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Research Article

Environmentally Sustainable Dentistry: Assessment of Waste Produced in Undergraduate Removable Prosthodontic Clinics

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Abstract

Background: Over the recent decades, the society has become more socially and ethically more aware and accountable for climate change and global warming. Much of the current literature agrees that the healthcare system is not sustainable with the growing demand that causes environmental strain, and its underlying economics. With growing evidence that overall health is greatly influenced by the health of our planet, there is utmost importance to question our current practices in dentistry.

Aim: The aim of this study was to investigate the amount of waste produced in the removable prosthodontics clinics, its impact on the environment, and suggest sustainable alternatives.

Materials and Methods: Undergraduate prosthodontics clinics at the Faculty of Dentistry, University of Otago, Dunedin, New Zealand were audited retrospectively to assess the amount of waste produced during the semester 2 of 2019. A total of 496 appointments were included during 6th of July and 23rd of October. Predetermined codes were used to represent the clinical armamentarium required for each stage of treatment so that a total carbon footprint could be calculated.

Results: A carbon footprint emission of $0.02tCO_2e$ was estimated to be produced within the second semester of the 4th year removable prosthodontics clinic in 2019. The most commonly used items were paper towels for pre and post appointment wipe downs followed by gloves and masks. When categorised by weight and type of waste, the greatest proportions were from sterilising packaging which contained both plastic and paper components (19.8%), followed by rubber (18.2%) and plastics (17.5%).

Conclusion: It is recommended that the dental school should establish a method to audit its use of energy, water, waste generation, and its carbon footprint to provide baseline measures to improve upon, and endeavour towards sustainable dentistry.

Keywords: Dentistry; Waste; Green Dentistry; Prosthodontics; Environmental

Introduction

Environmental sustainability refers to the ability for human civilisation to coexist with the ecosystems, where the use of natural resources avoids depletion and the ecological balance is maintained [1]. Unfortunately, sustainability is compromised through advancements of human civilisation, as it continues to rapidly develop with little consciousness of its potential consequences and impact on the environment [2]. However, there has been an increase in the awareness of different aspects of sustainability such as climate change and global warming, particularly in developed nations becoming more environmentally aware and accountable for the irreversible changes [3]. Much of the current literature agrees that the healthcare system is not sustainable with its growing demand which further compounds on the environmental strain and ongoing expenditure of natural resources [4-10]. These concerns inevitably also apply in dentistry.

Sustainability in dentistry has recently gained more traction through influences by general public awareness, global agreements and legislations [11]. Globally, one of the first ever frameworks formed was the United Nations Framework Convention on Climate Change in 1992, soon after which, New Zealand signed the Kyoto protocol in 1997 showing commitments to decrease the emissions of greenhouse gasses. A carbon footprint is a commonly used method to quantify the amount of greenhouse gasses emitted and health systems, such as the National Health Service of England utilises the carbon footprint as a way to monitor their emissions [10]. Rational changes in the everyday practice must also be implemented, such as to improve the awareness and education among dental graduates to relieve the ongoing environmental pressures [7].

One of the earliest studies concerning dental waste management was a national survey of waste management protocols in dental practices within New Zealand [4]. The study primarily focused on gathering quantitative information regarding the disposal of waste in each dental clinic and evaluated the immediate risks to the individuals handling potentially infectious waste. They also brought attention to the potential environmental harms, stating the considerable increase in the generation of waste, particularly with disposable gloves which was attributed to the rise in strict cross infection control protocols.

There is a considerable amount of research concerning the use of mercury in dentistry. While amalgam has been proven to be a safe, durable, and an affordable dental material, studies have pointed out its environmental disadvantages resulting in potential health risk to humans [12]. The 2013 Minamata convention on Mercury which promotes phasing out the mercury use has been signed by several countries including New Zealand [13]. While this is in the right direction to improve and benefit the environment in all sectors, further sustainability measures are required in dentistry which encompasses and looks to improve all factors in waste management, treatment protocols, use of power and travel [14]. There are several studies [15-17] which explore environmental sustainability within private dental practices showing an increasing number of responsible practitioners and organisations taking voluntary steps to make their practices more sustainable [5]. However, there are no studies assessing the same effort in teaching institutions.

Enforcing sustainability in dentistry may seem initially challenging due to the risk of cross-infection and financial commitment required to recycle or purchase more environmentally friendly items [18]. Single-use items are advocated as the simple solution to abide by the infection control protocols. Nevertheless, there are items such as Steriking® pouches which comprise of paper and plastic which can be easily separated for recycling and without the proper recycling regimens, the majority of the materials used in everyday dentistry will end up in the compressor which is ultimately directed to the landfill.

Aim of the Study

The aim of this study was to retrospectively calculate the amount of waste produced in undergraduate removable prosthodontics clinics and assess its environmental impact and in return provide sustainable alternatives.

Materials and Methods

The undergraduate removable prosthodontics clinics at the Faculty of Dentistry, University of Otago, Dunedin, New Zealand was chosen to assess the amount of waste produced during one semester of an academic year (8th July 2019 to 23rd October 2019). The electronic patient booking system (Titanium) which included the details about treatment provided at each appointment was evaluated retrospectively and categorised using a pre-established coding.

Clinical armamentarium required at different stages of appointments were predetermined in consultation with a specialist prosthodontist (SM) who was responsible for the coordination of the undergraduate removable prosthodontics programme. It was assumed that any items set up for appointments would have been removed from the sterilisation pouches and if the patient failed to attend the appointment, the required items for the following patient would have remained in the clinical operatory. The number of paper towels, latex gloves, masks used per appointment were assumed to be ten, four (pairs) and four respectively based on the clinical experience in the teaching environment. Any patient appointment that did not have the treatment details were excluded from the data analysis.

The weight of each item was measured in order to estimate the carbon footprint using the Annual Carbon Emission (ACE) calculator created by the company Catalyst on behalf of Sustainable Business Network NZ. ACE utilises international standard measures of greenhouse gas emissions based on the types of materials. They have several subcategories to encompass a variety of ways in which greenhouse gasses can be produced, such as waste generation, transport and stationary energy use [19]. Since waste generated within the faculty all end up in municipal waste, the specific subcategory used from ACE was the 'mixed waste' calculation to estimate the carbon footprint.

Results

There were a total of 644 appointments with 90 undergraduate students over the 15-week period. After assessing the treatment details, 91 clinical sessions were excluded due to insufficient information regarding the treatment carried out as well as 57 no-show appointments. Therefore, 496 appointments involving 126 patients were included for the data analysis (Figure 1).

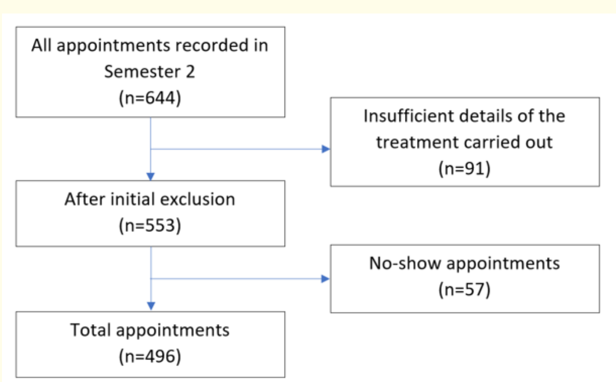

Figure 1: A flowchart of appointment details included for analysis.

The treatment details of each appointment were analysed and coded according to predetermined criteria (Table 1). Therefore, some appointments which had more than one treatment stage had multiple codes assigned to the appointments.

The total mass of waste produced within the undergraduate Year 4 removable prosthodontics clinics between 8th of July and 23rd of October was 77,058g. Therefore, the total carbon footprint emission was calculated to be 0.02tCO_2e [19].

The most commonly disposed individual item was paper towels which were used primarily for pre and post appointment wipe

Codes	Number of times the procedure occurred
1: Minimum set-up requirement for every appointment	496
2: Primary impression (RPD and Immediate)	17
3: Incomplete secondary impression	32
4: Tooth preparation (RPD)	21
5: Secondary impression (RPD)	27
6: Co-Cr framework try-in (RPD)	35
7: Occlusion rim try-in (RPD)	11
8: Set-up try-in (RPD)	25
8a: Set-up try-in (complete/ immediate)	80
9: Delivery of prosthesis	71
10: Composite resin restoration (RPD)	4
11: Primary impression (complete dentures)	3
12: Secondary impression (complete and immediate)	20
13: Occlusion rim try-in (complete and immediate)	64
14: Facebow transfer	57
16: Clinical remount	6
17: Review appointment	113
18: Chairside hard reline	8

Table 1: Predetermined codes to identify each clinical appointment and the total number of occasions per code.

Items	Number of items	Weight of each item (grams)	Total weight (grams)	Non-recyclable	Sustainable option
Paper towels	4960	1.5	7440	x	
Bibs	992	9	8928	x	
Plastic cup	496	4	1984	x	Non-recyclable (#6)
Pair of gloves	1984 pairs	7 (for a pair)	13,888	x	
Mask	1984	5	9920	x	
Gauze	496	0.9	446.4	x	
Suction tip *	496	3	1488		**
Plastic denture bowl	496	13	6448		Recyclable (#5)
Rubbish bag	496	3.5	1736	x	
Cellotape (measurement?)	496	21g (33m)		x	
Alginate (one scoop)	85 scoops	2 scoops: 62 3 scoops: 93	2: 868 3: 1767		
Impression trays (plastic)	28	Mx: 11 Mn: 9	Mx: 176 Mn: 108		
White wax	80 strips	2.5 per strip	200		
Plastic bag (take to lab)	67	7	469	x	
Disinfection tablet and dispensing plastic cup	535 occasions	1.2	642		
A set of straight handpiece and a tungsten carbide bur*	356	2.5	890		**
Exahiflex (tray-type)	32 occasions	27.5	880		
Scalpel handle*	142	3	426		**
Scalpel blade with packaging	142	0.9	127.8	x	
PVS putty type	21 occasions	41	861		
High Speed handpiece*	60	2.5	150		**
Slow speed handpiece*	60	2.5	150		**
Restorative kit*	21	19	399		**
Diamond burs*	60	1.3	78		**
Slow speed burs*	21	1.3	27.3		**
Portion cups	146	1.2	175.2		Recyclable (#5)
Rest seat burs*	21	1.3	27.3		**
Fluoride varnish and dispensing paper	21	0.5	10.5		
Exahiflex (regular body)	47 occasions	29.3	1377.1		
Exahiflex (light body), mixing tips and injector tip	27 occasions	PVS:8.8 Tip 0.1 Injector 4	PVS: 237.6 Tip: 2.7 Injector: 10.8		

Exabite	90 occasions	11	990		
PVS mixing tip	221	3.6	795.6		
Wax knife*	207	3	621		**
Cheek retractors *	27	4	108		**
Callipers*	35	3	105		**
PIP (paper+brush)	219	0.5+0.6	109.5 + 131.4		
Fit checker (Nozzle)	219	3.6	788.4		
Articulating paper	324	0.25	81		
Tinfoil sheet for portable burner	180	5	900		
Pink wax	180	12	2160		
Shimstock	176 5cm per piece	2g = a 5m roll = 100 usage	3.52g		
Willis gauge*	124	3	372		**
Restorative kit (black composite trays)	4	4	16		
Curing light tip (coverng)	4	2	8		
Metal impression trays*	3	3	9		**
Wax scraper*	64	8	512		**
Fox plane*	64	7	448		**
Dr Thompson's colour transfer applicator	64	0.3	19.2		
Facebow bite fork*	63	2	126		**
Plaster stone for mounting the facebow bite fork	57	110	6270		
Ufigel hard	8 occasions	Material: 7.8 Tips: 3.3	142.7 26.4		

Table 2: Number and weight of items used in the removable prosthodontics clinic with the indication of non-recyclable status and sustainable options available.

*: Sterilisable and is packaged.

**: Sterilisable packaging can be recycled.

downs. Gloves were the second most used item, followed by masks. If we take into account the cumulative amount of the wrapping of sterilisable items, that would equate to a total of 2200 which would make it the third most frequently disposed item.

There were seven types of waste produced in the undergraduate prosthodontics clinics (Figure 2). When measured by weight, the cumulative amount of sterilising packaging as well as the bibs (15,040.8g, 19.5%) which contains both plastic and paper components were the greatest followed by rubber (13,888g, 18.0%) and then plastics (13,576g, 17.6%). Waste made of metals was the least amount produced.

Discussion

Climate change is one of the greatest health threats in the 21st century [20]. Further scientific evidence associated with climate

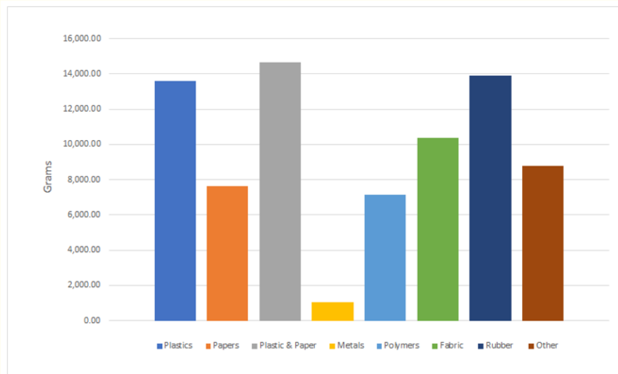

Figure 2: Weight of waste produced in the undergraduate prosthodontics clinics as categorised by the main type of composition.

change continues to be published supported by government agreements and legislations placed to promote sustainability and prevent further detriment towards our planet. The primary focus in dentistry is treating our patient's oral health but it can also be argued that there is an obligation within the holistic treatment approach to encompass other factors such as the environment that can affect our overall health. According to the WHO, they recognise the importance of the health sector to adopt new policies and develop the necessary skills to prevent the public from climate-related illness [20].

The carbon footprint is the quantity of greenhouse gases expressed in terms of carbon dioxide equivalents emitted into the atmosphere by an individual, organisation, process, product, or event from within a specified boundary [21]. It requires several assumptions to calculate an estimated carbon equivalent, which is a quantifiable measure that can be used for management in carbon emissions. By identifying the source of these emissions, it is then possible to implement and mitigate reduction strategies which coincide with the recent Climate Change Response (zero carbon) amendment act [10].

Quality improvement (QI) is one methodology, which is often incorporated in health care to measure and address deficits within patient care. Ultimately it is used to implement strategies to improve the area which is lacking [22]. The concept of QI can also be used for clinical teaching institutions such as dental schools to improve on its overall sustainability, primarily by introducing regular audits on waste, energy and water usage as well as the carbon footprint production. Currently, at the Faculty of Dentistry, University of Otago, there is no such clear guideline. A baseline measure should be recorded in which the institution can then formulate strategies to improve upon, with long term monitoring and reassessments. However, such resources are not readily available. Nevertheless, there are alternatives such as the Carbon Trust, who can provide services for large businesses to measure and monitor the organisation's carbon, water, energy usage, and waste [23].

As seen from the current study, plastics such as single-use cups, disposable impression trays, and rubbish bags made up a high proportion of waste produced in undergraduate prosthodontics clinics. Unfortunately, these plastics are made from non-renewable sources like fossil fuels and its production pathway from its raw material to the final product of plastic is energy intensive [24]. Therefore, items such as bioplastics which are biodegradable plastics composed of raw sustainable materials may be a better alternative [25]. Bioplastics have a shorter lifespan as they cannot fully emulate plastics [26] and this may be a deterrence in healthcare services. Nevertheless, due to the high turnover of such items used in clinics, longevity of the bioplastic materials may not be so problematic. Another challenge in switching to using bioplastics in teaching institutions such as dental schools may be the higher overhead costs [26]. Until manufacturers outline greater advantages for these products including its financial viability, the implementation of bioplastics may continue to be a slow uptake.

Disposable dental bibs with paper and plastic backing are used on every patient and these are unrecyclable. Converting to reusable cotton towels which can be cleaned through a simple wash, dry, and reuse system can greatly reduce the number of single use bibs. However, this alternative option must be considered with some caution as there is a potential for the cotton towels to harbour bacteria if they are not washed properly [27]. With the ongoing COVID-19 situation that has affected people globally, there is some anecdotal evidence that there is an increasing concern regarding cross-contamination and disease transmission between patients. Therefore, the sustainable alternatives must be implemented in consideration with the safety of our patients.

Removable prosthodontics clinics use a lot of dental materials which often end up in a landfill. Materials such as pink wax is a typical example in removable prosthodontics where the material is often eliminated during the fabrication of partial or complete dentures. Clinicians or technicians, however, are often unaware that approximately 80 to 90% of used wax can be recycled and re-used back into wax sheets by using a laboratory technique which removes its impurities. This highlights the importance of better dissemination of information within the profession so that they become more aware of recycling options in dentistry. The physical properties of the wax can be maintained even after processing it a number of times. It is also noteworthy that as the wax is produced mainly from natural resources, recycling it can reduce the amount of waste and reduce the necessity for further depletion in natural resources [28].

In the current study, there were 7,123.4g of polymers produced during the weeks of observation period. It is anticipated that as the auditing period was towards the later half of the academic year, most of the impressions would have already been completed and therefore there would have been a significant underestimation of the waste produced due to impression materials. While dental impression materials are easy and quick to use, they are ultimately disposed once they have been poured in physical casts. It is therefore valid to question their long-term feasibility especially in terms of sustainable dentistry. With the development of digital dentistry, adoption of using intraoral scanners or CAD/CAM systems [29] can reduce the unnecessary waste production of impression materials, stone casts and record blocks [30]. While there are a number of clinical advantages by digitally fabricating removable dentures, from a sustainability point of view, there is a potential for reducing the number of appointments which can also lower the mean carbon emissions produced by the patients during their travel to the clinic. However, there are several limitations of adopting digital dentistry such as much higher upfront equipment costs, difficulties of achieving predictable impressions when dealing with edentulous patients [29]. Therefore, in the meantime, any traditional dental impressions should be done using sterilisable metal trays rather than disposable plastic trays. Ongoing development and research in digital dentistry will also assist in these issues [31]. Physical lab prescription forms can also be eliminated by using an electronic system with each lab work logged in through a designated system. This would be a simple alternative to reduce the need of printing paper.

Items such as the "Steriking" pouches consist of paper and soft plastic. Currently there are no such products which are a sustainable alternative to the sterilisable pouches. Therefore, the next best option is to adopt recycling measures. Currently in New Zealand, there is a programme which recycles soft plastics domestically in certain regions of the North Island. This programme started recently in 2018 and there is a plan to expand depending on the demand as well as their capacity on processing the soft plastics [32].

There were 113 review appointments over the 15-week period included in the current study. One of the ways to reduce waste is to minimise any unnecessary appointments. Therefore, by carrying out systematic and well-planned appointments, this can result in fewer review appointments. Another approach in sustainable dentistry is to advocate preventative dentistry such as the use of fluoride varnish which could result in potentially fewer procedures required in the future [10]. In relation to the removable prosthodontic clinic, ensuring students provide proper oral hygiene and denture hygiene care to their patients may help result in fewer maintenance appointments in the long term. Improving student efficiency by maximizing each appointment and reducing clinic errors may also provide long term sustainable benefits.

Several studies have stated that limitation towards sustainable dentistry is due to the finances involved. However, there is a general agreement amongst recent papers that while adopting sustainability measures over current methods may seem expensive, the sustainable solutions may in fact prove cost savings in conjunction with benefits in health and for the environment [33]. Although these investments may take time to recognise the financial rewards, the primary outcome is knowing that you are enriching your life by taking part in supporting sustainable practice and minimising contributions to the depletion of natural resources that is occuring at an alarming rate [34]. There is also a need for ongoing education to increase the awareness of sustainability in dentistry. A recent questionnaire involving dental students at the University of Manchester showed that some students were unaware of waste segregation protocols and the amount of waste generated [7]. Therefore, sustainable education must be implemented to equip the necessary skills for our young clinicians to be competent in contributing to a more sustainable practice of dentistry. Teaching institutions should also support the use of well-labelled waste bins for proper waste segregation and reduce the consumption of energy, water, paper, and any materials as well as emissions to air and releases to water.

Due to the retrospective nature of data collection, it was difficult to accurately record the equipment, instrument and materials used in each appointment. Therefore, there is a high chance that the total amount of waste produced in this study was underestimated. However, this study also showed the potential minimum amount of waste produced in undergraduate removable prosthodontics clinics which have set guidelines for required armamentarium for each treatment stage.

Conclusion

Although literature on sustainable dentistry is rising, research is still limited. This study has added further evidence of the mass generation of waste within the dental field, specifically within prosthodontics. For this reason alone, students and staff should acquire knowledge on the awareness of sustainable dentistry and learn how to operate a sustainable practice. Strategies need to be implemented within the dental schools to track the carbon footprint production to allow possibilities to improve upon. With the ongoing environmental pressures, current practices within the education system should be questioned and amended appropriately to ensure the future graduates carry out sustainable dentistry out in the real world.

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Volume 5 Issue 8 August 2021