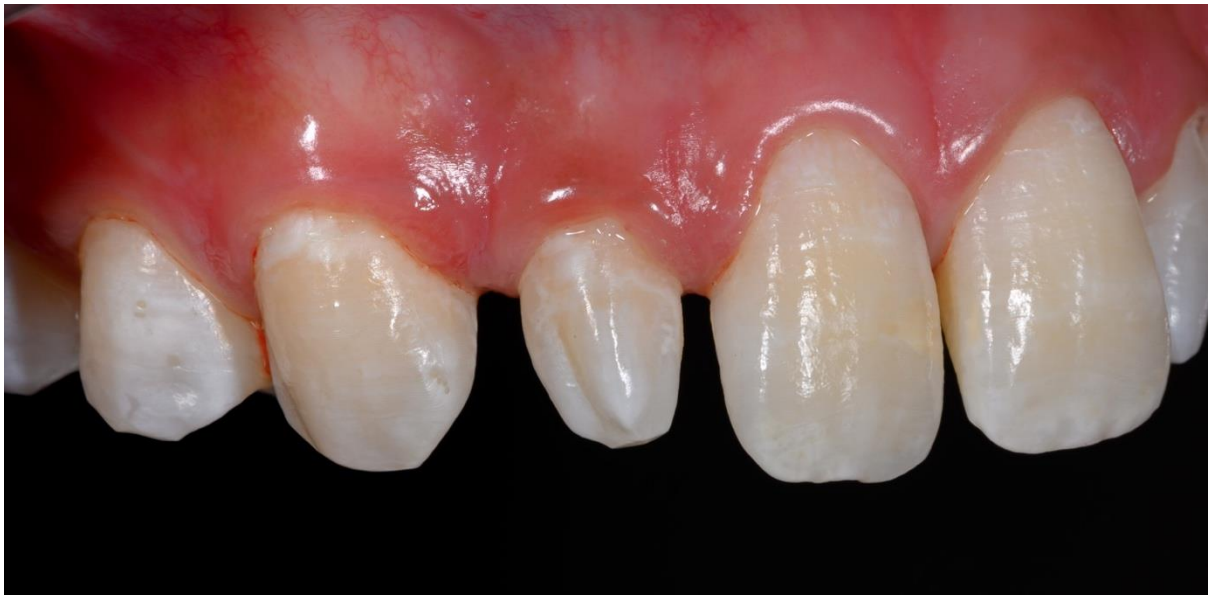

Figure 9. A close-up view of the right side, showing the resin-infiltrated teeth.

Figure 10. A close-up view of the left side, showing the resin infiltrated teeth.

Discussion

Tooth discolouration, especially dental fluorosis poses an aesthetic concern amongst many individuals especially in the anterior region where it is more visible to other people. It also can affect both self-confidence and people's perception of aesthetics, especially in younger individuals. This may have a profound impact on their psychosocial life in severe cases of dental fluorosis (Narayanan *et al.*, 2019; Duarte-Rodrigues *et al.*, 2020). It is also noted that nowadays patients are more inclined towards a non-invasive approach in having procedures done to their teeth (Frencken *et al.*, 2012). For the patient described in this case report, the resin infiltration technique was successful in giving aesthetic improvement of the appearance of the concerned teeth with a non-invasive approach.

For this patient, it was noted that the remaining part of the dentition, especially posterior to the teeth of concern was presented with severe fluorosis. The attempt to reduce the white discolouration and pitting of the posterior tooth was partially successful. As the whitish appearance is

somewhat reduced, the appearance is still considered suboptimal in aesthetic value. Therefore, in the authors' opinion, case selection is very important in determining the success of the resin infiltration technique. Patients with a severe level of fluorosis should be given the option of a combination approach, or more invasive restorative treatment such as cosmetic veneer. However, as the primary concern of the patient in this case only involved the appearance of his upper anterior teeth, such options were excluded. As the patient also required subsequent restorative treatment to close midline diastema and direct composite veneer on peg lateral incisors, application of an adhesive system during the direct resin composite procedure will provide higher bond strength as suggested by Wiegand and colleagues (Wiegand *et al.*, 2011). In the authors' opinion, shade matching will be much easier if the technique was done before the restorative procedure commencement as it will simplify the layering technique in the direct composite restoration.

Resin infiltration technique was also chosen because the patient is still young and any attempt to provide prosthetic treatment will result in unnecessary removal of tooth structure from relatively virgin teeth. Other treatments options were excluded in this patient as this approach is more cost-effective and can produce an immediate positive result in one appointment when compared with direct and indirect veneer. In addition, the procedure is pain-free as it eliminates the need to use local infiltration and as be seen in other restorative procedures (Auschill *et al*., 2015). Micro-abrasion is not suitable for this case as it has only been shown effective in treating milder cases of fluorosis and concern with the removal of tooth structure (Shenoi *et al.*, 2012.). There is a lack of consensus regarding the duration and the repetition cycles needed in the micro-abrasion technique to achieve the optimal result without exposing dentine (Watts & Addy, 2001).

Another non-invasive approach for this patient would be vital tooth bleaching which can either be home-bleaching or in-office professional bleaching treatment. One of the drawbacks of home bleaching is that it requires a long period of exposure to bleaching material (14 days) and would cause both fluorosed and non-fluorosed areas of teeth to be subjected to the bleaching agent. There is also a common complaint of post-treatment sensitivity from home bleaching which can affect patient compliance to the treatment itself (Bussadori *et al.*, 2004; Wright, 2002). In-office bleaching treatment also requires multiple visits to prevent the risk of tooth hypersensitivity which can prolong the treatment if the required shade is not achieved.

The infiltration technique itself is not new, being first described by Robinson and others back in 1976 in which they use resorcinol-formaldehyde as the infiltrant agent. However, due to concern regarding the toxicity of this material, it was barred from being used on the patient. A newer approach with a safer and higher penetration coefficient of the materials widen the usage of this technique in both caries control and masking dental discolouration (Paris *et al*., 2007; Meyer-Lueckel & Paris, 2008). The current infiltrant agent is a clear, unfilled composite resin with low viscosity, high surface tension and low contact angles relative to the enamel which allows the infiltrant to reach the honeycomb-like porosity in the pathological layer of enamel via capillary forces (Gugnani *et al.*, 2012). The porosities are usually filled with water and air which have a difference in the refractive index compared to the normal enamel. As the refractive index of resin-infiltrated enamel is close to that of normal enamel through the 'chameleon effect' properties of the resin, less light scattering occurs and give the infiltrated enamel the appearance that is relatively close to normal enamel.

Some concerns have been raised regarding the long term colour stability and susceptibility to staining of this technique based on *in-vitro* studies which need to be considered and included in treatment planning. Ulrich and colleagues found that

surface roughness of tooth treated with resin infiltration technique was higher than that of sound enamel in addition to demineralized enamel and this is supported by recent studies (Ulrich *et al.,* 2015*;* El-Meligy *et al.,* 2021). The micro-roughness of resin infiltrated surface can act as a medium for extrinsic staining agents and plaque to accumulate which over time will result in significant alterations in colour. The discolouration issue with resin infiltration also can be contributed by a high degree of water sorption of TEGDMA resin polymer in the infiltrating agent. The correlation between high water sorption and colour stability and discolouration issues are well documented in the past (Shintani *et al.*, 1985). Polishing the resin infiltrated surface has been suggested to improve the surface roughness in reducing the unwanted ageing process due to staining challenges (Borges *et al.,* 2014). However, Mueller and colleagues found that it is difficult to achieve a high degree of polishability as a lack of improvement was noted even after the infiltrated surface was subjected to polishing with Sof-Lex (3M ESPE) finishing and polishing system (Mueller *et al.*, 2011). The excess infiltrant agent also can be wiped off before polymerization to reduce the chance of decay from plaque accumulation at the residual resin layer (Paris *et al*., 2006). Wang and others also suggest that optimal maintenance of oral hygiene is imperative in ensuring a good aesthetic appearance after completing the resin infiltration treatment (Wang *et al.*, 2020).

Future studies may be needed to study the correlation of severity of the lesion and time of applications on colour stability of the resin-infiltrated tooth. This may aid in establishing accurate guidance on case selection and strict protocol to follow in ensuring the success of this treatment modality. The clinical outcome of the treatment showed acceptable results by patients regarding the aesthetic appearance of teeth in addition to duration and cost of treatment. However, in the authors' view, the result can be improved with a combination approach of other treatment modalities such as tooth bleaching and microabrasion.

Conclusions

This case report demonstrated that resin infiltration is a valuable option in treating mild to moderate severity of dental fluorosis, improving the appearance of the tooth by masking white spots in one appointment. It is also can be considered as a safe and minimally invasive approach in managing the unaesthetic appearance of teeth with dental fluorosis.

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