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Biomimetic Restorative Dentistry: an evidence-based discussion of common myths

Alessandra REIS[1] | Victor Pinheiro FEITOSA[2] | Ana Cláudia CHIBINSKI[1] | Michael Willian FAVORETO[1,3] | Mario Felipe GUTIERREZ[4] | Alessandro Dourado LOGUERCIO[1]

[1]Universidade Estadual de Ponta Grossa, Departamento de Odontologia Restauradora,Paraná, Brasil.
[2]University of Iowa College of Dentistry, Department of Operative Dentistry, Iowa City, IA, USA.
[3]Universidade Tuiuti do Paraná, Departamento de Odontologia Restauradora, Paraná, Brasil.
[4]Universidad de los Andes, Chile. Facultad de Odontología, Monseñor Álvaro del Portillo, 12455, Las Condes, Santiago, Chile.

Abstract

This narrative review critically examines some protocols of biomimetic restorative dentistry (BRD), which supposedly outperforms traditional adhesive techniques. This review explores the origins of BRD, introduces cognitive biases influencing the adoption of BRD protocols without evidence scrutiny, and discusses nine BRD protocols. For this, we searched randomized clinical trials and systematic reviews in the literature on the PubMed, Embase, and Cochrane Library CENTRAL databases, which lead to the following conclusions about the revised protocols: 1) The use of dyes excessively removes carious dentin; 2) Aluminum oxide air abrasion contributes to overtreatment and may pose long-term health risks to dental professionals; 3) Beveling enamel in posterior teeth is technically difficult and leads to unnecessary loss of adjacent sound enamel with no evidence of its use outperforming butt-joint preparations; 4) Deactivating matrix metalloproteinases with chlorhexidine shows no clinical evidence of improving restoration longevity. 5) "Elected" gold-standard adhesive systems perform no better than other good performing available systems; 6) Immediate dentin sealing and resin coating result in similar post-operative sensitivity and longevity of indirect fillings as delayed dentin sealing; 7) Deep margin elevation is a viable alternative to manage subgingival margins in occlusoproximal cavities; 8) The process of "decoupling" with time lacks scientific evidence to support its use; 9) Placing fiber inserts on the pulpal floor and/or axial wall to minimize stress offers no benefits over current alternatives. In conclusion, more rigorous research is needed to validate BRD protocols, focusing on important clinical outcomes that impact in the longevity of the restoration, such as fracture, debonding, post-operative sensitivity, esthetic quality, presence of caries lesions adjacent to restorations and patients' satisfaction need to be thoroughly investigated. Reliance on anecdotal evidence, clinical experience, and common sense propagates myths and undervalues the need for a critical approach in evaluating dental techniques.

Keywords: Adhesive dentistry. Restorative dentistry. Biomimetic restorations. Evidence-based dentistry. Evidence-based practice. *In vitro* techniques. Randomized controlled trial. Research design.

Corresponding address:
Prof. Alessandra Reis - Universidade Estadual de Ponta Grossa - Departamento de Odontologia - Avenida Carlos Cavalcanti, 4748 - Uvaranas - 84030-900 - Ponta Grossa - Paraná.
e-mail: reis_ale@hotmail.com

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Introduction

Health sciences pursuit innovative techniques. In dentistry, "biomimetic restorative dentistry" (BRD) [1-3] has gained considerable attention by asserting that it can revolutionize the current adhesive dentistry practices. BRD promises improved outcomes, reduced invasiveness, and longer-lasting restorations.[1,3] The interest in and spread of BRD is driven by humanity's natural inclination toward novelty and progress. Our innate desire for new solutions and advancements aligns with the claims of BRD techniques.

BRD originated in the late 20th century and has evolved under the influence of various professors, textbooks, laboratory research, and one association.[1,3] Dr. David Alleman is considered the "father" of BRD. Initially frustrated with restorative outcomes leading to sensitive or painful teeth, failed fillings, crowns, and root canals, he contemplated quitting dentistry (as described on his website). Around 1995, he was introduced to adhesive dentistry and reported that, after extensive collection of *in vitro* and case reports, he condensed them into a core collection establishing the foundation of BRD.[3]

Dr. Pascal Magne emerged as an important contributor in BRD, with over 150 articles registered on Medline as of May 2024. Most of these publications are laboratory studies, case reports, narrative reviews, and a few clinical trials. In 2002, his collaboration with Dr. Urs Belser led to the publication of "Bonded Porcelain Restorations in the Anterior Dentition: A Biomimetic Approach",[4] a landmark book for BRD. In 2022, the same authors published "Biomimetic Restorative Dentistry: Enduring Techniques and Technology,"[1] which popularized these protocols. Today, numerous other authors and clinicians practice BRD.

The Academy of Biomimetic Dentistry, founded in 2006, promotes BRD as a discipline, focusing on courses and related events. Parallel to this, the Bio-Emulation Group™,[5,6] an international think tank of dentists and researchers, founded in 2008, has contributed to the field. They emphasize the replication of natural tooth structure and function, aligning closely with the principles of BRD. While BRD and Bio-Emulation share a similar philosophy, the term "bio-emulation" is trademarked and cannot be used freely.

The current principles of BRD are based on four key paradigms: achieving maximum bond strength (BS) between restorative materials and dental structures, ensuring a long-term marginal seal, preserving pulp vitality, and reducing stress during polymerization.[3] These paradigms closely align with the current concepts of contemporary adhesive dentistry, which also prioritizes minimally invasive techniques, adhesive bonding, and the preservation of natural dental structure. This suggests the absence of a dichotomy between the two approaches.

Despite the solid and robust principles of BRD, there remain numerous challenges and questions regarding the scientific validity of many of its protocols,[7] which are often marketed as superior options to current adhesive dentistry, despite lacking strong scientific evidence to substantiate such claims. Therefore, this review aims to critically appraise BRD protocols with skepticism, following evidence-based practice (EBP) principles. It seeks to highlight cognitive biases that lead some dentists to adopt BRD without sufficient scientific support, treating it as the new standard for innovation in conservative and adhesive dentistry.

Cognitive biases behind "biomimetic restorative dentistry"

Numerous cognitive biases and heuristics shape dentists' perceptions of this "innovative protocol." These biases, combined with the selective exposure to positive narratives and testimonials and our primal "need to belong,"[8] contribute to the widespread acceptance of the proposed protocols of BRD.[3] This creates a cycle that perpetuate myths. In the digital age, many ideologies proliferate on online platforms (which serve as echo chambers), and anecdotal success stories and visually compelling images favor novelty over scientific rigor.

BRD professors often use persuasive tactics, coherent speech, biological plausibility, and logical fallacies either conscious or unconsciously; a marketing strategy that highlights the limitations of available protocols, discredits current adhesive dentistry, and proposes solutions without proper scientific support,[7] which may convince dentists to invest time and financial resources in BRD training courses.

The tendency to unquestioningly believe is rooted in our automatic thinking, known as System 1.[9] System 1, characterized by intuitive and fast thinking, relies on heuristics and mental shortcuts that can deviate from rationality.[9] Our viewpoints are inherently biased due to beliefs, desires, personality traits, experiences, and cultural influences.[10] Although intuition and automatic thinking enable quick decisions, especially

in situations with limited time and resources, they can pose challenges when more thoughtful consideration is needed, such as in healthcare areas for diagnostic processes and treatment planning.

In such cases, errors can impact patients' well-being. Unless an emergency occurs, intuition or common sense should not guide clinicians' decisions. Instead, reasoning and critical analysis are essential toward EBP. Therefore, healthcare providers should engage in System 2 thinking, though slower, it is deliberate and capable of analytical cognition.

Numerous cognitive biases and heuristics, such as *confirmation bias,*[11] contribute to the perception of BRD as innovative, cutting-edge, and effective. Once dentists believe in BRD, they may seek and interpret information favoring these techniques while dismissing contradictory evidence.[11] Social media algorithms personalize content based on user preferences and previous interactions, thus exacerbating this bias, which leads dentists to encounter information aligning with their views.

Thus, dentists overvalue readily available information.[12] Marketing materials, testimonials, and anecdotal success stories are perceived as proof of efficacy because individuals rely heavily on information that comes to mind quickly and easily, even without scientific validity due to what is known as *availability heuristic bias*. The *ostrich effect bias* complicates matters, as one may ignore any conflicting information with their positive beliefs,[13] focusing much more on favorable testimonials and promises of solutions.

As BRD professors are perceived as authoritative figures, particularly those with a substantial social media following,[14,15] dentists may uncritically adopt BRD. This stems from *authority bias,* in which information from authorities is accepted without questioning. The *halo effect*[16] exacerbates this bias as we attribute expertise and credibility to these figures, overlooking potential shortcomings. Additionally, the *bandwagon bias* and *social proof bias* come into play.[15,17] If a significant portion of the dental community embraces BRD, other dentists may feel pressured[8] to follow suit to avoid being perceived as outdated, thus leading to acceptance without a thorough analysis of scientific validity or long-term efficacy.

The more deeply involved one becomes, the harder it is to consider alternative protocols. Dentists who have invested time, resources, or professional reputation in advocating for BRD may engage in *motivated reasoning* to justify their decision, even facing contradictory evidence.[18] These cognitive biases, alongside others, contribute to popularizing BRD protocols without evidence scrutiny. However, we should evaluate these protocols following the principles of EBP by searching the best available evidence to make sure that anecdotal evidence fails to take precedence over scientific rigor.

Evidence-Based Practice (EBP): what it is and what it is not?

In many dental congresses, EBP has become synonymous with the citation of scientific articles to support speakers' opinion. However, this approach oversimplifies EBP and misses its essence. True EBP involves more than just citing articles or the quantity of cited research,[19] as it is relatively easy to find a scientific article to support almost any protocol nowadays. Genuine EBD involves critically appraising the quality of evidence, integrating multiple information sources, and considering biases, limitations, and applicability to real-world scenarios.[20]

It is vital to recognize the hierarchy of evidence as not all evidence is equal.[19,20] While laboratory studies offer valuable insights into basic biological processes and are crucial in advancing scientific knowledge, they must be validated by clinical trials — especially randomized controlled trials (RCTs) — to establish treatment efficacy. RCTs hold a higher position in the hierarchy of evidence for clinical recommendations. The EBP pyramid[20] ignores laboratory studies as they lack direct clinical applicability.

A useful analogy for understanding the hierarchy of evidence is to compare it with roads connecting two cities. RCTs resemble well-maintained highways, offering a direct and reliable route for making clinical decisions. Lower-quality evidence such as those from case reports, expert opinions, and laboratory studies can be seen as "unpaved, country roads." While they may lead to the destination, they are less reliable and may have uncertainties. In certain situations, such as protocols lacking clinical evidence, these "unpaved roads" may be the only option. Many dental protocols are entirely based on *in vitro* studies due to the absence of a superior level of evidence, and it is up to researchers to change this situation. However, their use should be transparent about limitations and potential side effects rather than claiming it as the best treatment option. Thus, if robust RCTs are available, EBP prioritizes their information to ensure optimal

patient outcomes.

Practicing EBP involves more than just identifying the best evidence, it requires evaluating the magnitude of benefits and weighing them against potential harms. Harms extend beyond physical damage to the patient or dental structure and include time, financial costs, increased visits, suboptimal outcomes, psychological impact, and resource allocation. Non-evidence-based techniques can lead to longer treatment times and multiple visits, which are inconvenient for patients and clinicians. Additionally, clinicians might feel pressured to purchase expensive equipment and materials to follow "trend protocols,"[21] believing they benefit patients more.

Patients may face higher costs due to corrective procedures for suboptimal outcomes or frequent visits for adjustments, repairs, or replacements, increasing the burden on patients and the healthcare system. These additional costs can cause stress and anxiety,[22] negatively affecting patients' overall well-being and trust in dental care.

Understanding the benefits and potential harms of a protocol is essential. Clinicians must balance their experience with the protocol and consider patients' values and preferences. Even if a protocol is deemed the best for patient well-being, it might be unsuitable under insufficient clinical expertise or if patients are unwilling to accept costs, disadvantages, and other aspects. Additionally, engaging in shared decision-making ensures that treatments are based on evidence and in line with patients' needs and values.

Protocols of the "Biomimetic Restorative Dentistry (BRD)"

The four key paradigms of BRD[1] can be categorized into stress-reducing protocols and bond-maximizing protocols (Figure 1).[3] Despite its many other protocols,[1] we will examine the bond-maximizing ones. Due to space restrictions, we will ignore stress-reducing protocols, except for that that entails "decoupling with time" and the use of fiber inserts in large cavities as they are intrinsically related to bonding.

This discussion is narrative. However, for each described BRD protocol, we have conducted a comprehensive and specific search strategy to identify the best available evidence from major databases of primary studies, such as Medline via PubMed, Embase, and the Cochrane Library CENTRAL. We utilized free terms and descriptors (MeSH and Emtree terms) and applied filters to identify randomized controlled trials, clinical trials, and systematic reviews of the literature.

Establishing a caries-free peripheral seal zone

BRD focuses on achieving the ideal balance in carious dentin removal to ensure restoration strength and durability.[23] It emphasizes the importance of creating a peripheral seal zone involving caries-free enamel, the dentin-enamel junction, and superficial dentin for optimal bonding.[23]

This philosophy closely aligns itself with minimally invasive dentistry, which advocates that carious tissue from the cavo-superficial margins and the lateral walls of the cavity should be removed to enhance adhesion, keeping a layer of demineralized dentin at the deepest bottom walls of the cavity to prevent pulp exposure; an adequate cavity sealing would enable tissue remineralization.[24] However, BRD and minimally invasive dentistry approaches differ in the recommended procedures to remove caries tissue and the amount of dentin retained in deep cavities. BRD suggests using caries-detecting dyes to diagnose and guide carious tissue removal, a concept from Prof.

Bond-maximizing protocols	Stress-reducing protocols
Establish a caries-free peripheral seal zone	Indirect/semi direct restorations for the occlusal and interproximal enamel replacements
Air abraded surfaces	Decoupling with time
Bevel enamel	Thin horizontal layers of composite < 1 mm
Deactivate matrix metalloproteinases	Fiber inserts on pulpal floor and axial walls
Employ gold-standard adhesives	Low start/pulse activation polymerization techniques
Immediate dentin sealing	Composites with shrinkage rates lower than 3% and elastic modulus between 12 GPa and 20 GPa
Resin coating	For pulp chambers, use dual cure composite for the first 5 min
Deep margin elevation	Removal of dentin cracks completely within 2 mm of the dentinoenamel junction
	Limit onlay cusps to thinner than 2 mm
	Verticalize occlusal forces

Figure 1- Protocols used in the BRD are categorized in stress-reducing protocols and bond-maximizing protocols[3]

Fusayama et al. in the 1970s,[25] whereas minimally invasive dentistry recommends the visual-tactile approach, based on the results of an international collaboration consensus[24] due to the limitations of the caries-detecting dyes.

Initially, it was believed that a less subjective way to differentiate the layers of carious dentin would be the use of a 0.5% basic fuchsin-propylene glycol solution.[25] However, subsequent research showed that caries-detecting dyes failed to provide the anticipated benefits, as this diagnostic method lacked specificity and sensitivity.[26,27] Instead of only selectively staining denatured collagen and non-remineralizable dentin tissues, these dyes stain any dentin with reduced mineral content, including sound circumpulpal dentin and the enamel-dentin junction.[26-28]

This staining even extends to the carious dentin at the bottom of the dental cavity that could be remineralized after cavity sealing. Although BRD recommends maintaining a softened dentin layer near the pulp tissue, the use of caries-detecting dyes alongside Al_2O_3 air abrasion (discussed later) often removes more demineralized tissue and may increase the chances of pulp exposure, especially in deep cavities.[29,30] This contradicts the minimally invasive principles of BRD.[1,3]

Additionally, BRD removes a broader zone of peripheral "caries-affected" dentin to reach sound dentin to improve bond strength (BS),[1,31] posing higher risks to pulp vitality. Despite lower BS to "caries-affected" dentin than caries-free dentin,[32,33] maintaining a larger peripheral seal rather than retaining more affected dentin at the cavity bottom fails to necessarily compromise sealing or long-term restoration performance.

It is claimed that the low BS values in "caries-affected" dentin might compromise the biomechanical integrity of restored teeth.[31] However, the high clinical success rates of atraumatic restorative techniques and treatments involving incomplete caries removal without the use of dyes suggest otherwise.[34,35] Consequently, caries-detecting dyes have been abandoned for over 20 years. More recently, even the terminology of "caries-affected dentin" and "caries-infected dentin" have been replaced. Currently, these terms are substituted by terms that describe the clinical features of the carious tissue as soft, leathery, firm, and hard.[24,33]

To date, the only systematic review on this topic recommends against caries detector dyes, as removing all stainable dentin increases the risk of complications, prolongs procedure duration, and intensifies patient-reported pain or discomfort without clear advantages over other methods.[33] Using caries detector dyes as proposed by BRD contradicts its principle of preserving the dental structure, leading to unnecessary dentin removal and entailing its discontinuation. The visual-tactile approach is the most suitable method to guide caries removal, particularly in deep dental cavities.[24,33]

Aluminum oxide air abrasion

Air abrasion, a technique dating back to the 1940s,[36] involves altering material surfaces using abrasive particles propelled by compressed air. Various devices have since been developed for applications such as cavity preparation, prophylaxis, stain, selective caries removal, tribochemical coating, and surface polishing or roughening.[36] Different particles such as sodium bicarbonate, glycine, bioglass, and Al_2O_3 are employed based on the intended use. Aluminum oxide air abrasion, traditionally used in dental laboratories, was introduced for intraoral use and it is extensively used in BRD. It is advocated that Al_2O_3 air abrasion cleans cavity surfaces, removes residues, and enhances bonding by creating a rough surface for micromechanical retention.[31]

Laboratory studies examining the BS of adhesive systems to air-abraded dentin show conflicting results,[37,38] likely due to variations in air abrasion parameters such as particle size, air pressure, duration, and distance.[36] A well-defined protocol has yet to be established under *in vitro* conditions. Moreover, a recent systematic review of *in vitro* studies found that the BS of adhesives on air-abraded dentin fails to outperform other methods such as no treatment, bur, hand excavator, silicon carbide paper, or acid etching.[38] Although this review[38] suggests higher BS with certain air abrasion parameters, immediate and long-term laboratory data available remain limited.

Even if air abrasion were proven superior in a laboratory setting, its implementation would require rigorous clinical evaluation about the benefits and potential harms in RCTs. Currently, the only ongoing clinical study on the impact of Al_2O_3 abrasion on retention rates of composite restoration in non-carious cervical lesions is ongoing.[39]

The harms of Al_2O_3 air abrasion are overlooked. The high pressure used to propel Al_2O_3 particles can

significantly remove sound tissue due to hardness differences between Al_2O_3 and dentin.[38,40] Performing air abrasion near soft tissues increases the risk of tissue laceration and erosion.[41] While short-term exposure may pose no significant risks to patients, it presents a concern for clinicians and their teams. Long-term inhalation of Al_2O_3 particles can induce respiratory symptoms and potentially pulmonary fibrosis.[42] To mitigate these risks, appropriate protective equipment, ventilation, and rubber dam isolation are necessary in all clinical conditions as airborne particles remain suspended in the air. Water-based air abrasion devices can reduce airborne particles but they are costly and likely inaccessible to many clinicians.

Clinicians should ask themselves if aluminum oxide is truly beneficial and, if so, under what conditions and circumstances. If a positive effect exists, what is the magnitude of the benefit? Does it outweigh the disadvantages of this protocol? Without this information, incorporating this clinical protocol into a clinical scenario fails to follow EBP principles. Investing time and resources and potentially posing risks without clear evidence of its benefits is unjustified.

It is important to say that the burden of proof of any clinical protocol belongs to its proponents. So, before recommending its use, BRD professors should conduct *in vitro* studies to establish the optimal parameters to improve BS and then run RCTs to evaluate whether this variable provides clinically important benefits over potential harms under the complex clinical scenario.

Bevel enamel in posterior restorations

BRD recommends placing a 45° bevel, especially in proximal boxes[1], as enamel prisms lie at a right angle to the cavosurface in this area. In occlusal margins, the cavosurface angle should be smoothed with a mini bevel using a fine diamond bur to remove any weakened enamel, improve the aesthetic blending of the composite resin, and enhance bonding and marginal adaptation.[43] This recommendation is probably due to the results of *in vitro* studies showing that enamel beveling exposes enamel prisms transversally, facilitating acid etching, enhancing enamel bonding,[44,45] and reducing microleakage.[46-49] However, the microleakage test has been discredited.[50]

Revisiting the literature on BRD shows a historical shift regarding enamel beveling in occlusal cavities. While once considered advantageous, this practice was abandoned in adhesive protocols during the 1990s, likely due to the results of some clinical trials[51,52] that showed no benefit compared to butt-joint preparations. By 2010, the abandonment of enamel beveling was evident in Irish dental school teachings,[52,53] in which authors raised concerns about techniques lacking evidence or discredited practices,[52,53] such as enamel beveling for posterior restorations.

The authors of previous articles[52,53] highlighted the harms of enamel beveling. The increased risk of fractures and adhesive failures was likely due to the creation of thin composite extensions on the occlusal enamel.[52,53] Moreover, beveling can complicate restoration refurbishment, repair, or replacement, resulting in the unnecessary loss of adjacent sound enamel. Aside from that, it is technically challenging, especially in proximal boxes, as it may damage the adjacent tooth and compromise marginal adaptation, even with a well-adapted matrix.[52,53]

The debate over beveling in posterior teeth remains active today and it is still controversial at a laboratory level.[54-56] The most recent controlled trial on this topic is limited in statistical power, with only 29 posterior restorations being evaluated — half of which were beveled and half were non-beveled. Results showed less marginal staining in the beveled group.[57] However, this study ignores the clinically relevant outcomes for posterior restorations and carries potential biases such as those related to randomization issues and outcome measurement due to a lack of blinding.[57] Until well-designed RCTs show that benefits outweigh harms, this protocol should be avoided for cavity preparations in the occlusal and proximal boxes of posterior teeth.

Deactivate matrix metalloproteinases

Several laboratory studies have shown that applying chlorhexidine (CHX) on acid-etched dentin can reduce the degradation of BS.[58-60] CHX serves as a powerful inhibitor of endogenous metalloproteinases (MMP), preventing them from degrading non-encapsulated collagen by resin monomers within the bottom part of the hybrid layer. Other MMP inhibitors, such as EDTA, doxycycline, grapefruit seed extract, and bisphosphonates, have shown similar *in vitro* benefits.[59] BS values measured immediately and after long-term water storage (at five and 10 years) remained the same when CHX was applied either as a solution, gel, or incorporated into the phosphoric acid conditioner, degrading without its application.[61,62]

An *ex vivo* study[63] clinically placed restorations,

performing BS tests after tooth extraction. It found that, when CHX was applied, BS values remained the same after 14 months[63] but dropped without it. While this and another *ex vivo* study[64] found clinical evidence of the efficacy of CHX in ensuring long-lasting restorations, those articles ignored clinically relevant outcomes,[65] which is crucial for high-level evidence. Clinically relevant outcomes measure tangible benefits to patients and, despite efforts to correlate BS data with clinically relevant outcomes, this relationship was not established.[66,67]

In restorative dentistry, a clinically relevant outcome for restoration longevity is the fracture, debonding, the presence of caries lesions adjacent to restorations or some esthetic concerns. The retention rates of restorations in non-carious cervical lesions with and without CHX application showed no significant differences in follow-up periods of up to three years.[68-70] Although these studies are inconclusive due to their low statistical power and middle-term follow-up time, the null hypothesis that bonding with and without CHX fails to influence restoration longevity should be maintained, as per a recent systematic review of clinical studies.[71]

In situ studies fail to confirm the claim that CHX could serve as a cavity cleaner or an antimicrobial agent to reduce the number of microorganisms and consequently decrease the secondary caries potential.[72,73] Additionally, we should keep in mind that bacterial counts is a surrogate outcome[74] as it fails to predict restoration longevity.

Additionally, the potential adverse effects of this protocol [75] should be mentioned. Adding an extra step to the already complex adhesive procedure may increase the risk of operator errors, potentially leading to bonding failures. Unless in the hands of extremely well-trained dentists, who are less prone to operator errors, this protocol should be avoided until future studies bring evidence of its benefits.

Employ gold-standard adhesive systems

When performing adhesive restorative protocols, clinicians may choose the etch-and-rinse technique or the self-etch approach. Among the three-step etch-and-rinse and two-step self-etch adhesives, the adhesive brands OptiBond FL (Kerr Corp; Orange, CA, USA) and the Clearfil SE Bond (Kuraray; Tokyo, Japan) have been considered the "gold standard" materials by many researchers and clinicians.[1,31,76]

Following this trend, BRD began advocating for their use to achieve long-term restorations. This belief was based on several *in vitro* studies and two systematic reviews of non-carious cervical lesions, which showed the lowest mean annual failure rates for three-step etch-and-rinse adhesives and two-step self-etch adhesives.[77,78] Although these systematic reviews pioneered dentin bonding, encouraging the use of this methodology on the dental field, they show methodological flaws. Additionally, these systematic reviews evaluated no adhesive brands, and the decision about Optibond FL and Clearfil SE Bond was supported by a meta-analytical review of parameters affecting BS values,[79] showing that these two adhesive brands outperformed others.

As previously mentioned, BS tests provide laboratory results, rather than clinically meaningful outcomes. To make clinical recommendations we should rely on patient-oriented evidence (i.e., outcomes of importance to patients, such as restoration retention, pain, and quality of life) rather than basic results or disease-oriented evidence (e.g., biofilm accumulation, surface texture, bond strength tests). A systematic review comparing retention rates of restorations using OptiBond FL and Clearfil SE Bond with other materials found no superiority in both short- and long-term follow-ups, challenging their status as gold standards.[80]

It is worth mentioning that OptiBond FL and Clearfil SE Bond are excellent choices for clinical use but they should not be declared as gold standard. If this were true, they would have outperformed other adhesive brands across the numerous controlled trials conducted to date.[80] Considering them gold standards may inflate costs without sufficient evidence, potentially reducing the number of restorations performed in public healthcare settings due to budget constraints. Therefore, other well-performing adhesives in RCTs can also provide similar clinical outcomes with reduced costs, assisting in public policy decisions.

Immediate dentin sealing (IDS) and resin coating

Many laboratory studies have evaluated the resin coating technique[81] or IDS[82] and shown its efficacy.[83] The procedure relies on protecting fresh-cut dentin in indirect preparations to preserve pulp vitality and close open tubules, avoiding the seepage of water from dentin. It requires the application of dentin adhesives (sometimes with an additional flowable

composite layer on top) before either the impression or provisional phase of indirect restorations.

Several laboratory data confirm the increase of BS[82,83] and long-term *in vitro* BS values of adhesive cementation, especially when using multi-step adhesives.[84] *In vitro* studies also showed improvements in the marginal integrity of indirect ceramic restorations[85,86] and superior fracture resistance in indirect restorations.[85,87]

BRD often cites an 11-year clinical trial to support the long-term efficacy of laminate veneers bonded with IDS.[88] However, the lack of comparison with protocols without IDS prevents the study from attesting that IDS outperforms the traditional cementation systems. Additionally, the results from that study should be interpreted with caution as the absence of examiner blinding introduces a high risk of bias in the outcome measurement. Moreover, dentin exposure occurs infrequently when dealing with laminate veneer preparation, thus extrapolating the conclusions for onlays/crowns is an overstatement as reported in a recent RCT.[89]

The most recent RCTs[89,90] showed no significant differences between IDS and delayed dentin sealing for indirect restorations. Furthermore, the systematic review of Josic, et al. (2021) confirmed that the resin coating technique/IDS fails to favor post-operative sensitivity or longevity of indirect fillings. A more recent systematic review report clinical benefits of IDS but the study is full of methodological flaws that reduce the reliability of its findings.[91]

Although the use of IDS can be seen as an alternative protocol, one must avoid saying that successful luting procedures are unable to be achieved using traditional methods. Additionally, in a digital era in which scanners and milling units are more present in dental clinics, temporary restorations are becoming less frequent, and perhaps the IDS protocol with the waiting time will be infeasible in future decades as clinicians will employ CAD-CAM technology more frequently and most indirect restorations will be made chairside without delayed dentin sealing.

Deep margin elevation (DME)

Subgingival margins in Class II cavities pose significant challenges due to limited access and difficulties in maintaining isolation from saliva, crevice fluid, and blood. These issues, coupled with the high polymerization shrinkage of early composite resins,[92] insufficient enamel for bonding at the gingival margin, and poor dentin bonding of previous-generation adhesive systems,[93] likely contributed to the observed reduced marginal integrity at the gingival interfaces of posterior restorations.[43,94,95]

To overcome these problems, the concept of DME was proposed.[96] It involves applying a base of composite resin over the preexisting cervical margin to relocate it coronally.[96,97] This approach was similar to the open-sandwich technique, in which resin-modified glass ionomer cements fill the cervical part of the proximal box [98, 99] to improve dentin bonding and reduce polymerization shrinkage stresses.

As reported by Samartzi, et al.[100] (2022), the open-sandwich technique can be considered the forerunner of deep marginal sealing.[101] Later, flowable composite resin replaced glass ionomer cements to work as a stress-absorbing layer.[95] Although these techniques resemble each other, DME was initially described for indirect restorations, whereas the other two aimed at direct restorations.

Some clinicians claim that DME can avoid more invasive approaches such as orthodontic extrusion or surgical crown lengthening; these approaches should only be considered when DME is unable to be performed. A complete isolation of the working field, accurate fitting of the proximal matrix, and the non-violation of the supracrestal tissue attachment are essential to accomplish DME.[97,102] If a rubber dam can be placed, the working field is confined to the epithelial area, making surgical intervention unnecessary.[103] When the supracrestal tissue attachment is biologically ignored, a higher incidence of bleeding on probing can be expected.[104,105]

The open-sandwich technique[99,106] and the use of flowable composites as stress-absorbing layers have been evaluated in RCTs[95] as being alike current restorative approaches used for comparison. These findings may be considered indirect evidence for the efficacy of DME, which follows the same rationale of these earlier techniques. The reluctance toward dentin marginal elevation likely stems from its rebranding under BRD, which lacks clinical studies under this new terminology.[100]

Some case reports and retrospective and non-RCTs have shown high success rates and good periodontal parameters for DME.[104,107-110] Recently, an RCT comparing DME to surgical crown lengthening reported favorable periodontal outcomes for both techniques,[109]

with DME being advantageous for being non-invasive.

Despite the promising results with DME, one is unable to say that this procedure with indirect restorations is superior to traditional techniques such as direct restorations with or without bases. This comparison is yet to be studied and such an assumption lacks appropriate clinical validation. The myth surrounding this protocol lies in assuming that subgingival margins can only be effectively managed using DME.

Additionally, an important concern arises: if bonding is successfully achieved in the most challenging area of the restorative procedure, why opt for indirect restorations over direct restorations when sufficient dental structure remains? Faithfully, more recently BRD has considered DME as a preliminary step before placing large direct composite resin restorations[1] as it facilitates the placement of matrix and the separation for improved contours and tight proximal contacts. Large direct composite resin restorations have been increasingly placed,[111,112] showing clinical performance as good as indirect restorations.[71,113]

Finally, it is worth noting that laboratory studies sometimes bring problems that fail to manifest themselves in clinical scenarios. While laboratory studies suggest that achieving a good seal and high marginal quality around cavosurface margins with composite resins is nearly impossible,[114] this contradicts research on the long-term durability of composite restorations in posterior teeth.[112,115] Van Dijken[116] (2010) underscored this concern, reporting that the anticipated high failure rate in high C-factor cavities due to polymerization shrinkage stress failed to occur after a 12-year follow-up of restorations using various strategies to manage the high C-factor.

Decouple with time

This protocol raises a significant challenge. It rests on the belief that composite material shrinks toward the most mineralized and dry walls of the preparation and away from the walls that are the most moist and organic, guided by the so-called "hierarchy of bondability" since the multiple types of dental hard tissues with varying percentages of mineral content affect the establishment of a strong bond between each of them. The "decouple with time" principle — recently described in a review article[117] — referenced sources that failed to substantiate this concept. An exhaustive search in the literature about the hierarchy of bondability found no strong scientific evidence (RCTs) validating this concept.

The protocol recommends that after IDS, resin coat steps, and the placement of a composite layer of no more than 1.5 mm, clinicians should perform "decouple with time" for at least 5 minutes (up to 30 min) to enable the dentin hybrid bond layer to mature.[117] During this period, clinicians must refrain from light curing or adding any increments. The authors[117] state that this five-minute interval is crucial for the maturation of the hybrid layer[118] as failure to form it in a stress-free environment can reduce BS by around 80-90%.

Apart from being unrealistic from a clinical point of view, only limited literature exists on this topic, making it a classic case of cherry-picking in science, in which specific studies are selected to support a concept while ignoring broader evidence. BRD used few studies to advocate this procedure: 1) a clinical case report[119] performed decoupling by separately bonding dentin and enamel, 2) another series of cases[120] decoupled the deepest 1-mm layer of the composite from the more superficial 2-mm layers by adding an unbonded separating layer, and 3) an *in vitro* study that indicated that thinner horizontal layers of composite resin yielded higher BS at the deepest floor of the preparation.[121]

However, no high-quality scientific evidence supports the notion that this protocol (decouple with time) provides clinical benefits over traditional techniques without decoupling. Such a recommendation should be avoided before validation by an RCT.

Place fiber inserts on pulpal floor and/or axial walls to minimize stress

Severely compromised teeth are challenging to restore and several protocols, such as direct composite restorations, endodontic treatment with glass-fiber post-cementation, cuspal coverage amalgam, composite/ceramic onlays, or crowns, have been suggested. BRD advocates fiber-reinforced composites encompassing polyethylene fibers, such as EverX and Ribbond, for the pulpal wall/surrounding cavity walls[2] to reduce polymerization shrinkage stress in large posterior composite restorations.[122] It claims that this protocol increases fracture resistance[123] and reduces gap formation.[124] Although it also claims that this procedure can increase BS, this fails to occur when compared to the traditional composite layering technique.[124]

To the extent of the authors' knowledge, only four RCTs have addresses this topic, most of which showed no benefit of short-fiber reinforced composites over the current alternatives. Some authors[125,126] showed that nanohybrid or bulk-fill composite resins (packable and flowable) were similar to the use of short fiber-reinforced composites in posterior teeth after one- and two-year follow-ups, respectively. A three-year follow-up study[127] showed that the failure rate of EverX Posterior was higher than a microhybrid composite in posterior restoration. Moreover, one other RCT treated the molar-incisor hypomineralization. The three-year follow-up[128] showed that short-fiber reinforced composites were similar to a high-viscosity glass ionomer.

Trusting in the performance of short fiberglass reinforced composites or the combination of polyethylene fibers with composites, BRD discourages the use of glass-fiber posts, suggesting replacing them with fiber-reinforced composite inserts. Such insight is based on laboratory investigations,[129,130] which showed similar fatigue resistance for severely compromised teeth regardless of the placement of glass-fiber posts. However, BRD ignores the body of the literature, synthesized in a systematic review of *in vitro* studies, that reported that glass fiber posts increase the fracture resistance of endodontically teeth.[131] Even evidence from laboratory findings, as highlighted in another systematic review,[132] reports that findings about the fracture resistance of short fiber-reinforced composite resins is limited.

This review found no clinical trial that compared short fiber-reinforced composites/polyethylene fibers with composites with glass-fiber posts, endocrowns, or other alternatives, meaning that this clinical BRD protocol was exclusively based on a few *in vitro* studies. On the other hand, many controlled trials compared the longevity and fracture resistance of endodontically treated teeth restored with glass fiber posts,[133-135] attesting to clinical success. So, without clinical evidence of the short-fiber reinforced composite inserts as a replacement for fiber-glass posts, this procedure should not be implemented.

Implications for practice and research

Growing interest in BRD emphasizes that new protocols must be thoroughly studied and supported by data before being included into clinical practice. Innovation is important, but to minimize the risks of adopting new techniques too soon, it is essential that solid scientific data fully verify and support them.

Implementing BRD protocols without evidence support wastes time and may cause overtreatment, which can initiate a repetitive restorative cycle,[136,137] leading to complications such as the need for endodontic treatment or even tooth loss. This cycle increases treatment costs, risks to long-term oral health, and psychological impact on patients, particularly when anterior teeth are affected.

Improving the longevity of restorations must address the real problems that influence outcomes. These include material characteristics, operators' abilities and expertise, and patient-related considerations (such as caries risk, oral hygiene, and patients' occlusion). Any dental procedure has a higher chance of success with highly trained practitioners.[138] However, an experienced operator should also be well-versed in the fundamentals of EBP.[139,140] Clinicians must be able to distinguish between well-supported practices and those driven more by trends than by data.

Continuous education in EBP and training are vital to ensure that all dental professionals are equipped with both the practical skills and the critical thinking needed to apply evidence-based methods effectively. Studies on EBP report that, although healthcare providers have a positive attitude toward EBP, there remain many barriers to its implementation due to lack of knowledge, cultural barriers, and other reasons.[141-144]

Future research should prioritize more laboratory studies and well-designed RCTs and systematic reviews to establish the efficacy and safety of BRD protocols. Additionally, studies should focus, on true outcomes — such as restoration longevity, esthetic quality, patients' satisfaction, and tooth loss — rather than on surrogate ones.

Final considerations

EBP integrates the best available research evidence, clinical expertise, and patient values to inform clinical decisions, cultivating reliability, higher chances of beneficial outcomes, and safety.[19] As most protocols advocated in BRD lacks robust, high-level evidence, this has led to adjustments in the EBP principles, a manifestation known as *cognitive dissonance bias*.[15] Cognitive dissonance arises when individuals experience discomfort from holding conflicting beliefs or values (the BRD and the EBP pillars) and attempt

to solve this discomfort by modifying their beliefs or justifying their decisions. To justify their beliefs, BRD proposes an alternative foundation, emphasizing research, experience, common sense, and patient values.

In these four key elements, BRD overvalues clinical practice, patients' experience, and clinical expertise and undervalues scientific research. BRD claims that clinical recommendations should rely on common sense and personal experience because science, being conducted by humans, is inherently flawed. This viewpoint is contradictory as both science and common sense fall subject to human fallibility.

Moreover, emphasizing common sense and experience as equally important to scientific evidence overlooks their subjective nature. Clinical experience and the results observed in patient follow-ups in clinical practices are often taken as key evidence sources. While clinical experience is vital, it is inherently biased. Not all patients return for follow-ups, leading to skewed perceptions of treatment efficacy due to availability bias. Those who do return, often due to failures, may mislead clinicians into believing no failures occurred. Observation and confirmation biases can influence clinicians' assessments as they are aware of the given treatments. It may also affect patients' perceptions due to the Hawthorne effect.[145] Clinicians may also remember outstanding and long-lasting outcomes while overlooking less notable ones, known as selective recall bias. Additionally, many variables, such as comorbidities and individual behaviors, and patients' features affect patient outcomes and are neither controlled nor randomized in everyday practice, leading to misleading conclusions.

Unlike clinical experience, scientific clinical research under rigorous methodology aims to mitigate biases and provide reliable and generalizable data. While acknowledging that the scientific method fails in ensuring objectivity and impartiality and is transitory as new evidence is constantly being gathered, it remains the best framework for understanding the natural world and making informed healthcare decisions. Rather than abandoning it, we should strive to enhance and refine scientific methods to improve reliability and reproducibility.

The authors also acknowledge that conducting RCTs is demanding, expensive, and often challenging, especially in some universities and research centers. However, the inability of institutions and researchers to conduct RCTs fails to diminish their importance or make them replaceable by laboratory studies in dentistry. Collaboration between academic institutions, industry partners, funding agencies, research networks, and multi-center-controlled trials can help overcoming the challenges associated with conducting RCTs. Moreover, regulatory bodies and professional organizations can advocate for and support initiatives that promote rigorous clinical testing.

Lastly, but equally important, it is crucial to recognize that every review, including this one, is influenced by the authors' personal experiences, histories, and perspectives. As humans, we are all susceptible to cognitive biases, and the authors of this study are no exception. It is by acknowledging our own fallibility that we apply the principles of EBP and search for the best available evidence before making any clinical recommendation.

Our intention in offering this critique is, rather than undermining the efforts of others, to constructively contribute to the ongoing discourse. We hope to enhance the development of BRD within the framework of EBP and to ultimately enhance dental protocols to benefit patients.

Conflict of interest

The authors declare no conflicts of interest.

Data availability

The datasets generated during and/or analyzed in this study are available from the corresponding author on reasonable request.

Authors´contributions

Reis, Alessandra: Conceptualization (Equal); Data curation (Equal); Formal analysis (Equal); Funding acquisition (Equal); Investigation (Equal); Methodology (Equal); Project administration (Equal); Resources (Equal); Supervision (Equal); Validation (Equal); Visualization (Equal); Writing - original draft (Equal); Writing - review & editing (Equal). **Feitosa, Victor:** Conceptualization (Equal); Data curation (Equal); Formal analysis (Equal); Investigation (Equal); Methodology (Equal); Resources (Equal); Validation (Equal); Visualization (Equal); Writing - original draft. **Chibinski, Ana Claudia Rodrigues:** Conceptualization (Equal); Data curation (Equal); Investigation (Equal); Methodology (Equal); Resources (Equal); Validation (Equal); Visualization (Equal). **Favoreto, Michael:** Conceptualization (Equal);

Data curation (Equal); Investigation (Equal); Methodology (Equal); Resources (Equal); Validation (Equal); Visualization (Equal); Writing - original draft (Equal). **Gutiérrez, Mario Felipe:** Conceptualization (Equal); Data curation (Equal); Investigation (Equal); Methodology (Equal); Resources (Equal); Validation (Equal); Visualization (Equal); Writing - original draft (Equal). **Loguercio, Alessandro D.:** Conceptualization (Equal); Data curation (Equal); Formal analysis (Equal); Funding acquisition (Equal); Investigation (Equal); Methodology (Equal); Project administration (Equal); Resources (Equal); Supervision (Equal); Validation (Equal); Visualization (Equal); Writing - original draft (Equal); Writing - review & editing (Equal).

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