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Implementation in restorative treatments in public health: a 10-year analysis of resin composite procurement in Brazil

Implementação de tratamento de restauração na saúde pública: uma análise de dez anos de compras de resina composta no Brasil

Implementación de tratamientos restaurativos en salud pública: un análisis durante 10 años de las adquisiciones de resina compuesta en Brasil

Gabriela de Souza Balbinot [1]
Roger Keller Celeste [1]
Vicente Castelo Branco Leitune [1]
Fabrício Mezzomo Collares [1]

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Abstract

This study aims to assess the resin composite purchases in a public health system and understand the variables associated with its cost and with the decision-making process over a period of 10 years. Secondary data collection was performed using the Brazilian Healthcare Prices Database (BDHP) from 2010 to 2019. All conventional and bulk-fill composites were selected. Date of purchase, institution type and location, procurement modality, number of purchased items, manufacture, and unit prices were collected. A multiple linear regression model assessed the influence of price in the procurement variables, while a multinomial logistic regression compared purchase probabilities between the materials. In total, 18,138 observations were collected with 2,129,294 purchased units and a total cost of USD 43,504,260.00. Conventional composites appeared in 98.5% of the procurement process. Nanofilled conventional composites were the most purchased materials, with an increased probability of purchase over time, despite its higher prices. An increase in prices was predicted for bulk-fill materials when compared to conventional ones. The odds of purchasing this category increased by 3.14x for every price increase over the years. Sociodemographic and type of institution influences the prices and the probability of procurement in the healthcare system. Nanofilled and bulk-fill resin are increasingly included in clinical practice. These findings highlight possible modifications to the standard-of-care in restorative treatments and how the translation of knowledge may occur from the development of new materials to the clinical application considering the economic impact of these modifications.

Dental Materials; Information Systems; Public Health Dentistry; Knowledge Translations; Costs and Cost Analysis

Correspondence
R. K. Celeste
Departamento de Odontologia Preventiva e Social, Faculdade de Odontologia, Universidade Federal do Rio Grande do Sul.
Rua Ramiro Barcelos 2492, Porto Alegre, RS 90035-003, Brasil.
roger.keller@ufrgs.br

[1] *Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil.*

Introduction

Resin composites were introduced in the dental practice decades ago, substantially changing the concept of restorative treatments for tooth structure rehabilitation [1,2,3]. The long-term success for resin composites is well-established, with up to 30 years of reported longevity restorations establishing this as the most commonly used material for direct restorative procedures [4,5]. Improvements to the composite properties and in the application of these materials have been studied for years to improve the clinical success of restorations and reduce the technical sensitivity of procedures [6].

The modifications of reinforcing fillers into conventional composites resins have enabled the production of universal composites that combine mechanical strength and esthetics for posterior and anterior applications [7,8,9]. These modifications changed the state-of-the-art of resin composites and supported the application of nanocomposites for long-term retention of restorative procedures [7]. The simplification of composite application is being studied by adopting bulk-fill strategies to avoid the need for the conventional 2mm-incremental technique and is implemented by modifying the monomer and filler compositions [10]. The application of bulk-fill composites in direct restorations gained popularity in the clinical practice in recent years [11] while evidence has been generated [12,13].

The modifications to the restorative materials are well described in the literature, which recommends modifications to the standard-of-care in clinical practice. Although restorative treatments are responsible for a great number of interventions in dentistry [14], little information is known about the relationship between emerging evidence in the scientific field and their implementation in dental treatments [15,16]. The translation of scientific knowledge is a well-known challenge [15,17,18,19] since it requires the generation of high-quality evidence, its synthesis and dissemination in the academic field, and, most importantly, its transference into tangible information for the population. Thus, the relationship between the state-of-the-art and standard-of-care in restorative treatment is related to understanding the translation of knowledge, especially in large-scale public healthcare systems, of which the strategies may affect millions of people. Besides, since many purchases are made, the economic impact of such strategies must be considered [20]. This analysis may be valuable to optimize the implementation of innovation, adjusting the application of obsolete techniques, and providing health and cost-effective treatments for the population [20,21].

The screening for resin composites procurements in one healthcare system may shed light on the current standard-of-care that is being provided, allowing for an economic analysis of the impact of purchased materials and technology implementation in the allocation of public resources. While the purchase of other health products have been analyzed [22,23,24], there have been no previous reports assessing the purchase patterns and economic impact of materials used for tooth restorations. This study aims to assess the resin composite purchases in a public health system and identify the variables associated with its cost and the decision-making process over a period of 10 years.

Methods

Data collection

In this longitudinal retrospective observational study, data collection was performed in the Brazilian Healthcare Prices Database (BDHP) of the Brazilian Ministry of Health from January 1st, 2010 to December 31, 2019. The composite resin information was collected for different conventional composite resins according to their filler size. Flowable and bulk-fill composite information was collected as well. The data were reorganized into categories to perform the analysis. The institutions were categorized according to their location within the Brazilian macroregions. The procurement modality and the type of institutions were recategorized as well. The unit prices were collected in Brazilian Reais (BRL), and inflation was used to adjust the values from 2010-2019. The Extended National Consumer Price Index (IPCA) was applied based on the month and the year of purchase. The adjusted prices were converted to American Dollars (USD), and values were matched based on the day when the procurement was performed by the Central Bank of Brazil. The Consumer Price Index

(CPI) from 2010 to 2019 was used to adjust the converted prices. All analyses were performed using Stata 14 (https://www.stata.com).

The number of the procurement process, the total number of purchased units, and the total cost of resin composites purchased were calculated. The average price for each category was collected and analyzed by one-way ANOVA and the Tukey's test at a 5% significance level.

Conventional resin composites

A multiple linear regression model was used to evaluate the effect of the adjusted unit price on the collected variables. The class of conventional resin composite, the macroregion, the year of procurement, the type of institution, the procurement modality, and the manufacturer were included in the univariate analysis model. The significance was assessed for each variable considering $\alpha = 0.05$, and the selected variables were included in the multinomial regression analysis using ordinary least square means. The model was used to assess outliers within the database. These values were removed in case the studentized residuals surpass 10 standard deviations, totaling 178 observations excluded (0.98% of the entries).

The probability of procurement was assessed with year, type of institution, price, procurement modality, and macroregion as the logistic model response variables. In this case, the unit price was divided by 10 for a better interpretation of the results. A chi-square univariate analysis was performed on the variables, and the multinomial model was adjusted with the variables that were statistically different ($\alpha = 0.05$). The predictive margins were calculated based on the logistic model to estimate average probability for each variable based on the category reference (nanofilled).

Bulk-fill vs. conventional composites

Recategorization was performed in the material description to classify composites as conventional and bulk-fills to then compare their procurement process. The linear and logistic models were used to describe the influence of adjusted unit price in the procurement process and the odds of purchasing bulk-fills compared to conventional. All analyses were conducted as aforementioned.

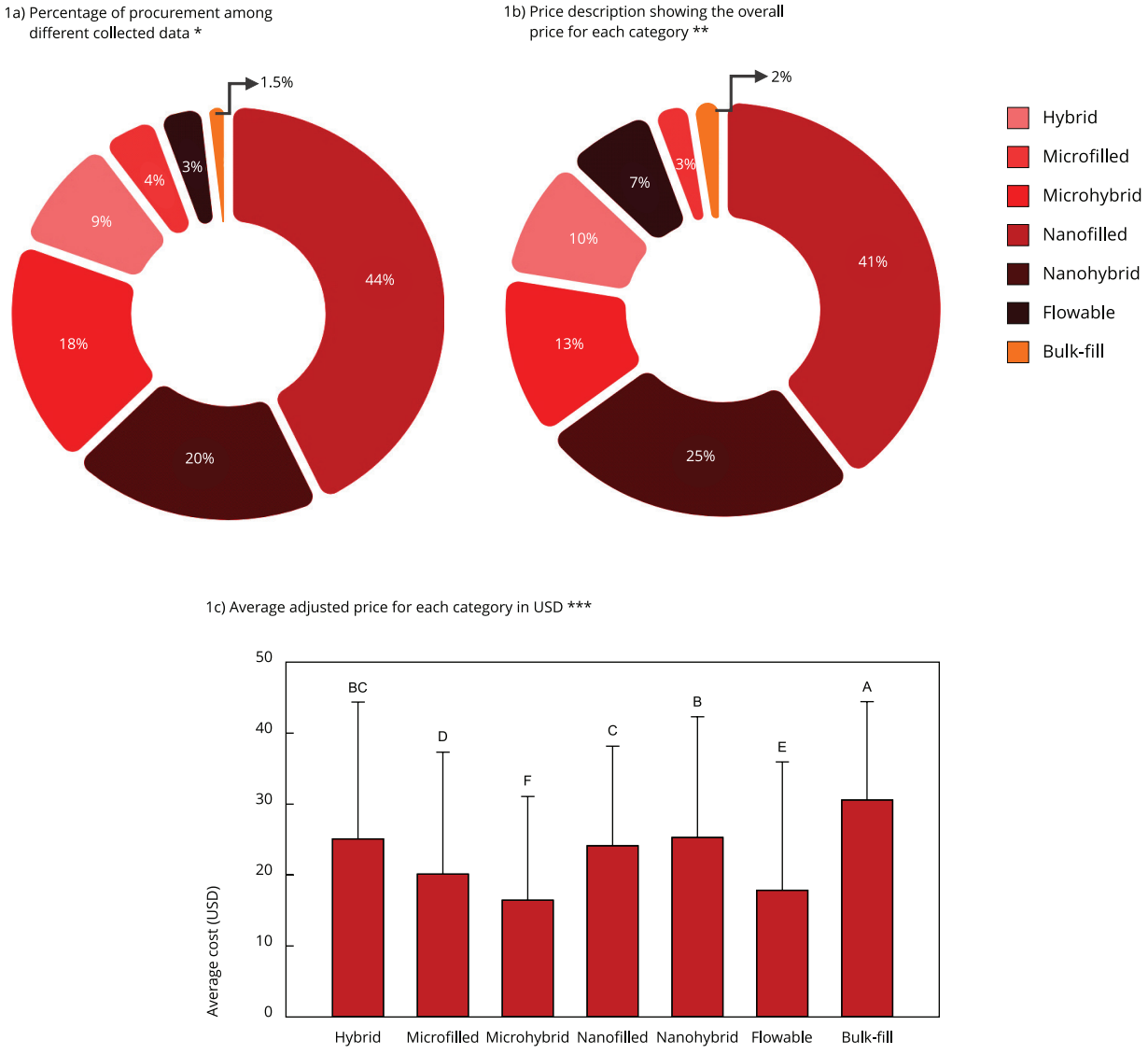
Results

The collected data resulted in 18,138 observations that corresponded to 2,129,294 units of composites being purchased, from 2010 to 2019, with an average price of USD 22.25 ± 16.47 per unit and a total cost of USD 43,504,260.00 (Figure 1). Nanofilled composites were the most frequently purchased composite resin corresponding to 34.6% of the total purchased units, representing 41.2% of the total cost of composites in Brazil, in the analyzed period. The average adjusted unit price for these composites was USD 24.13 ± 14.04 ($p < 0.05$). Microhybrids were the cheapest materials in this analysis, with an average price of USD 16.44 ± 14.62 ($p < 0.05$), corresponding to 18% of the total purchased units. From the total amount of procurements, 1.5% corresponded to bulk-fill composites, that were purchased for the highest average adjusted unit prices (USD 30.57 ± 13.87; $p < 0.05$), corresponding to 2.2% of the overall expenditure.

Table 1 shows the linear model for conventional composites. All analyzed variables were statistically significant, being used in the multiple analysis. The reference categories were the most frequent categories in the databank for each variable. The unit price analysis is shown in the adjusted model, considering the predictor variables. The nanofilled composites were used as the reference category, and only the nanohybrids were more expensive than the reference (USD 1.58; $p = 0.001$), whereas the other categories presented reduced coefficients when compared to the reference. All macroregions presented reduced prices when compared to the reference (Southeast). The procurement modality was shown to influence the price of composites. When compared to the reference category (auction), the bid waiver and other modalities increased the unit price to USD 8.79 and USD 3.77 in the adjusted model, respectively. Universities paid USD 1.67 less than other federal institutions (Table 1; $p = 0.001$). The manufacturer analysis showed that the reference category (3M) has higher values in

Figure 1

Distribution of the procurement process of the collected data.



* Total number of purchased items and % of procurement process for resin composites between 2010 and 2019. A total of 2,129,249 resin composites items were purchased;

** Overall cost (USD) and the % cost for class of resin composite. USD 43,504,260 was spent in the 10-year analysis;

*** Different uppercase letters indicate statistically significant difference between materials.

the adjusted model when compared to 13 out of 17 manufacturers. Ivoclar, Shofu, and Voco composites were purchased for higher values when compared with 3M.

Tables 2 and 3 show the individual analysis for each category and the multinomial logistic regression model among conventional composites. All response variables were statistically significant in the analysis; thus, all were included in the multinomial logistic regression where the type of composite was used as the response variable. The odds for purchasing hybrids, microfills, and micro-

Table 1

Average price of all purchases (n = 17,702) by different covariates and adjusted price differences in the multiple linear regression model for the different types of resin.

	Bivariate analysis				Adjusted differences	
	Average price (USD)	SD	Frequency	p-value	Coefficient	95%CI
Resin composite type						
Hybrid	25.12	19.38	2,435		-1.14	-1.79; -0.48
Microfilled	20.12	17.20	939		-3.08	-4.02; -2.13
Microhybrid	16.44	14.62	3,161		-6.36	-6.96; -5.75
Nanofilled	24.13	14.04	6,420		1.58	0.96; 2.19
Nanohybrid	25.29	17.03	2,700		Reference	
Flowable	17.84	18.10	2,047	< 0.01	-0.97	-1.66; -0.28
Year						
2010	45.75	21.15	191			
2011	49.26	29.72	276			
2012	31.10	19.14	724			
2013	28.20	17.51	2,135			
2014	28.87	15.09	2,470			
2015	18.72	11.11	1,706			
2016	17.40	12.30	2,359			
2017	19.49	15.57	2,389			
2018	18.01	14.47	2,643			
2019	17.16	13.78	2,809	< 0.01	-2.61	-2.70; -2.51
Macroregion						
South	23.34	16.93	3,996		-0.51	-1.07; 0.41
Southeast	24.57	17.75	4,791		Reference	
Central-West	20.90	14.17	2,654		-2.28	-2.92; -1.64
Northeast	20.55	16.16	4,196		-0.19	-0.75; 0.37
North	18.90	14.80	2,065	< 0.01	-1.17	-1.87; -0.48
Procurement modality						
Auction	20.86	15.19	15,497		Reference	
Bid waiver	31.40	21.61	2,144		8.79	7.07; 10.57
Other	19.90	18.11	61	< 0.01	3.77	0.27; 7.26
Type of institution						
Universities	20.56	15.99	3,838		-1.67	-2.17; -1.17
Other federal institutions	23.06	16.59	13,236		Reference	
Municipalities	12.08	12.48	628	< 0.01	-1.91	-3.08; -0.74

(continues)

hybrids decreased from 2010 to 2019 when compared with nanofilled composites. Nanohybrid resin composites were more likely to be purchased over the years when compared with nanofilleds (OR = 1.04; $p < 0.001$). For each USD 10.00 increase in the price, a reduction in the odds is observed for the purchase of hybrids, microfills, microhybrids, and flowable; whereas an increase is observed for nanohybrids (OR = 1.07; $p < 0.001$). Universities were more likely to purchase microfills and nanohybrid resins when compared with nanofilled, whereas reduced odds were found for hybrids, microhybrids, and flowable.

Table 1 (continued)

	Bivariate analysis				Adjusted differences	
	Average price (USD)	SD	Frequency	p-value	Coefficient	95%CI
Manufacturer						
3M	25.60	14.03	8,535		Reference	
Biodinâmica	7.74	9.10	929		-14.37	-15.31; -13.43
Coltene	13.09	12.65	533		-15.54	-16.73; -14.36
Densell	15.34	0.00	5		-22.40	-33.95; -10.84
Dentisply	16.48	14.50	496		-12.47	-13.69; -11.24
DFL	8.35	8.88	133		-14.95	-17.24; -12.65
FGM	12.83	11.65	2,776		-12.55	-13.14; -11.96
Ivoclar	42.72	15.55	391		16.46	-15.07; 17.85
Kavokerr	14.40	13.54	364		-6.75	-8.15; -5.36
Kulzer	18.99	10.58	751		-4.90	-5.95; -3.85
Maquira	6.26	6.22	91		-15.38	-18.14; -12.62
SDI	16.37	9.76	38		-5.00	-9.21; -0.80
Shofu	88.89	5.87	11		59.85	52.03; 67.07
Technew	13.10	5.15	195		-7.07	-8.95; -5.18
Tokuyama	16.49	8.36	14		-11.69	-18.70; -4.69
Ultradent	17.66	16.77	79		-1.71	-4.65; 1.21
Voco	32.51	12.77	14		11.52	4.60; 18.44
Other	30.28	18.77	2,349	< 0.01	-4,57	-6.21; -2.64
Constant					5,282.03	5,097.37; 5,466.68

95%CI: 95% confidence interval; SD: standard deviation.

Note: $R^2 = 0.36$ for multiple regression.

Table 2

Odds ratio (OR) with the 95% confidence interval (95%CI) for purchasing different dental resins (compared with nanofilled) for public health system according to the procurement process type. Multinomial logistic regression (base outcome: nanofilled).

	Hybrid		Microfilled		Microhybrid		Nanohybrid		Flowable	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Year	0.71	0.70; 0.73	0.73	0.71; 0.76	0.71	0.70; 0.73	1.04	1.02; 1.06	1.00	0.97; 1.03
Price *	0.83	0.80; 0.86	0.71	0.68; 0.75	0.56	0.53; 0.58	1.07	1.04; 1.10	0.75	0.72; 1.03
Macroregion (reference: Southeast)										
South	1.25	1.09;1.44	1.99	1.62; 2.45	0.85	0.74; 0.97	1.10	0.96; 1.25	0.86	0.74; 1.00
Central-West	2.22	1.9; 2.60	1.47	1.13; 1.91	1.50	1.30; 1.73	1.40	1.21; 1.63	1.37	1.16; 1.61
Northeast	1.39	1.20; 1.61	1.82	1.47; 2.26	1.37	1.21; 1.56	1.34	1.17; 1.52	0.90	0.77; 1.04
North	2.22	1.86; 2.65	3.32	2.60; 4.24	1.37	1.16; 1.62	1.58	1.34; 1.87	1.78	1.51; 2.10
Procurement modality (reference: auction)										
Bid waiver	4.16	3.62; 4.79	2.55	2.06; 3.14	2.21	1.90; 2.58	1.10	0.93; 1.28	2.35	1.99; 2.78
Other	15.76	2.01; 132.01	12.96	1.42; 118.31	18.55	2.24; 153.16	0.00	-	16.65	2.01; 137.95
Type of institution (reference: other federal institutions)										
Universities	0.91	0.80; 1.04	1.04	0.87; 1.25	0.69	0.61; 0.78	1.55	1.39; 1.72	0.66	0.57; 0.76
Municipalities	9.29	6.85; 12.59	7.44	5.13; 10.79	4.09	3.02; 5.53	0.33	0.15; 0.69	6.64	4.94; 8.92

* For each increase in USD 10.00.

Table 3

Frequency of the procurement process for each category for the analyzed variables. Univariate analysis.

	Resin composite						Total	p-value
	Hybrid	Microfilled	Microhybrid	Nanofilled	Nanohybrid	Flowable		
Year								
2010	113	17	43	0	0	18	191	
2011	94	52	77	0	0	53	276	
2012	205	54	195	159	57	54	724	
2013	459	120	390	722	260	184	2,135	
2014	280	168	529	935	321	237	2,470	
2015	321	91	375	570	183	166	1,706	
2016	207	73	487	1,014	393	185	2,359	
2017	381	159	423	766	519	141	2,391	
2018	255	125	619	1,007	518	119	2,757	
2019	120	80	23	1,247	449	890	2,951	
Total	2,435	939	3,161	6,420	2,700	2,047	17,702	0.001
Macroregion								
South	577	277	557	1,565	610	410	4,033	
Southeast	578	175	843	1,957	656	582	4,818	
Central-West	457	103	547	826	399	322	2,700	
Northeast	540	238	874	1,447	718	379	4,256	
North	283	146	340	625	317	354	2,152	
Total	2,435	939	3,161	6,420	2700	2,047	17,702	0.001
Procurement modality								
Auction	1,814	789	2,772	5,888	2,448	1,786	2,190	
Bid waiver	601	144	369	531	252	247	15,708	
Other	20	6	20	1	0	14	62	
Total	2,435	939	3,161	6,420	2,047	2,700	17,702	0.001
Type of institution								
Universities	495	214	578	1,418	834	299	3,878	
Other federal institutions	1,787	663	2,420	4,933	1,858	1,575	13,434	
Municipalities	153	62	163	69	8	173	648	
Total	2,435	939	3,161	6,420	2,700	2,047	17,702	0.001

The conventional composites were grouped in a single category to compare these materials with bulk-fill composites. The price and the type of composites were used in the regression models as aforementioned. Table 4 summarizes the linear regression models with the price as the predictor for the response variables; the multiple regression model results are found in Figures 2 and 3 and in Tables 5 and 6. The bulk-fill composites were purchased for a higher price (Table 4; USD 15.45; $p < 0.01$) when compared with the conventional ones, when adjusted for all response variables. The other response variables followed the findings of the price analysis performed for the conventional composites. The year, the procurement modality, the type of institution, and the manufactures influenced the unit price.

Compared with the conventional composites, the probability of purchasing the bulk-fill composites was modeled with a logistic model. An increase in the probability of purchasing the bulk-fill composites is observed over time, when compared with the conventional ones (Figure 2; OR = 3.14; $p < 0.01$). For each USD 10.00 increase, the odds of purchasing the bulk-fill increased by 64% (Figure 3). The North region presented a 5x higher probability of bulk-fill purchase when compared to the Southeast region (Figure 4). Universities were less likely to purchase bulk-fill composites than conventional resins when compared with other federal institutions (Figure 4; OR = 0.55; $p < 0.01$).

Table 4

Average price of all purchases (n = 17,702) by different covariates and adjusted price differences in the multiple linear regression model among conventional and bulk-fill composites purchases.

	Bivariate analysis				Adjusted differences	
	Average price (USD)	SD	Frequency	p-value	Coefficient	95%CI
Resin composite						
Conventional	22.13	16.47	17,702			
Bulk-fill	30.57	13.87	258	< 0.01	15.45	13.74; 17.08
Year						
2010	45.75	21.15	191			
2011	49.26	29.72	276			
2012	31.10	19.14	724			
2013	28.20	17.51	2,135			
2014	28.87	15.09	2,470			
2015	18.72	11.11	1,706			
2016	17.40	12.30	2,359			
2017	19.49	15.57	2,391			
2018	18.78	14.93	2,757			
2019	17.58	13.81	2,951	< 0.01	-2.43	-2.52; -2.34
Macroregion						
South	23.48	16.99	4,033		-0.24	-0.80; 0.32
Southeast	24.61	17.73	4,819			
Central-West	21.08	14.20	2,700		-2.25	-2.90; -1.60
Northeast	20.62	16.22	4,256		-0.34	-0.91; 0.22
North	19.36	14.70	2,152	< 0.01	-1.44	-2.13; -0.74
Procurement modality						
Auction	20.97	15.20	15,708			
Bid waiver	31.51	21.47	2,190		9.49	7.71; 11.27
Other	19.69	18.05	62	< 0.01	3.51	-0.05; 7.02
Type of institution						
Universities	20.72	16.08	3,878		-1.62	-2.11; -1.12
Other federal institutions	23.19	16.55	13,434			
Municipalities	11.96	12.36	648	< 0.01	-2.14	-3.57; -1.25

(continues)

Discussion

Over the years, changes in the resin composites formulations modified their physicomechanical properties and their application in restorative treatments, leading to the incorporation of new materials in the market share [6,7]. Among several attempts to increase their clinical effectiveness, the particle size modifications towards the nanoscale were shown to improve their properties, supporting the application of these materials in the clinical scenario. However, it is not clear how this knowledge affects the establishment of public policies in large-scale public health systems. In this study, we screened public procurements within a public health system, assessing the variables that may influence this process. Nanofilled resin composites were the most purchased materials over the 10 years analyzed, compared with other conventional composites. All analyzed variables influenced the unit price of resin composites, and they predicted an increase in the odds of purchasing nanofilled and nanohybrid composites over time. Bulk-fill composites are increasingly being purchased in the public system with higher costs when compared with conventional composites.

Table 4 (continued)

	Bivariate analysis				Adjusted differences	
	Average price (USD)	SD	Frequency	p-value	Coefficient	95%CI
Manufacturer						
3M	25.72	14.01	8,655			
Biodinâmica	7.73	9.09	932		-16.65	-17.57; -15.73
Coltene	13.06	12.60	537		-16.63	-17.51; -15.14
Densell	15.34	0	5		-20.71	-32.43; -9.98
Dentisply	16.47	14.46	500		-13.06	-14.29; -11.84
DFL	8.35	8.88	133		-15.49	-17.81; -13.17
FGM	13.18	11.98	2,841		-13.31	-13.88; -12.73
Ivoclar	42.72	15.55	391		17.52	16.15; 18.89
Kavokerr	14.40	13.54	364		-7.13	-8.54; -5.72
Kulzer	18.99	10.58	751		-7.74	-8.76; -6.72
Maquira	6.41	6.39	93		-15.29	-18.05; -12.54
SDI	16.13	9.65	40		-6.89	-11.05; -2.73
Shofu	88.89	5.87	11		58.48	50.58; 66.39
Technew	13.10	5.15	195		-8.47	-10.38; -6.57
Tokuyama	16.49	8.36	14		-9.48	-16.58; -2.38
Ultradent	17.66	16.77	79		-3.16	-6.13; -0.19
Voco	32.51	12.77	14		10.82	3.79; 17.84
Other	30.31	21.75	2,405	< 0.01	-6.01	-7.73; -4.28
Constant					5,933.22	4,751.87; 5,114.57

95%CI: 95% confidence interval; SD: standard deviation.

Note: $R^2 = 0.36$ for multiple regression.

Figure 2

Predictive margins with 95% confidence intervals in the adjusted logistic model showing the average response, over the years, for bulk-fill composites purchase with conventional composites as reference.

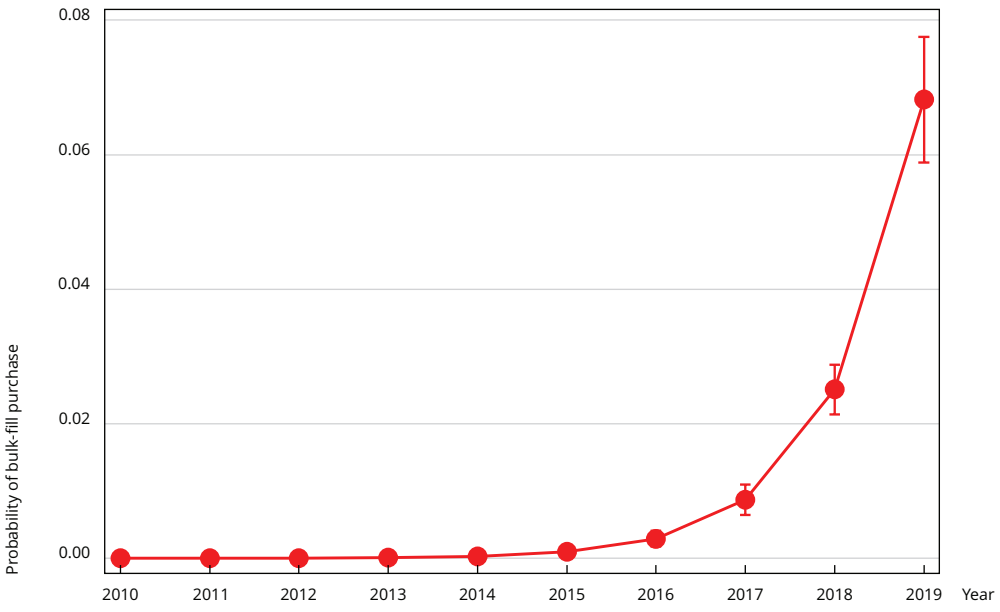
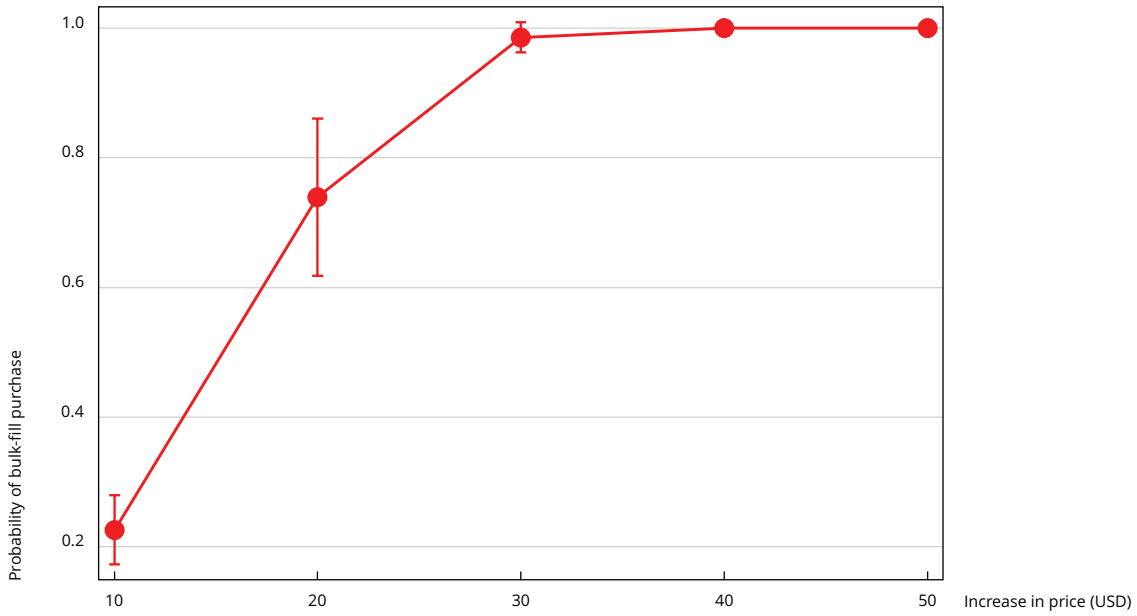


Figure 3

Predictive margins with 95% confidence intervals in the adjusted logistic model showing the average response, for the unit price, for bulk-fill composites purchase with conventional composites as reference.



Conventional composites corresponded to 98.5% of the total purchased items from 2010 to 2019 in the data from the BDHP (Figure 1). The reinforcing fillers characteristics divided the conventional composites in the database, and this information was used to compare the materials in this class of resin composites according to a previously reported classification [6]. Nanofilled composites are the most purchased materials showing that the collected data follows the current evidence that classifies the nanofilled and nanohybrid resin composites as being a state-of-the-art material within the field [6]. The nanocomposite formulation was the most recent formulation of conventional resin composites; which allows for the incorporation of increased amounts of fillers into the base resin and contributes to lower polymerization shrinkage, increased physical properties, and enhanced aesthetics [7]. Laboratory [8,25] and clinical [26,27,28,29] data suggest that nanocomposite formulation may present different behavior compared to microfilled compositions, showing better mechanical properties or increased long-term success for restorative treatments [6]. Despite differences in their composition, the annual failure rates for resin composite restorations are close to 2% regardless of the filler size [26,30,31]. Recently, the clinical evidence comparing hybrid composites with nanofilled and nanohybrids was systematically performed, showing no difference in surface features, risk of fracture, loss of restoration, and annual failure rates between different filled composites [9,32]. Despite conflicting results being found in the laboratory and clinical evidence, it is possible to observe that nanocomposites are well-established within the analyzed data, considering that these materials were more recently included in the market. The year significantly predict an increase in the purchase of nanohybrids and reduction in the purchase of hybrids, microfilled, and microhybrids composites when compared with nanofilled. The increase in the probability of purchasing nanocomposites is observed even considering their higher costs. However, the year predicted a reduction in the average unit price in the adjusted model (Table 1; -USD 2.61/year; $p < 0.001$), contributing to the reduction in prices of these materials. Although nanocomposites were the newest materials among the conventional composites, their effectiveness

Table 5

Univariate analysis for conventional and bulk-fill composites according to the selected variables.

	Resin composite		Total	p-value
	Conventional	Bulk-fill		
Year				
2010	191	0	191	
2011	276	0	276	
2012	724	0	724	
2013	2,135	0	2,135	
2014	2,470	0	2,470	
2015	1,706	0	1,706	
2016	2,359	0	2,359	
2017	2,389	2	2,391	
2018	2,643	114	2,757	
2019	2,809	142	2,951	
Total	17,702	258	17,960	0.001
Macroregion				
South	3,996	37	4,033	
Southeast	4,791	28	4,818	
Central-West	2,654	46	2,700	
Northeast	4,196	60	4,256	
North	2,065	87	2,152	
Total	17,702	258	17,960	0.001
Procurement modality				
Auction	15,497	211	2,190	
Bid waiver	2,144	46	15,708	
Other	61	1	62	
Total	17,702	258	17,960	0.001
Type of institution				
Universities	3,838	40	3,878	
Other federal institutions	13,236	198	13,434	
Municipalities	628	20	648	
Total	17,702	258	17,960	0.001

was described in the early 2010s, and thus, it is expected that the translation of knowledge associated with these materials had overcome the gap between research and clinical practice [15]. The reduction in prices also corroborate with the increase in popularity of nanocomposites.

Besides the year of purchase, all other variables influenced the unit price of resin composites (Table 1). The adjusted model shows that the reinforcing filler drives differences in the unit price, and when compared to nanofilled composites, only the nanohybrids are purchased at higher prices (1.58; $p < 0.001$). Also, for each increase in USD 10.00 in the unit price, the nanohybrids were 7% more likely to be purchased, whereas hybrids, microfilled, microhybrids, and all flowable composites were less likely to be chosen when compared with nanofilled composites (Table 2). While the differences among composite prices may affect the total amount spent in a public health system, people responsible for public procurements must critically evaluate the cost-effectiveness of the restorative treatments in the formulation of public policies for materials purchase. The development of new composites for dental restorations aims to improve the quality of treatments, and new materials are constantly being developed in the field [33,34,35]. The economic impact of the implementation of new technologies is known to happen in other areas of healthcare [36], and this may be balanced with the possible benefits of these technologies for the population primarily based on the effectiveness of these materials. While the

Table 6

Logistic regression model comparing bulk-fill purchases to conventional composites ones.

	Bulk-fill	
	OR	**95%CI**
Year	3.14	2.67; 3.69
Price *	1.64	1.53; 1.77
Macroregion (reference: Southeast)		
South	1.72	1.03; 2.87
Central-West	2.88	1.76; 4.73
Northeast	2.96	1.82; 4.83
North	5.51	3.48; 8.73
Procurement modality (reference: auction)		
Bid waiver	1.19	0.81; 1.77
Other	0.79	0.09; 6.70
Type of institution (reference: other federal institutions)		
Universities	0.55	0.37; 0.82
Municipalities	3.82	2.27; 6.42
Constant	0.00	-

95CI: 95% confidence interval; OR: odds ratio.

* For each increase in USD 10.00.

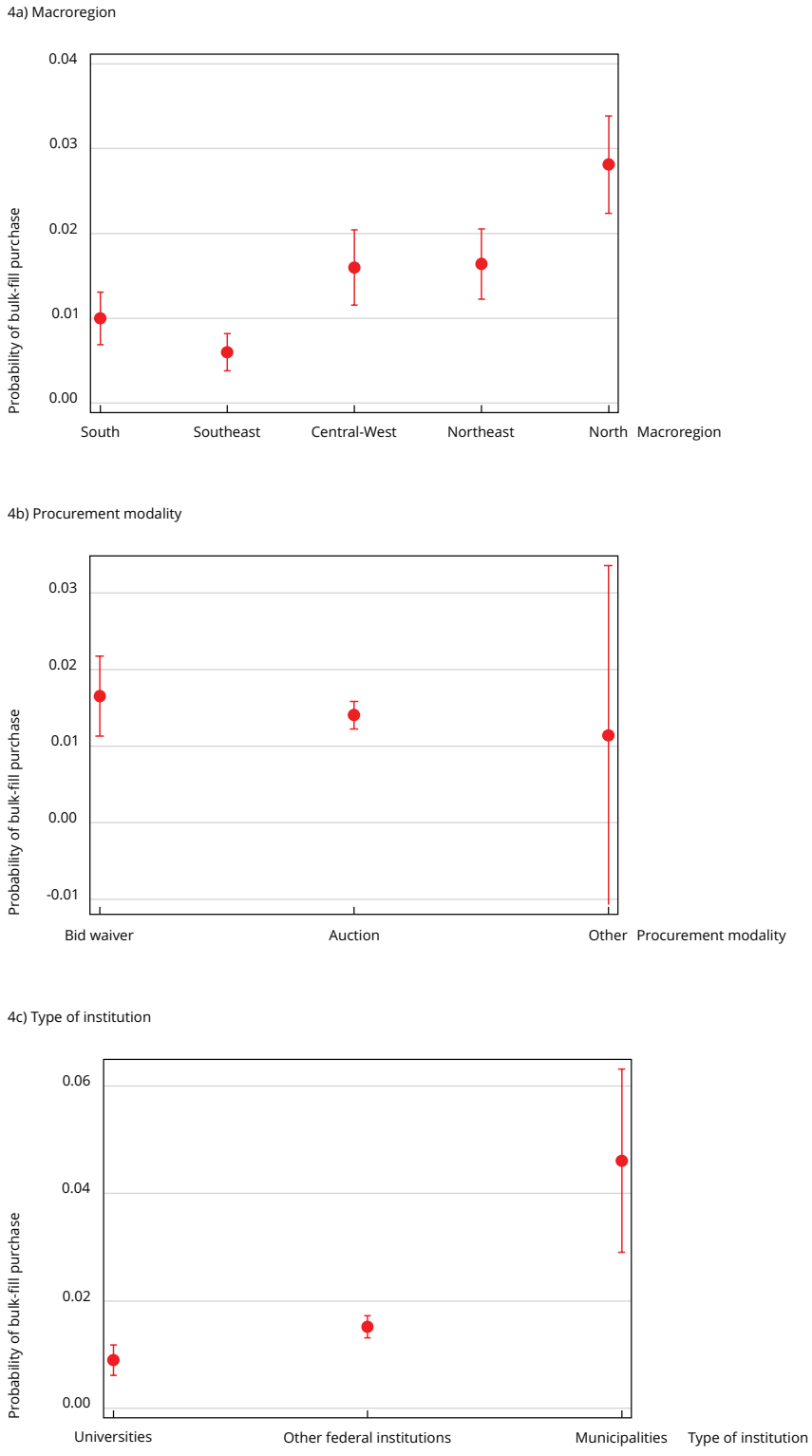
price may influence the decision-making process, it does not uniquely determine the treatment cost. Public managers must consider the overall cost for implementation of new materials in a broad sense, considering direct costs for treatment and possible retreatments, as well as the indirect and intangible costs related to the population's health and quality of life [37,38].

The price differences may also be explained by socioeconomic characteristics found over the country, the type of institution, and the procurement modality. These factors may influence access to information in different places and institutions, impacting the decision-making process and the establishment of evidence-based practices in the selection of materials [39]. Universities may be more up-to-date in the advances in the scientific field, and this may facilitate the two-way interaction in the knowledge translation, between research findings and the clinical practice [39]. We observed that universities are more likely to choose nanocomposites in their composite procurements, when compared with other federal institutions (Table 2), highlighting a possible slower translation of knowledge in non-academic fields. Although universities are more prone to purchase nanocomposites, the adjusted unit price in the procurement process is lower when compared with other institutions (Table 1; -USD 1.67; $p < 0.01$). Controlling the unit price in these public procurements is complicated, since many variables are involved in the process; however, the modeled data suggest that procurement processes that are performed under the auction modality may be efficient in reducing prices, even when the most expensive materials are chosen (Table 1). This modality is recommended by regulatory agencies [23,40] and could be an effective strategy to establish rationality in the public expenditure to achieve cost-effectiveness in the health system.

The most recent innovation in the field of resin composites is low-shrinkage materials [6]. The bulk-fill composites were developed based on a simplification concept to guarantee an adequate polymerization, without the need for incremental technique [11]. Despite the conflicting results found in in vitro attempts to reduce the shrinkage in these materials, recent data supported their application on direct restorative procedures with comparable results to conventional composites [12,41]. The BDHP registered the first bulk-fill purchase only in 2017, and the number of analyzed processes corresponds to 1.5% of all procurements for resin composites (Figure 1). However, from 2017 an increase in the number of purchased bulk-fills is observed regardless of their higher cost (Table 4). This result is followed by logistic regression findings that show an increase in the odds of purchasing bulk-fill, instead of a conventional composite, as the price increased (Figure 2; Table 6).

Figure 4

Predictive margins with 95% confidence intervals in the adjusted logistic model showing the average response for the variables in bulk-fill composites purchase with conventional composites as reference.



The trend for an increase in the bulk-fill procurement process in the last years is observed in the predictive margins that calculate the average probability in the response variable, based on the predictors in the adjusted model (Figure 3). The logistic model predicts 3.14x higher odds of purchasing bulk-fill composites for each price increase over the years when compared with the conventional ones (Figure 3; Tables 5 and 6). The simplification appeal for this type of composites contributed to its popularity among dentists in the last years, as growing evidence is being generated showing laboratory [13,42,43,44] and clinical [12,13,45,46,47,48] outcomes related to these materials. Notably, these procurements still represent a small fraction of the overall process and this is not consistent with the institutions in the country. The universities are 45% less prone to purchase bulk-fills when compared to other federal institutions (OR = 0.55; $p < 0.01$), while the most developed region (Southeast) in the country is less likely to purchase bulk-fills when compared with the other regions (Table 6). These results are contrary to the conventional composites results, in which the institutions that are more closely related to the scientific knowledge were more likely to purchase newly developed materials. In this case, the difference could be related to the maturity in the evidence to support the large-scale implementation of healthcare technologies [21,36]. While innovation is desired – and the gap between scientific development and clinical practice should be narrowed – the establishment of synthesized evidence of its effectiveness and the translation of this information may take time [17]. The synthesized evidence about the clinical effectiveness of bulk-fill composites is recent [12,13], and these studies highlight the need for further analysis with long-term follow-ups to support their findings. Strategies for the implementation of new technologies and material in restorative dentistry are limited, and they are usually centered in an individual experience [49,50,51,52] or generic recommendations for healthcare services [53,54]. Technology assessments and horizon scanning for healthcare technologies, usually for new drugs, are recommended by the Brazilian Ministry of Health in the attempt to identify emerging technologies from research and development process, understand its adoption and performance allowing rational decisions in the modifications of healthcare patterns [55,56,57]. The use of implementation strategies in Dentistry, and especially in restorative treatments, may contribute towards the use of simplified composites in the public system. Changes may be performed with caution, especially considering the economic impact observed in this analysis (Figure 2).

In this study, secondary data were used to evaluate resin composite purchases, and such databases have limitations. The BDHP is filled by local managers in different institutions over the country following no standardization, which introduces random and measurement errors in the registration process. Although inconsistencies were detected in the current data, sensitivity analysis was performed to assess the impact of such issues. The results were robust and the conclusions remained unchanged. The high number of purchases registered over the last 10 years provide significant data for analysis and it is expected that the adherence to government recommendations, for product registration in the database, may contribute to future studies and for the formulations of public policies in the purchase of healthcare products for restorative treatments. Understanding the type of resin composite used in the public health system, considering the characteristics of this process, shows the importance of an evidence-based decision-making process by public institutions to maintain and to improve the quality of provided restorative treatments. The differences between institutions over the country must be considered in the attempt to draw strategies for better allocation of resources in the purchase of clinical and cost-effective materials. The continuous analysis of evidence and the application of strategies to control prices could contribute to the implementation of new technologies to improve healthcare and to minimize the impact of these materials on public resources. Assessing the adherence to scientific evidence in the clinical practice over time may also contribute to the interaction between research and development areas to produce improved materials in consonance with the population's needs.

Conclusions

The procurement processes in this 10-year analysis were mostly performed to purchase nanofilled conventional composites. In the most recent year, procurements conducted in universities were made by the auction modality at lower prices when considering the conventional and the bulk-fill composites. The conventional nanocomposites and bulk-fill resin composites were increasingly purchased over the years, despite the predicted higher unit prices of the items. These findings highlight possible modifications to the standard-of-care provided in the analyzed public health system, how the prices may influence the market share, and how the translation of knowledge may occur from the development of new materials to their clinical application.

Contributors

G. S. Balbinot contributed to the study conception, data analysis and curation, and writing. R. K. Celeste contributed to the data analysis and curation, writing, and review. V. C. B. Leitune contributed to the writing and review. F. M. Collares contributed to the study conception, writing, and review. All authord approved the final version of the manuscript.

Additional informations

ORCID: Gabriela de Souza Balbinot (0000-0001-9076-2460); Roger Keller Celeste (0000-0002-2468-6655); Vicente Castelo Branco Leitune (0000-0002-5415-1731); Fabrício Mezzomo Collares (0000-0002-1382-0150).

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Resumo

O estudo buscou avaliar as compras de resina composta em um sistema público de saúde e compreender as variáveis associadas com o custo e o processo decisório ao longo dos últimos dez anos. Os dados secundários foram coletados do Banco de Preços em Saúde (BPS), do governo federal, entre 2010 e 2019. Foram selecionadas todas as resinas compostas convencionais e bulk-fill*. Os seguintes dados foram coletados: data de compra, tipo e localização da instituição, modalidade de licitação, número de itens comprados, fabricante e preços unitários. Um modelo de regressão linear múltipla avaliou o impacto do preço nas variáveis de licitação, enquanto a regressão logística variada comparou as probabilidades de compra entre os materiais. Foram coletadas 18.138 observações com 2.129.294 unidades compradas e um custo total de USD 43.504.260,00. As resinas convencionais apareceram em 98,5% dos processos de licitação. As resinas convencionais* nanofilled *foram os materiais mais comprados, com um aumento na probabilidade de compra ao longo do tempo, apesar dos preços mais elevados. Foi previsto um aumento nos preços de materiais* bulk-fill *em comparação com os convencionais. A probabilidade de compra dessa categoria aumentou em 3,14 vezes por ano. Variáveis sociodemográficas e educacionais influenciam os preços e a probabilidade de compra no sistema de saúde. As resinas* nanofilled *e* bulk-fill *são incluídas cada vez mais na prática clínica. Os achados destacam possíveis modificações no padrão de tratamentos de restauração e na maneira que a translação de conhecimento pode ocorrer, desde o desenvolvimento de materiais novos até a aplicação clínica, à luz do impacto econômico dessas modificações.*

Materiais Dentários; Sistemas de Informação; Odontologia em Saúde Pública; Translação do Conhecimento; Custos e Análise de Custo

Resumen

El objetivo de este estudio fue evaluar las adquisiciones de resina compuesta en un sistema público de salud y comprender las variables asociadas con el coste y proceso de toma de decisión a lo largo de los últimos diez años. Se realizó una recogida de datos en el Banco de Datos de Precios de Atención Sanitaria (BDHP), de Brasil, de 2010 a 2019. Se seleccionaron todas las resinas convencionales y bulk-fill*. Se recogieron: fecha de compra, tipo de institución y localización, modalidad de adquisición, número de ítems comprados, manufactura, y precios unitarios. Un modelo de regresión lineal múltiple evaluó la influencia del precio en las variables de adquisición, mientras una regresión multinomial logística comparó las probabilidades de compra entre los materiales. Se recogieron 18.138 observaciones con 2.129.294 unidades adquiridas y un coste total de USD 43.504.260,00. Las resinas convencionales aparecieron en un 98,5% del proceso de adquisición. Las resinas convencionales de nanorelleno fueron los materiales más comúnmente comprados, con una probabilidad mayor de compra a lo largo del tiempo, pese a sus precios más altos. Se predijo un aumento de los precios en los materiales* bulk-fill*, cuando se compararon con los convencionales. La probabilidad de compra en esta categoría se incrementa un 3,14x por cada aumento durante el año. Las variables sociodemográficas y educacionales influencian los precios y la probabilidad de adquisición en el sistema de salud público. Las resinas de nanorelleno y* bulk-fill *están incluidas cada vez más en la práctica clínica. Estos resultados subrayan las posibles modificaciones en el estándar de cuidado de los tratamientos restaurativos, y cómo se produce la transferencia de conocimientos, desde el desarrollo de nuevos materiales hasta su aplicación clínica, a la luz del impacto económico de estas modificaciones.*

Materiales Dentales; Sistemas de Información; Odontología en Salud Pública; Traslación del Conocimiento; Costos y Análisis de Costo

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