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Knowledge and Attitude Toward the Practice of Circular Economy in Conjunction with Biomedical Waste Management Among Dental Practitioners and Technicians in Belagavi, India

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Abstract

Background Circular economy promotes resource sustainability and has positive impact on the environment. It helps in the sustainable use of biomedical waste (BMW) that is generated in dental care facilities and laboratories.

Aims This article assesses the knowledge and attitude toward the practice of circular economy in conjunction with BMW management among dental practitioners and technicians.

Methodology This study adopted a cross-sectional design. Based on the findings from the pilot study, the sample size was estimated and 640 total participants were included. Reliability of questionnaire comprising of 23 close-ended questions were assessed with Cronbach's α value of 0.85, face validity of 84%, and content validity ratio of 0.78.

Statistical Analysis Data was analyzed using descriptive analysis, chi-square test, analysis of variance test, Pearson's correlation coefficient, and multiple linear regression.

Results Mean overall knowledge score was highest among faculty (5.28 ± 1.53) and least among technicians (1.88 ± 0.84). There was a statistically significant difference in knowledge among the five groups ($p < 0.001$). Majority of the participants had a positive attitude toward circular economy; however, technicians had the least mean overall attitude scores (7.50 ± 1.84). A positive linear correlation was seen between the knowledge and attitude scores. The dependence of various demographic variables on knowledge and attitude was found to be 46.1 and 11.6%, respectively.

Conclusion Dental faculty had significantly higher knowledge compared with other dental practitioners and technicians. However, knowledge on circular economy was below the optimal level among the participants, but all had predominantly favorable attitude toward circular economy.

Keywords
- biomedical waste
- circular economy
- dental waste
- sustainability
- waste management
- solid waste

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Introduction

Biomedical waste (BMW) is defined as "any waste, which is generated during the diagnosis, treatment, or immunization of human beings or animals, or in research activities pertaining thereto, or in the production or testing of biologicals."[1] Majority of the health care waste generated are nonhazardous (85%) and the remaining are classified as hazardous material (15%).[2] Dental care facilities and laboratories also generate a large amount of BMW and they have a high chance of exposure to infected human saliva and blood. There is also an increased concentration of heavy metals in the BMW generated from spent X-ray fixer solution and the use of amalgam fillings, which is still prevalent in India. The handling of impression materials in dental laboratories can release toxic byproducts during various procedures. Improper disposal and management of these wastes can cause various health hazards.[3]

India produces approximately 619 tons of BMW per day. The state of Karnataka produces the most (77.5 tons/day) among all the states.[4] Biomedical waste rules (2016) of India increased the coverage of BMW management (BMWM) to include various health care setups. The categories of BMW have been reduced to four (yellow, red, blue, and white) to bring about ease of segregation, packaging, transport, and storage of BMW.[5] Amidst all these rules there is still a widespread laxity among dental practitioners and technicians in adhering to the BMWM protocols.[3] The current methods of BMWM in India commonly employ landfilling and incineration. These methods negatively affect the soil and air, hence it cannot be a long-term solution.[5]

Coronavirus disease 2019 (COVID-19) had a significant impact on the management of BMW in the Indian subcontinent.[6] In both medical and dental care, the use of personal protective equipment (PPE) and other protective gear increased dramatically. Airports in India handled over 340 million passengers in 2020 and PPEs were mandated for all passengers,[4] this increased the burden on landfilling.[7] Also, the sudden increase in COVID-19 cases in India was estimated to have increased the yellow category of BMW putting more strain on incineration facilities.[8] It has exacerbated an existing environmental problem and there is an urgent need for an effective and sustainable way of managing the BMW.

The United Nations issued 17 Sustainable Development Goals (SDGs) in 2015 with a focus on sustainability. It emphasized the importance of circular economy in fulfilling various SDGs.[9] The Ellen MacArthur Foundation defines circular economy as "one that is restorative, and one which aims to maintain the utility of products, components, and materials and retain their value" (EMF, 2015).[10] Unlike linear economy which fosters resource exploitation and waste generation, circular economy encourages resource sustainability and has a positive effect on the environment. It can overcome the shortcomings of current approaches for the preservation of natural resources and can be included in the indicators for Human Development Index.[11] Circular economy model adopts the three R's philosophy (reduce, reuse, recycle) of waste management. It offers functional, safe, and high-quality products that are more efficient, affordable, and long-lasting. This can be made possible through new recyclable product models, digital solutions in laboratories, and innovative resource analysis that will generate less waste, create innovative jobs, upgrade knowledge and skills, and ultimately, a higher quality of life.[12] The knowledge about circular economy is essential among medical and dental practitioners and technicians and it should be imparted along with BMWM.

The incorporation of circular economy in dental health care facilities and laboratories at this juncture following the impact of COVID-19 in various facets of BMWM is more important now than ever.[13] Therefore, this study was conducted to assess the existing knowledge and attitude toward the practice of circular economy in conjunction with BMWM among dental practitioners and technicians.

Material and Methods

Study Design

This study used an observational, cross-sectional study design and was performed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.

Study Setting

It was conducted among faculty, postgraduates, interns, clinical undergraduates (3rd and 4th year of study), and technicians of two dental colleges located in the Belagavi district of Karnataka state. These groups provided dental care and handled patient care materials at the clinics and laboratories. This survey was performed between April and May of 2022.

Eligibility Criteria

The study included all the participants from the two dental colleges who were willing to give informed consent. Those who were not willing to give consent for the study were excluded (►**Fig. 1**).

Questionnaire Validation

A pilot study was conducted on a representative sample consisting of 10 participants from each group to detect any design flaws such as word ambiguity, inability to understand the questions, and other questionnaire-related errors. The questionnaire's reliability was deduced to be 0.85 using Cronbach's α, and its validity was deduced using face validity (84%) and content validity ratio (0.78). Based on the pretest feedback, the questionnaire was further refined by additions and deletions to make it more appropriate and specific to the purpose of the study, and thus a valid questionnaire was designed.

Questionnaire Characteristics

The self-administrated questionnaire included 23 close-ended questions in English, 12 of which were knowledge based and 11 of which were attitude based. The questionnaires were distributed to the participants during the working hours of the two dental colleges. Participants

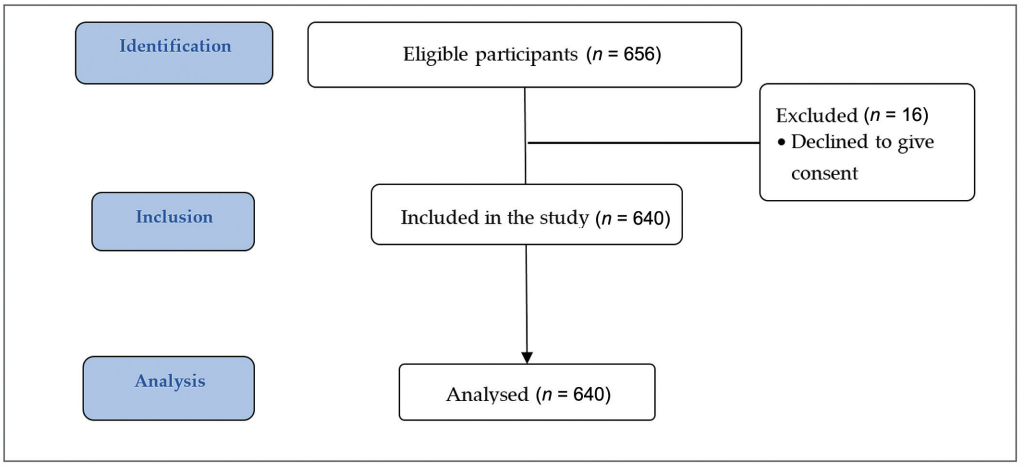

Fig. 1 Study enrolment Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) flowchart.

were instructed to attempt all the questions in 15 minutes. The first section of the questionnaire contained general sociodemographic information about the participant, which was used for qualitative analysis, and the second section covered multiple elements of circular economy.

Bias

The questionnaire was administered by a single investigator in a classroom setting on a specified date and time. To mitigate potential bias, the process was closely supervised by volunteers, ensuring unbiased completion of the questionnaire. This approach helped maintain the integrity of the responses as participants were not influenced by other individuals in the classroom

Sample Size Estimation and Sample Distribution

From the pilot study, the minimum sample size was estimated to be 568 with type I (α) error = 0.05 and power ($1-\beta$) = 0.95 using G*Power statistical software (Ver. 3.1.9.4.). The list of participants belonging to various affiliations from the two dental colleges in Belagavi was obtained. All the participants were recruited from the list by simple random sampling. Hence, a total sample size of 640 was obtained.

Statistical Analysis

Collected data were entered in Microsoft Excel 2019 and analyzed using IBM-SPSS Statistics, Version 21 (United States). Descriptive statistics were computed, which included percentages, means, and standard deviations. The normality of the data distribution was determined using the Kolmogorov–Smirnov test and the data was found to be normally distributed. Chi-square test was used to check for the association between the study variables among the participants. Analysis of variance (ANOVA) test was performed to check for any significant differences in the study parameters. Multiple linear regression analysis was also performed. For all the tests, confidence level and level of significance were set at 95 and 5%, respectively. The knowledge scores were categorized into high ($>$ 8 score/$>$ 80th percentile), medium (4–8 score/ 40th–80th percentile), and low ($<$ 4 score/$<$ 40th percentile) and the attitude scores into positive ($>$ 6 score/$>$ 50th percentile) and negative ($\leq$ 6 score/$\leq$ 50th percentile).[14]

Results

Among the 640 participants, dental undergraduates (32.81%) made up the majority of the participants while the lowest were technicians (9.06%). The sociodemographic characteristics of the respondents are depicted in ►**Table 1**. Chi-square association between participants with their knowledge and attitude are depicted in ►**Table 2**.

Knowledge about Circular Economy

Majority of participants had low (74.5%) followed by medium (24.1%) and high (1.4%) knowledge score. ►**Fig. 2** illustrates the violin plot comparing the kernel density estimate of the knowledge scores in percentile among the study participants. The ANOVA test showed that there was a significant difference in the knowledge scores among the five study groups ($p < 0.001$); similarly, the ANOVA test depicted that there was a significant difference ($p < 0.001$) in the knowledge scores among the participants of different age groups (20–30, 31–40, $>$ 40). The mean overall knowledge score was highest among dental faculty (5.28 ± 1.53) and the least among dental technicians (1.88 ± 0.84) (►**Table 3**).

Attitude toward Circular Economy

Majority (79.4%) of the study participants had a positive attitude and 20.6% participants had a negative attitude toward circular economy. ►**Fig. 3** illustrates the violin plot comparing the kernel density estimate of the attitude scores in percentile among the study participants. The ANOVA test showed that there was a significant difference in the attitude scores among the five study groups ($p < 0.001$); similarly, the ANOVA test depicted that there was a significant difference ($p = 0.026$) in the attitude scores among the participants of different age groups (20–30, 31–40, $>$ 40). The mean overall attitude score was highest among dental interns (9.10 ± 1.33) and the least among dental technicians (7.50 ± 1.84) (►**Table 3**).

Table 1 Descriptive statistics of demographic details

Characteristics	Faculty $n = 108$ (%)	Postgraduates $n = 144$ (%)	Interns $n = 120$ (%)	Undergraduates $n = 210$ (%)	Technicians $n = 58$ (%)	Total $n = 640$ (%)
Age						
20–30	1 (0.9)	141 (97.9)	120 (100)	210 (100)	45 (77.6)	516 (80.6)
31–40	72 (6.7)	3 (2.1)	0 (0)	0 (0)	10 (17.2)	86 (13.4)
> 40	35 (32.4)	0 (0)	0 (0)	0 (0)	3 (5.2)	38 (5.9)
Mean age (mean ± SD)	39 ± 4.5	25.9 ± 1.4	23.36 ± 0.776	21.44 ± 1.40	25.78 ± 9.91	26.21 ± 7.16
Gender						
Male	39 (36.1)	30 (20.8)	30 (25)	48 (22.9)	49 (84.5)	196 (30.6)
Female	69 (63.9)	114 (79.2)	90 (75)	162 (77.1)	9 (15.5)	444 (69.4)

Abbreviation: SD, standard deviation.
Note: All values are expressed as frequency with percentages (in parentheses).

Table 2 Association between affiliation and knowledge/attitude

(A) Based on knowledge of respondents			
Question	**Response**	**Frequency *n* (%)**	***p***
Have you had any training in BMWM?	Yes[b]	221 (34.5)	< 0.001[a]
	No	419 (65.5)	
In BMWM 3 R's stands for?	Reduce, Reuse, Recycle[b]	238 (37.2)	< 0.001[a]
	Retake, Reproduce, Recycle	402 (62.8)	
Which prescribed authority implements BMWM rules in Karnataka?	Karnataka State Pollution Control Board[b]	352 (55)	< 0.001[a]
	Health and Family Welfare Department of Karnataka	288 (45)	
	Arogya Karnataka		
	Public Health Foundation of Karnataka		
Which biomedical/dental waste can be recycled?	Plastic packaging[b]	477 (74.5)	< 0.001[a]
	Gypsum	163 (25.5)	
	Gloves (used)		
	Medicines (expired)		
Which one of the following is a successful utilization of the BMW ash obtained after incineration?	In agriculture as fertilizer and construction[b]	405 (63.3)	< 0.001[a]
	Food for cattle	235 (36.7)	
	To prevent soil erosion and reforestation		
	As disinfectant		
Are you aware of ISO 14001 accreditation for organizations in India?	Yes[b]	133 (20.8)	< 0.001[a]
	No	507 (79.2)	
NITI Aayog on the press release dated March 18, 2021 advocates the idea of Aatmanirbhar Bharat (self-reliant India) by adopting which model?	Circular economy[b]	47 (7.3)	< 0.001[a]
	Alternate economy	593 (92.7)	
	Reversible economy		
	Linear economy		
Have you heard the term "Circular Economy" before?	Yes[b]	176 (27.5)	< 0.001[a]
	No	464 (72.5)	
Do you think disposable/single use products in dentistry contribute to CE?	No[b]	524 (81.9)	< 0.001[a]
	Yes	116 (18.1)	
How many times can a reusable dental bur used before disposing?	30 times[b]	114 (17.8)	< 0.001[a]
	10 times	526 (82.2)	
	20 times		
	40 times		

Table 2 (*Continued*)

How much lesser environmental impact do reusable dental burs have compared with disposable ones?	40%[b]	210 (32.8)	< 0.001[a]
	20%	430 (67.2)	
	30%		
	50%		
What is the percentage of garbage that is generated from a product's waste packaging?	33%[b]	305 (47.7)	< 0.001[a]
	23%	335 (52.3)	
	43%		
	53%		
(B) Based on attitude of respondents			
Question	**Response**	**Frequency *n* (%)**	***p***
Do you think you need more understanding and training in the concepts of CE?	Yes[b]	633 (98.9)	< 0.001[a]
	No	7 (1.1)	
Do you think the concepts CE should be included along with BMWM in the curriculum of undergraduates and postgraduates?	Yes[b]	636 (99.4)	< 0.001[a]
	No	4 (0.6)	
Do you think there should be a public policy on CE?	Yes[b]	633 (98.9)	0.015[a]
	No	7 (1.1)	
Do you think all recyclable BMW should be further segregated based on their carbon footprint?	Yes[b]	602 (94.1)	< 0.001[a]
	No	38 (5.9)	
Do you think COVID-19 pandemic has aggravated the need for adopting an efficient CE model in conjunction with BMWM?	Yes[b]	507 (79.2)	< 0.001[a]
	No	133 (20.8)	
Which syringe do you prefer to use in your clinical practice?	Nondisposable metallic syringe[b]	499 (78)	< 0.001[a]
	Disposable syringe	141 (22)	
Do you think there is a need for dental product manufacturers to cut down on the amount of packaging of their products?	Yes[b]	565 (88.3)	< 0.001[a]
	No	75 (11.7)	
Which dental product would you prefer to use in your practice?	One which has biodegradable packaging but has high cost[b]	396 (61.9)	< 0.001[a]
	One which has nonbiodegradable packaging but has low cost	244 (38.1)	
Which dental material would you prefer to use in your practice?	One with less carbon footprint and long treatment time[b]	319 (49.8)	< 0.001[a]
	One with more carbon footprint and short treatment time	321 (50.2)	
Which imaging technique would you prefer to use in your practice?	Digital imaging [b]	604 (94.4)	< 0.001[a]
	Conventional radiography	36 (5.6)	
How do you prefer to order dental materials in your practice?	Order in bulk[b]	417 (65.2)	< 0.001[a]
	In multiple shipments	223 (34.8)	

Abbreviations: BMWM, biomedical waste management; CE, circular economy; COVID-19, coronavirus disease 2019; ISO, International Organization for Standardization; NITI, National Institution for Transforming India.
Note: All values are expressed as frequency with percentages (in parentheses). The statistical test used: chi-square test.
[a]$p \leq 0.05$ is considered a statistically significant association.
[b]Indicates (A) correct response and (B) positive attitude.

Relationship between Study Variables Using Pearson's Correlation Coefficient

A positive linear correlation ($r = +0.257$) was seen between the knowledge and attitude scores that was statistically significant ($p < 0.001$) using Pearson's correlation coefficient test. The field-wise correlation data are presented in ►**Table 4**.

Association between Demographic Variables and Knowledge/Attitude Scores Using Multiple Linear Regression

Multiple linear regression analysis depicted a significant relationship between knowledge of the participants and their age ($p < 0.001, R = 0.223$) and affiliation ($P < 0.001, R = 0.601$). The attitude of the participants showed significant relationship

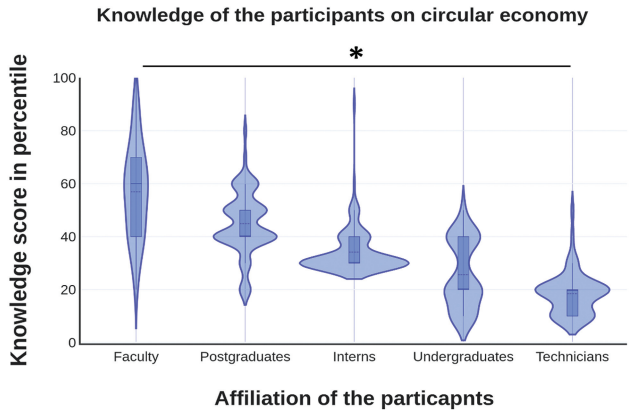

Fig. 2 Comparison of knowledge score in percentile among dental postgraduates and faculty on circular economy. Knowledge score indicators: low (< 40th percentile), medium (40th–80th percentile), and high (> 80th percentile). The statistical test used: analysis of variance (ANOVA); level of significance: $^{*}p \leq 0.05$ is considered statistically significant.

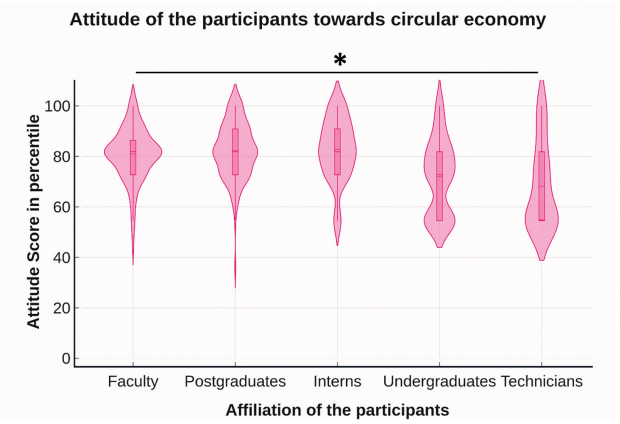

Fig. 3 Comparison of attitude score in percentile among dental postgraduates and faculty toward circular economy. Attitude score indicators: negative (≤ 50th percentile) and positive (> 50th percentile). The statistical test used: analysis of variance (ANOVA); level of significance: $^{*}p \leq 0.05$ is considered statistically significant.

Table 3 Knowledge and attitude of dental postgraduates and faculty

Parameters	Knowledge score	*F*	*p*
Affiliation			< 0.001[a]
Technicians	1.88 ± 0.84	143.02	
Undergraduates	2.56 ± 1.26		
Interns	3.43 ± 0.82		
Postgraduates	4.76 ± 1.44		
Faculty	5.28 ± 1.53		
Age			< 0.001[a]
20–30	3.31 ± 1.55	47.84	
31–40	4.74 ± 1.92		
> 40	5.16 ± 1.64		
Parameters	**Attitude score**	***F***	***p***
Affiliation			< 0.001[a]
Technicians	7.50 ± 1.84	29.04	
Undergraduates	7.92 ± 1.62		
Interns	9.10 ± 1.33		
Postgraduates	9.06 ± 1.18		
Faculty	8.91 ± 1.12		
Age			0.026[a]
20–30	8.45 ± 1.49	3.66	
31–40	8.78 ± 1.35		
> 40	9.00 ± 1.14		

Note: All values are expressed in mean ± standard deviation (SD). The statistical test used: analysis of variance (ANOVA).
[a]$p \leq 0.05$ is considered statistically significant.

with affiliation ($p < 0.001$, $R = 0.334$). The dependence of knowledge and attitude on the variables, including age, gender, and affiliation, were found to be 46.1 and 11.6%, respectively (►**Table 5**).

Table 4 Correlation between knowledge and attitude of the study participants

Variable		Attitude
Knowledge	r	0.257
	p	< 0.001[a]

Note: The statistical analysis used: Pearson's correlation coefficient.
[a]Correlation is significant at the 0.05 level.

Discussion

Sustainability has become a topic of interest in many countries. Countries across the globe began advocating bureaucratic policies that have rules and regulations which favors sustainability of resources.[15] India has imposed a ban on the import of solid plastic waste to curb the growing environmental issue of waste management.[16] BMWM in India has become a challenging task post-COVID-19 pandemic.[6] The knowledge and attitude of dental practitioners and technicians toward circular economy were assessed in this study, given that there is a preexisting knowledge gap on BMWM among this population.[3] The study participants were majorly females belonging to a younger age group. Majority (65.5%) of them did not have any training in BMWM. Studies reported by Indhulekha et al,[17] Khubchandani et al,[3] and Rao et al[18] had similar findings, indicating that frequent training programs on BMWM were required. More than half of the participants (55%) were aware about the prescribed authority that implements BMWM rules in the state of Karnataka. These findings were similar to that of Khubchandani et al.[3]

Awareness about Circular Economy

The Ellen MacArthur Foundation has outlined three main principles for describing the philosophy behind circular economy and they are to eliminate waste and pollution, circulate products and materials, and regenerate nature

Table 5 Association between demographic variables and knowledge/attitude scores of the study participants

Predictors	Coefficient r	SE	*t*	95% CI	*p*	Adjusted R^2
Dependent variable: knowledge score						
Constant	–	0.291	18.212	4.731 to 5.874	< 0.001[a]	0.461
Age	0.223	0.093	7.425	0.509 to 0.874	< 0.001[a]	
Gender	0.046	0.111	−1.541	−0.390 to 0.047	0.124	
Affiliation	0.601	0.040	−19.809	−0.862 to −0.706	< 0.001[a]	
Dependent variable: attitude score						
Constant	–	0.333	28.947	8.978 to 10.285	< 0.001[a]	0.116
Age	0.035	0.106	0.920	−1.111 to 0.307	0.358	
Gender	0.019	0.127	−0.486	−0.312 to 0.188	0.627	
Affiliation	0.334	0.045	−8.601	−0.478 to −0.300	< 0.001[a]	

Abbreviations: CI, confidence interval; SE, standard error.
Note: The statistical analysis used: Multiple linear regression analysis.
[a]$p \leq 0.05$ is considered statistically significant.

(►**Fig. 4**).[19] Only 37.2% participants were aware of the three R's philosophy (reduce, reuse, and recycle) of waste management. The National Institution for Transforming India (NITI Aayog), India's apex public policy body, advocates Aatmanirbhar Bharat (self-reliant India) by implementing circular economy to generate significant annual benefits while reducing congestion and pollution. Eleven committees have been established to expedite the country's transition from a linear to a circular economy.[20] Majority (72.5%) of the participants in this study were unfamiliar with the term circular economy, and 92.7% were unaware of the country's adoption of the circular economy model for self-sufficiency. Majority (98.9%) of them desired explicit training in circular economy principles, while 99.4% advocated that concepts of

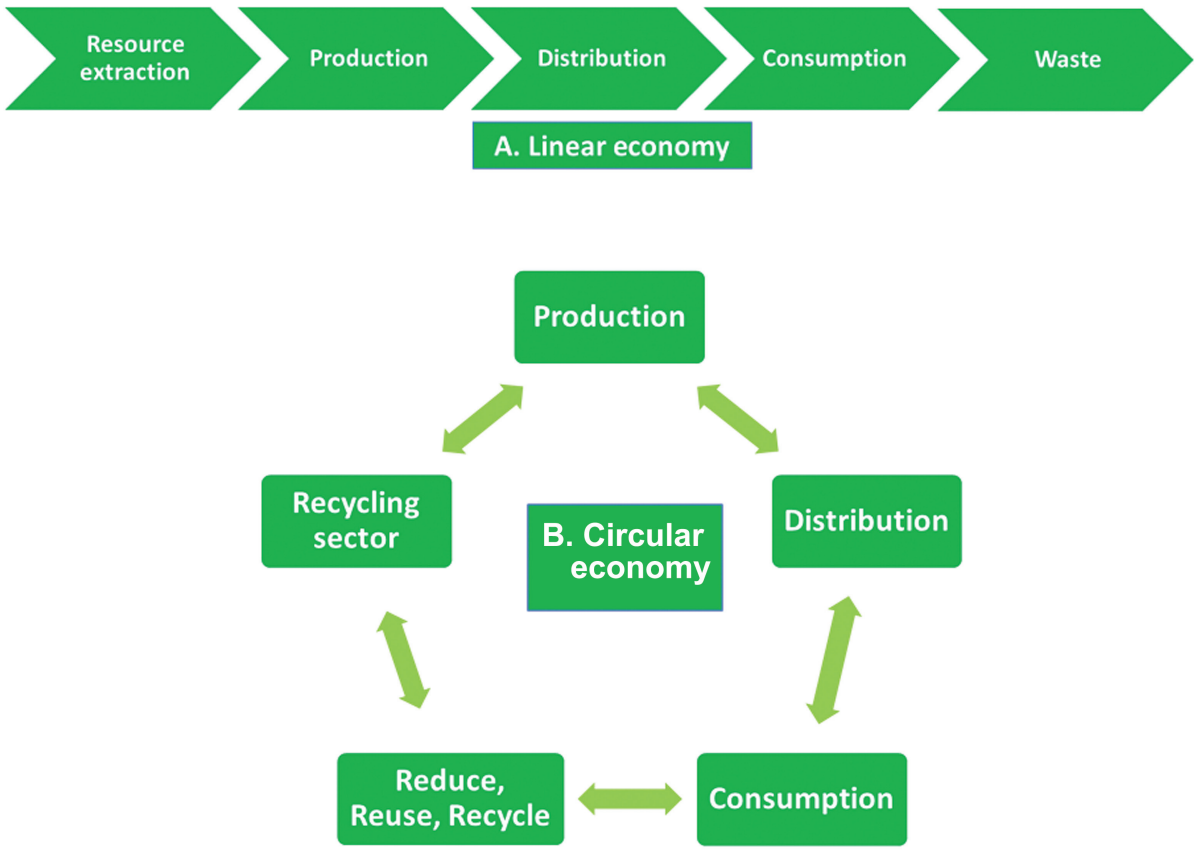

Fig. 4 Key differences between (**A**) linear economy and (**B**) circular economy given by AkzoNobel (2015).

circular economy should be introduced in undergraduate and postgraduate curriculums and 98.9% expressed that there is a need for a public policy on circular economy. The participants predominantly (79.2%) felt that the COViD-19 pandemic has aggravated the need for adopting an efficient circular economy model. This can be correlated with the findings from the study by Mariam et al,[21] where 88.65% participants were of the opinion that the pandemic has increased financial burden on BMWM.

Reduce, Reuse, and Recycle Philosophy

BMW is frequently disposed through incineration and landfilling in developing countries like India.[4] When BMW ash from incineration is disposed by landfilling there is a greater risk of groundwater contamination due to metal leaching. Additionally, there is the issue of scarcity of space and high cost for land disposal. It meant that the most sustainable way to use BMW ash was in agriculture as fertilizer and in the construction sector to ensure minimal metal leaching.[12] Majority (63.3%) of the participants were aware of this sustainable mode of BMW ash disposal. In dental practice one of the most commonly used instruments is a syringe and in India majority of the clinicians preferred a disposable one. In the current study, 81.9% participants believed that disposable/single-use products in dentistry do not contribute to circular economy and 78% preferred to use nondisposable metallic syringe. A metallic syringe generates less waste but creates an inconvenience of autoclaving after every use. The energy spent for autoclaving is a factor to be considered. According to Unger and Landis' comparative lifecycle assessment, one reusable dental bur can be used for a maximum of 30 instances and only 17.8% participants were aware of the same. It was also revealed that only 32.8% study participants were aware that when ultrasonic and autoclave loads were optimized, reusable burs had a 40% lower environmental impact than disposable burs.[12,22]

Plastic waste packaging that comes along with dental products accounts for the large chunk of waste that is generated. In this study, 74.5% study participants were aware that plastic packaging can be recycled, on the contrary 52.3% were not aware of the amount of garbage (33%) generated from a product's waste packaging. Similarly, 88.3% participants believed that manufactures should cut down on the packaging of the dental products and 61.9% preferred to use products with biodegradable packaging that is relatively expensive. From this it can be interpreted that manufactures can use packaging that may marginally increase the overall cost of the product but causes minimal damage to the environment. They can think of materials such as nanocellulose as an alternative to plastic packaging.[23] Shipping charges can be reduced by purchasing often-used dental products in bulk. It can lower the usage of fuel and waste packaging needed for shipping. In this study, 65.2% participants believed in ordering the shipments in bulk. Increasing the shelf life of some of these products could prove to be beneficial as this will reduce the need for multiple shipments.[12] Dental care facilities and laboratories generate wastewater containing silver thiosulfate from the X-ray fixer solution and use impression materials like polyvinyl siloxane and polyethers. The toxic byproducts from these materials are leached into the environment creating a major source of environmental pollution.[13] A study by Al Mortadi et al revealed the unsatisfactory practices of dental laboratory technicians in impression disinfection, increasing the chance of cross-infection.[24] Majority (94.4%) of the participants in this study preferred using digital imaging techniques. This emphasizes that digital solutions for imaging and impression of oral structures should be fully integrated into dental care facilities and laboratories to completely replace the conventional methods.[12]

Achieving Sustainability through Regulations and Monitoring

International Organization for Standardization (ISO) 14001 is a globally recognized standard that specifies the requirements for an environmental management system. It assists companies of all sizes and sectors in making their day-to-day operations more sustainable. Majority of the participants (79.2%) in this study were not aware of ISO 14001, an internationally accepted accreditation. Health care sector accounts for 5% of the global carbon emissions, therefore it is essential for manufactures to cut down on the carbon footprint of their dental products. Majority (94.1%) of the study participants preferred that the BMW to be further segregated according to their carbon footprint. In contrast, half (50.2%) of the participants opted to use products with a higher carbon footprint that can cut short the treatment time. Perhaps more awareness on carbon emissions and their negative effects on the environment should be disseminated among this population. A possible solution could be the use of electronic health records and dashboards that include data on emissions which facilitates decision making to reduce carbon footprint at dental care facilities.[25]

The study participants had an overall favorable attitude toward circular economy but the knowledge on circular economy was found to be moderate to low. Dental professionals and laboratory technicians should comprehend the value of effective BMWM and its implications on public health.[26] A study conducted by Parida et al among other health care workers (HCWs) also reported inadequate knowledge on BMWM. This existing knowledge gap among the HCW on BMWM must be filled along with the incorporation of principles of circular economy.[27] This study recognizes an opportunity to significantly broaden the reach of the importance of circular economy among dental institutions to promote sustainability. Hence, dissemination of knowledge, adoption of sustainable services guidelines, and effective management of resources in dental care facilities and laboratories is required. They should strive to align themselves with the nation's sustainable developmental goals and be trained in BMWM that is more suitable for the current scenario. As part of their training, routine monitoring and supervision and special inputs in enhancing the existing BMW treatment modalities at the community level should be stressed. Furthermore, there is a need to assist other organizations working toward circular

economy, as individual action may not be successful, and collective effort is required, given the importance of this issue to public health.

This study was limited to one region of the country due to the restrictions imposed by the global pandemic. Perhaps a large-scale study, across different dental institutions and laboratories in other parts of the country will give an overall outlook on circular economy.

Conclusion

This study reported that the attitude toward circular economy was predominantly positive among the participants but their knowledge was below the optimal level. When different study groups were focused, it was observed that knowledge among dental faculty was significantly high, while technicians had the least knowledge among them. It highlights that education plays an essential role in making BMWM sustainable. As the world is moving toward sustainability, health care institutions should incorporate various models of circular economy into BMWM training at the grassroot level for technicians and clinical practitioners. This is especially important in developing countries like India, where there is a growing scarcity of resources and increased pollution.

Authors' Contributions

V.N.S.: Conceptualization, investigation, project administration, visualization, writing - original draft, and writing - review and editing.

A.A.: Resources, supervision, validation, data curation, formal analysis, and methodology.

R.S.: Resources, supervision, methodology, validation, and writing - review and editing.

S.J.: Resources, supervision, validation, writing - original draft, and writing -review and editing.

A.J.P.K.: Software, data curation, writing - original draft, and writing - review and editing.

A.S.V.: Data curation, software, and writing - review and editing.

P.C.: Software, data curation, and writing - review and editing.

Ethical Approval and Informed Consent

Ethical approval for this research was obtained from KLE VK Institute of Dental Sciences Institutional Review Board (Ref. No: 1530).. The study's purpose was explained to the participants, and their written informed consent was obtained.

Conflict of Interest

None declared.

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Supplementary Appendix

Tick (✓) the Most Suitable response for the questions

1. Have you had any training in Bio-Medical Waste Management?
   a. Yes
   b. No
2. In Bio-Medical Waste Management, 3R's stands for?
   a. Retake, Reproduce, Recycle
   b. Reduce, Reuse, Recycle
3. Which prescribed authority implements bio-medical waste management rules in Karnataka?
   a. Health & Family Welfare Department of Karnataka
   b. Karnataka State Pollution Control Board
   c. Arogya Karnataka
   d. Public Health Foundation of Karnataka
4. Which bio-medical/dental Waste can be recycled?
   a. Gypsum
   b. Plastic Packaging
   c. Gloves (used)
   d. Medicines (expired)
5. Which one of the following is a successful utilization of the bio-medical waste ash obtained after incineration?
   a. Food for cattle
   b. To prevent soil erosion
   c. In agriculture as fertilizer and construction
   d. As disinfectant
6. Are you aware of ISO 14001 accreditation for organizations in India?
   a. Yes
   b. No
7. NITI Aayog on the press release dated 18 March 2021 advocates the idea of Aatmanirbhar Bharat (self-reliant India) by adopting which model?
   a. Circular Economy
   b. Alternate Economy
   c. Reversible Economy
   d. Linear Economy
8. Have you heard the term "Circular Economy" before?
   a. Yes
   b. No
9. Do you think disposable/single use products in dentistry contribute to circular economy?
   a. Yes
   b. No
   c. Not sure
10. Do you think you need more understanding and training in the concepts of circular economy?
    a. Yes
    b. No
11. Do you think the concepts of circular economy should be included along with bio-medical waste management in the curriculum of undergraduates and postgraduates?
    a. Yes
    b. No
12. Do you think there should be a Public Health Policy on circular economy?
    a. Yes
    b. No

13. How many times can a reusable dental bur be used before disposing?
    a. 10 times
    b. 20 times
    c. 30 times
    d. 40 times
14. How much lesser environmental impact do reusable dental burs have compared with disposable ones?
    a. 20%
    b. 30%
    c. 40%
    d. 50%
15. What is the percentage of garbage that is generated from a product's waste packaging?
    a. 23%
    b. 33%
    c. 43%
    d. 53%
16. Do you think all recyclable biomedical waste should be further segregated based on their carbon footprint?
    a. Yes
    b. No
17. Do you think COVID-19 pandemic has aggravated the need for adopting an efficient circular economy model in conjunction with bio-medical waste management?
    a. Yes
    b. No
18. Which syringe do you prefer to use in your clinical practice?
    a. Disposable syringe
    b. Non-disposable metallic syringe
19. Do you think there is a need for dental product manufacturers to cut down on the amount of packaging of their products?
    a. Yes
    b. No
20. Which dental product would you prefer to use in your practice?
    a. One which has biodegradable packaging but has high cost
    b. One with non-biodegradable packing but has low cost
21. Which dental material would you prefer to use in your practice?
    a. One with less carbon footprint and long treatment time
    b. One with more carbon footprint and short treatment time
22. Which Imaging technique would you prefer?
    a. Digital Imaging
    b. Conventional radiography
23. How do you prefer to order dental materials in your practice?
    a. Order in Bulk
    b. In Multiple Shipments

