Cost-effectiveness of glass ionomer cements in Atraumatic Restorative Treatment

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Abstract

Background

High-viscosity glass ionomer cements are the preferred materials for conducting restorations using Atraumatic Restorative Treatment (ART). However, there are more affordable alternatives available in the market that do not possess high viscosity. The objective of this study was to evaluate the cost-effectiveness of Glass Ionomer Cement (GIC) for Atraumatic Restorative Treatment (ART) in deciduous teeth.

Methods

The study conducted an economic analysis of the cost-effectiveness type. The cost of ART was determined using micro-costing techniques, and the survival rates after 1 year (effectiveness) were obtained from existing literature studies. Decision trees were constructed to compare the materials used in ART for both simple and composite cavities, considering the perspective of the local health manager. To estimate the cost-effectiveness of treating 1000 primary teeth, a Monte Carlo microsimulation was performed. The incremental cost-effectiveness ratio (ICER) was used to indicate the additional cost required to increase effectiveness after 1 year. The analyses were conducted using TreeAge Pro software.

Results

Regarding ART in single cavities, Maxxion R (FGM) was found to have a lower cost (BRL 22,945.23), while Ketac Molar (3M ESPE) exhibited greater effectiveness (891.3 teeth). The alternatives FUJI IX (GC America, ICER = 3.12) and Ketac Molar (ICER = 5.27) were considered more cost-effective. For composite cavities, Ketac Molar (ICER = 3.65) was identified as the most cost-effective option.

Conclusion

The study revealed variations in both cost and effectiveness among different materials used in ART. Lower cost may indicate lower effectiveness.

Background

Dental caries represents a serious public health challenge worldwide[1]. Despite being preventable, caries is highly prevalent throughout the course of life[2]. It was estimated that in 2017, nearly 600 million teeth had not received treatment for caries in the primary dentition[3]. Failure to treat caries leads to psychological, functional and social damage, directly impacting family life[2]. Due to the costliness of performing dental treatments, which makes universal reach impossible, Minimal Intervention Dentistry (MID) becomes a feasible option for radically reducing the cost of dental treatment[3].

MID has grown in recent years as a patient-centered philosophy being biologically and economically acceptable. This contemporary way of providing dental care implies changes in the field of public health[4]. The understanding of MID is that the dental structure is kept in the mouth in a healthy way for as long as possible, this favors the conservation of the dental structure and pulpal health[5]. Among the possibilities offered by MID, Atraumatic Restorative Treatment (ART) is considered the treatment of choice for dentin caries, aligning with the International Caries Consensus Collaboration[6].

ART was created in the 80s to be used in the most adverse situations, where there is no water, electricity and/or dental equipment. However, its use has been disseminated beyond remote locations[7]. Due to the selective removal of dental caries, the use of dental anesthesia is significantly reduced, which is beneficial for pediatric patients[6]. Glass Ionomer Cement (GIC) is the recommended material for sealing cavities using ART[8].

GICs are biomaterials consisting of a mixture of powder and liquid. They have the following characteristics: favorable setting time, chemical bonding with enamel and dentin[9], in addition to continuous fluoride release, which contributes to a possible inhibition of caries formation[10]. High-viscosity GICs are the materials of choice for creating ART[8,9] restorations. However, in the Brazilian market, there are cheaper options, which, although not high viscosity, are indicated for use in ART by manufacturers and could potentially reach a greater number of users if used in public services[9]. However, these cheaper options have very dubious effectiveness, and therefore their choice should be analyzed with great care.

There is a range of studies in the literature that verified the effectiveness of these GICs, however, there is still a great heterogeneity in the ART survival rates, mainly for composite restorations in deciduous teeth[11]. Accompanied by the variation in effectiveness, the costs of these materials can also vary, reaching differences of around 70% between one product and another[9].

Despite having a clear relevance to reduce the cost of dental care, MID approaches have not yet been implemented in countries as oral health policies[1]. For this implementation to occur effectively in the Brazilian Unified Health System (SUS), an economic analysis is necessary to reduce the opportunity cost, as well as to increase access to oral health. Therefore, the aim of this study is to verify the cost-effectiveness of GICs used in ART in primary teeth of 5-year-old children.

Methods

General Outline of the Study

A complete economic evaluation of the cost-effectiveness type was designed according to the Economic Evaluation Guidelines of the Brazilian Health Technology Assessment Network (REBRATS)[12,13], conducted using computerized modeling and reported according to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS)[14]. The model variability was analyzed using a Monte Carlo micro-simulation.

Characterization of the Problem

From the perspective of the public sector, what is the most cost-effective glass ionomer cement to perform atraumatic restorative treatment on molar teeth of children *aged 5 years*, in simple and compound cavities*?*

Outlook and Target Population

For this analysis, the perspective of a local health manager was adopted, based on financial transfers for the provision of dental services. The population used for the analysis model consisted of a hypothetical cohort of 1000 teeth (patients aged 5 years). These patients should have one or more molar teeth compromised by caries, requiring a restorative intervention in a simple or composite cavity. This study did not consider the need to repair pre-existing restorations.

Interventions

A single intervention (ART with CIV) was proposed for the problem situation (dental caries at 5 years old) placed in the hypothetical cohort. The difference lies in the materials used, since the presence of high-viscosity IVC are more expensive, and the low-cost ones available for the Brazilian market can bring considerable variation in the survival of treatments and in the parameters of cost and effectiveness. It was decided to use only the GICs that are presented in powder + liquid form, to maintain standardization and in view of the availability of studies.

Discount Rate and Time Horizon

An annual discount rate of 5% was applied to the costs, as per the guidelines of the REBRATS Guidelines[12]. The time horizon of the analysis was defined as 12 months. This time horizon was defined according to the time used by most studies in effectiveness assessments.

Model Structure

Two decision trees were developed specifically for this study, with the aim of capturing the clinical and economic results of the proposed materials (Fig. 1A and B). The model consisted of two mutually exclusive health states: rehabilitated without complications (state A) and failure (state B). The success of the materials (state A) was associated with the functional maintenance of the restorations during the 1-year period. Failure (state B) is related to the irreversibility of success (restoration fracture, pulp exposure, extraction) during the same period.

Model Input Parameters

Cost

Cost data collection was based on the micro-costing technique, in which the direct costs incurred to perform a primary molar tooth restoration using the ART technique were considered. This estimation took place in three steps:

1 – Identification of all the necessary resources to conduct the ART.

2 – Quantification of resources needed for each restoration performed, using the bottom-up technique.

3 – Valuation of consumed resources, in monetary terms, in Brazilian Reais (R$).

The values were extracted from three websites specialized in the area to compose an average market price. The collection of this information took place in October 2021. The data were categorized for performing simple and composite cavities, where they are differentiated by the instruments used, clinical time and amount of VSD. The clinical time, measured in minutes, was based on two studies[15,16].

For the cost of restoring simple cavities, the following were considered: clinical mirror, explorer probe, clinical tweezers, dentin excavator, plastic ionomer spatula, insertion spatula, cap, gloves, disposable mask, n95 mask, face shield, cotton roller, hydrophilic cotton roll, solid Vaseline, carbon paper, glass ionomer cement, dental surgeon, oral health assistant. For composite cavities, the Tofflemire matrix holder and metallic matrix band tape was also added.

Effectiveness

Effectiveness was defined from a literature search (Randomized Clinical Trials) by success and failure rates and years of survival. The survival parameter was set at 12 months, to cover a larger number of products. The published articles were published between 1999 and 2021 and composed the average effectiveness for single cavities of the materials FUJI IX[17–28], Ketac Molar[15,17,25,29,30–35], Ionofil[36], Maxxion R[9,24,33], Vitrofil[33,37], Vitromolar[9,34,35,38], and for compound cavities: FUJI IX[17–22,25,28,39], Ketac Molar[11,15,20,25,29,31,32,35], Maxxion R[24], Vidrion[29], Vitromolar[11,35,40].

Analyses

The analyses were performed using the TreeAge Pro Version 2019 R1.1 software. The models analyzed according to Monte Carlo microsimulation generated dynamic tests and acceptability curves. Gamma distributions were obtained for the parameters of cost, effectiveness and probability of failure, considering the variation of the parameters in 5%, according to the guidelines of REBRATS[12]. The cost-effectiveness of interventions was compared using the Incremental Cost Effectiveness Ratio (ICER).

Results

For single cavities, the individual price of the restorations varied little, ranging from R$22.94 to R$24.79, with an average effectiveness of successful restorations ranging from 54.2–89.12% after 12 months. The results of the cost-effectiveness analysis considering the occlusal restoration of 1000 deciduous molar teeth are shown in Table 1 and Fig. 2. In Fig. 2-A, it is observed that the materials Vidrion and Ionofil were dominated, meaning that there are other materials with lower prices and superior effectiveness.

Table 1
Cost-effectiveness analysis results for 1000 single cavities treated with GIC in ART, using Monte Carlo microsimulation.

Material	Cost (R$)	Cost Incr (R$)	Effec	Effec Incr	RCEI	NMB
Maxxion R	22.945,24		540,84			
Vitro Fil	22.985,63	40,39	640,90	100,06	0,40	18,54%
Vidrion*	23.083,05	137,82	629,62	88,79	1,55	16,45%
VitroMolar	23.257,84	312,60	799,69	258,85	1,21	47,95%
Ionofil*	23.321,97	376,74	709,37	168,53	2,24	31,22%
Fuji IX	23.895,55	950,31	845,36	304,53	3,12	56,40%
Ketac	24.793,66	1.848,42	891,33	350,49	5,27	64,91%

*Dominated Technology. Cost: Cost of treatment (in R$), Incremental Cost (Cust Incr): Additional cost compared to the previous option (in R$), Effectiveness (Effec): Number of successfully treated teeth, Incremental Effectiveness (Effec Incr): Additional number of successfully treated teeth compared to the previous option, Cost-Incremental Effectiveness (ICER): Ratio of incremental cost to incremental effectiveness, Net Monetary Benefit (NMB): Overall financial benefit of the treatment.

Among the non-dominated or dominant technology Among the non-dominated or dominated materials, the manager must pay attention to the ICER, this measure identifies the incremental value needed to invest and achieve a greater measure of effectiveness (successfully restored tooth). In Table 1, ICER values are being compared with the lowest cost material (Maxxion R). By adopting Vitro Fil, for example, it is possible to observe that with an additional cost of R$0.40 (forty cents) for each tooth, success is obtained in more than 100 teeth (Effec Incr) of the 1000 analyzed, when compared to Maxxion R.

Table 2
Cost-effectiveness analysis results for 1000 composite cavities treated with GIC in ART.

Material	Cost (R$)	Cost Incr	Effec	Effec Incr	RCEI	NMB
Vidrion	33.248,54		180,12			
Maxxion R	33.278,94	30,40	368,56	188,44	0,16	105,21%
VitroMolar	33.428,54	180,00	567,11	387,00	0,47	216,05%
Fuji IX	34.211,68	963,14	676,16	496,04	1,94	276,92%
Ketac	35.110,84	1.862,30	689,33	509,21	3,66	284,26%

Cost: Cost of treatment (in R$), Incremental Cost (Cust Incr): Additional cost compared to the previous option (in R$), Effectiveness (Effec): Number of successfully treated teeth, Incremental Effectiveness (Effec Incr): Additional number of successfully treated teeth compared to the previous option, Cost-Incremental Effectiveness (ICER): Ratio of incremental cost to incremental effectiveness, Net Monetary Benefit (NMB): Overall financial benefit of the treatment.

In Fig. 2-B, the sensitivity analysis of cost-effectiveness shows the overlapping points between the studied materials, this demonstrates that some materials can behave in the same way in a real scenario due to the variability of cost-effectiveness. In Fig. 2-C, it is observed that in a willingness to pay of up to R$10.00 per tooth, VitroMolar should be the material of choice, between R$15.00 and R$20.00 Fuji should be chosen, for greater willingness to pay, Ketac should be the choice.

For composite cavities, the individual price of restorations also had a small variation, ranging from R$33.24 to R$35.11 and an average effectiveness of successful restorations between 18.01% and 68.26% after 12 months. The results of the cost-effectiveness analysis considering the restoration composed of 1000 deciduous molar teeth are shown in Table 2 and Fig. 3.

For this analysis, no technology was found to be dominated. It is possible to observe that with more R$0.16 (ICER) for each tooth, it is possible to obtain success in more 188 (Effec Incr) teeth when comparing the Maxxion R in relation to the Vidrion. All materials are being compared with the lowest cost (Vidrion) (Table 2).

In Fig. 3-A, it is observed that a higher cost was associated with greater effectiveness. In Fig. 3-B, the comparison between materials reveals a greater distinction in terms of effectiveness, however with a greater similarity between the Fuji IX and Ketac materials. In Fig. 3-C it is possible to observe that Fuji IX can be an option of choice, if the willingness to pay is up to R$70.00, for a greater availability of resources, Ketac should be the material of choice.

Discussion

The results of the present study indicate that for simple cavities, considering the relationship between health gain and cost, the Vidrion and Ionofil materials should not be considered for implementation in public health services, considering that their effectiveness does not follow the cost, which make to be dominated options within health economics analysis. Among the non-dominated technologies, that is, the cost and effectiveness are equivalent, Maxxion is the one that would allow a greater number of teeth restored at a lower cost, however, its effectiveness after 12 months is low when compared to materials such as Fuji and Ketac, which have a higher cost.

When analyzing the materials for composite cavities, none of the technologies were found to be dominated, however, an extremely low effectiveness was observed, mainly between the Vidrion and Maxxion R materials. Again, Fuji and Ketac were the ones that presented the best effectiveness performance; however, it would be greater willingness to pay on the part of the manager to opt for these materials.

In view of the findings of this study, the importance of ensuring timely care for children intensifies to prevent the progression of caries, destruction of the dental element with consequent impact on the quality of life related to oral health[41] and the increase in health expenses. Monetary impact studies are necessary in these cases to evaluate the long-term implications of adopting specific materials for large-scale use, considering that in cases of failure, the need to redo the restoration could generate losses for patients in addition to expenses additional health.

Data from the present study show that the materials used in ART have a variation in effectiveness rates, however, this technique has several advantages from a clinical and financial point of view[16] and this suggests that it can be used in a program within the policy national oral health service, considering that the benefits outweigh the costs. It should be noted that there is a greater need for personal protective equipment because of the covid-19 pandemic, such as N95 mask and face shield. These additions tend to raise the overall cost of dental care, as identified in a study that assessed the impact of the pandemic on dental care costs.

When implementing this program and achieving continuity of care, other facets that were not economically evaluated in this study need to be incorporated into the oral health policy, such as: oral hygiene guidance programs, topical application of fluoride varnish, diamine fluoride silver, among others. This set of actions could, over the years, further reduce the need for restorative treatments, and consequently, improve the quality of life of users and redirect health spending.

With the help of cost-effectiveness analyses such as this one, we can support the manager's decision-making based on the judgment between the expected benefit and the expenditure limit. It is worth noting that decision-making in health must consider the best available evidence, the preferences of patients and professionals, as well as the availability of resources involved in offering treatments[43]. Studies already show a high acceptability of pediatric patients regarding ART, which is also a positive point for the implementation of this program[44–46].

The choice of a material with low effectiveness can cause waste of public resources and harm to patients due to the need for retreatment. If we consider that we are operating within a public health system that aims to provide comprehensive care for its patients, when we adopt a material like Maxxion, in 12 months, out of 1000 children treated with occlusal caries, 460 will need retreatment. With Ketac, this number would drop to 109. Thus, analyzing only the costs, especially for just 12 months, may be underestimating the real financial impacts of this adoption.

In addition to the financial field, it is necessary to think about the oral health of the population that will benefit from this offer of care in the SUS. Choosing a cheaper material will be related to the need for faster re-intervention, that is, rework. A re-intervention on a restoration may involve repair or replacement, increasing the likelihood of requiring additional dental procedures. The long-term cycle of interventions emphasizes that restorative interventions cannot be repeated endlessly: each restoration is larger than the last and, at some stage, restorative options may run out, necessitating tooth removal[47].

Among the limitations of this study, we can mention that it is a theoretical analysis based on data published in scientific journals so far on the effectiveness of materials, a broad search was conducted to build an average capable of approach the reality of each locality. However, for some materials the number of available studies is not so high, as well as there are differences in the follow-up time between the materials. New effectiveness studies may emerge and the need to conduct a new cost-effectiveness analysis.

Another point is the lack of studies that follow up patients after failure, raising questions: is the second restoration less effective than the first? What is the rate of catastrophic failures leading to tooth loss? In addition, the values related to costs do not consider the displacement of oral health teams to the place of interventions, as well as it does not provide for the provision of expenses with training courses for these teams. It should be noted that the analysis was built for the Brazilian market, and there may be variations between states, and should only be extrapolated to another country and/or health system, if the cost information is updated for the local reality.

Finally, the manager's willingness to invest in oral health services should carefully evaluate the data contained in this study. The poor choice of a material to be used by a large audience can lead to significant future challenges for the local health system, as opting for a low-cost material may result in higher expenses overall. We recognize the need to bring management closer to the academy, since the bidding process cannot be used as a justification for the acquisition of low-cost, low-quality and effective materials. Therefore, a better scientific basis for the manager could generate better benefits for society. Therefore, observing the analyzed scenarios, Fuji and Ketac materials should be widely considered by the management for a large-scale implementation, in which the initial investments will be overcome by the high effectiveness.

Conclusion

The Fuji and Ketac materials presented the best cost-effectiveness performances for the treatment of caries in deciduous teeth, considering the time horizon of 12 months. Therefore, the health manager's willingness to pay should consider the effectiveness of the materials, given that the need to repeat the treatment will increase oral health costs in the long term and may cause harm to patients.

Abbreviations

GIC
Glass Ionomer Cement
ART
Atraumatic Restorative Treatment
SUS
Brazilian Unified Health System

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ROS design of the work and the acquisition, analysis and have drafted the work or substantively revised it, ECFA the acquisition, analysis, LLSF the acquisition, analysis, MMB have drafted the work or substantively revised it,YWC the acquisition, analysis and have drafted the work or substantively revised it, EHGL design of the work and have drafted the work or substantively revised it.

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Figures

Figure 1

A - Decision tree used for Monte Carlo microsimulation, where cost and effectiveness estimates are assigned to each GIC proposed for use in ART in single cavities for the treatment of caries in children aged 5 years. **B -** Decision tree used for Monte Carlo microsimulation, cost and effectiveness estimates are assigned for each GIC proposed for use in ART in composite cavities for the treatment of caries in children aged 5 years old.

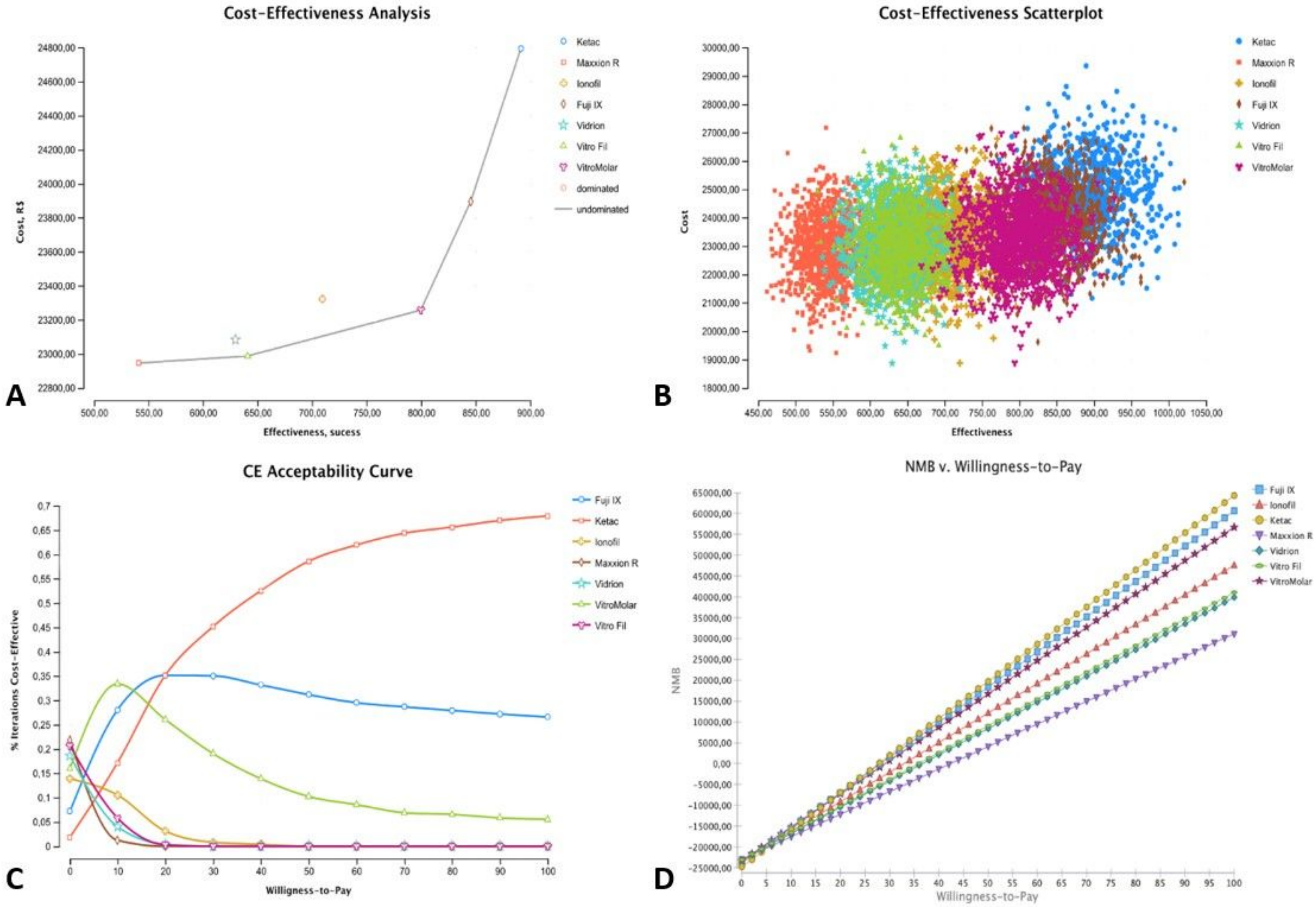

Figure 2

Cost-effectiveness analysis for IVC used in ART in single cavities. **A -** Cost and effectiveness are projected in Cartesian points. The union between the points by a line means that these materials did not dominate each other. **B -** Distribution of costs (in Brazilian Reais) and effectiveness (survival after 12 months) of the materials under investigation. The distribution of points symbolizes the points of variability after Monte Carlo microsimulation (variation of parameters by 5%). **C -** Acceptability curve for decision making on each of the interventions, according to willingness to pay. More cost-effective materials occupy the top of the chart as per willingness to pay. **D –** Net Monetary Benefit based on willingness to pay. Materials with greater monetary benefit come out on top with increasing willingness to pay.

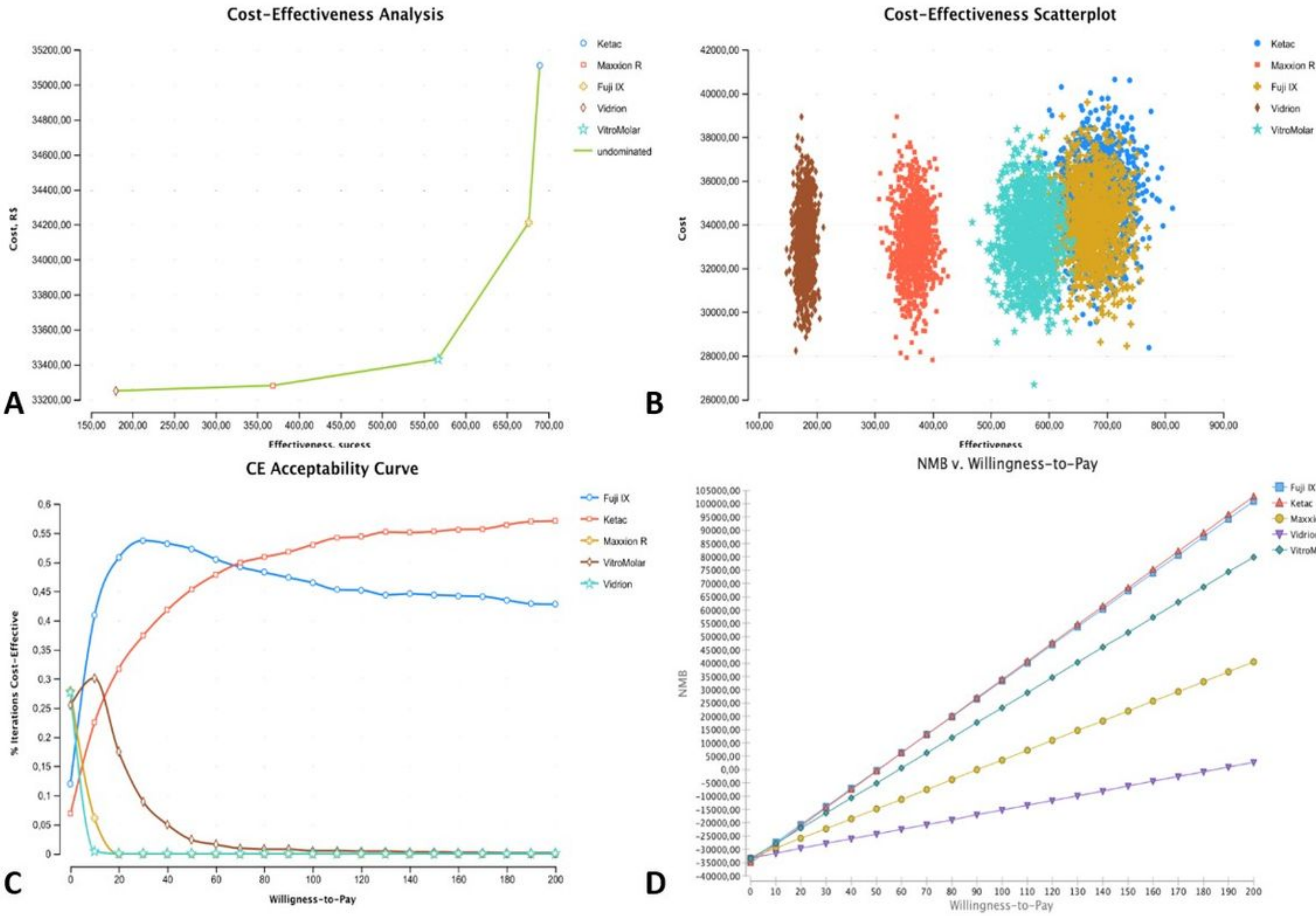

Figure 3

Cost-effectiveness analysis for CIV used in ART in composite cavities. **A -** Cost and effectiveness are projected in Cartesian points. The union between the points by a line means that these materials did not dominate each other. **B -** Distribution of costs (in Brazilian Reais) and effectiveness (survival after 12 months) of the materials under investigation. The distribution of points symbolizes the variability after Monte Carlo microsimulation. **C -** Acceptability curve for decision making on each of the interventions, according to willingness to pay. More cost-effective materials occupy the top of the chart. **D –** Net Monetary Benefit based on willingness to pay. Materials with greater monetary benefit come out on top with increasing willingness to pay.