

Knowledge, Attitude, and Practices on the Use of Cross-Linkers during Dentin Bonding among Practitioners Specialised in Conservative Dentistry

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ABSTRACT

Introduction: Biomodification involves the application of exogenous cross-linkers to stabilise collagen molecules through the formation of inter- and intramolecular cross-links. This approach shows potential for improving bonding performance in adhesive restorations.

Aim: To assess the Knowledge, Attitude, and Practices (KAP) regarding the use of cross-linkers during dentin bonding among practitioners specialising in conservative dentistry.

Materials and Methods: An online survey was conducted among dentists practicing conservative dentistry across India from September 2022 to November 2022. The survey consisted of a semi-validated questionnaire with 24 questions and was distributed through personal email and social media. Data was collected over a period of three months and analysed using statistical evaluation in the Statistical Package for the Social Sciences (SPSS) via chi-square test.

Results: A total of 181 responses were received. Of the study population, 68.2 percent became aware of biomodification through articles in various journals. According to the study, 85 individuals (47%) acknowledged that using cross-linkers could enhance the mechanical properties of dentin by stabilising collagen. However, it is interesting to note that only 33 individuals (18.2%) actually incorporated biomodification techniques in their dental practice.

Conclusion: Nearly half of the study population were aware of the use of cross-linkers to enhance dentin strength, prevent degradation and preserve resin-dentin bonds, inhibit demineralisation, and prevent root caries. However, only 18.2% of the participants reported practicing biomodification procedures in their dental practice.

Keywords: Biomimetics, Chlorhexidine, Collagen, Matrix metallo protease inhibitor, Proanthocyanidins

INTRODUCTION

The success of adhesive restorations depends on the stability of the hybrid layer. Despite continuous advances in adhesive systems, bonding to carious dentin remains a challenge in restorative dentistry due to the degradation of the resin-dentin interface over time [1]. Various factors are related to the degradation of the bonding interfaces. However, during the bonding procedure, incomplete infiltration of resin monomers into exposed collagen may leave it unprotected, thus making it vulnerable to hydrolysis and enzymatic degradation. The degradation at resin-dentin interfaces hampers dentin bonding stability, resulting in a decrease in bond strength and an increase in nanoleakage [1].

Dentin is a complex mineralised tissue composed of organic and inorganic matrix. Fibrillar type I collagen constitutes 90% of the organic matrix, along with non-collagenous proteins such as phosphoproteins and proteoglycans [2]. Dentin undergoes various modifications due to physiological aging and disease processes, producing different forms of dentin that affect the biomechanics and biochemistry of the tissue [3]. Although dentin does not possess the ability to heal when tissue is lost as a consequence of dental caries, tooth wear, and injury, the presence of collagen is advantageous as it provides the backbone for tissue repair and regeneration [2].

Various attempts have been made to improve the stability of resin-dentin interfaces by inhibiting collagen degradation and improving the mechanical properties of the hybrid layer. One such approach is dentin biomodification [4]. Biomodification of existing hard tissue structures, specifically tooth dentin, is a novel and biomimetic therapeutic strategy to mechanically strengthen the existing collagen

network and control the biodegradation rates of Extracellular Matrix (ECM) components [5]. Biomodification of dentin through collagen cross-linking agents is thus a biomimetic strategy to preserve adhesion stability over time [6]. Collagen cross-linking agents can be applied to dentin as a pretreatment, incorporated into the phosphoric acid etchant, or added to the adhesive system [7].

Collagen cross-linking (biomodification) agents can be naturally derived or synthetic. Natural agents include proanthocyanidin (grape seed extract and cocoa seed extract), green tea, Epigallocatechin Gallate (EGCG), biocalcin, quercetin, naringin, cardol, cardinal, aroeira, while synthetic agents include Chlorhexidine (CHX), glutaraldehyde, riboflavin, etc., [8].

The cross-linking agents improve the covalent intermolecular cross-links and also possess an inhibitory effect on endogenous proteases such as Matrix Metalloproteinases (MMPs) and cathepsins, thus preventing the disruption of the hybrid layer. Therefore, the stabilisation and strengthening of collagen fibrils can be considered a potential approach for restoring dentin damaged by caries and improving bond durability [9,10]. These procedures enhance the durability of the resin-dentin bond by improving the mechanical properties of dentinal collagen, making it resistant to degradation [11].

The use of these cross-linkers has increased in the last decade, and there is a plethora of data in the literature regarding the use of cross-linkers and MMP inhibitors [8,12,13]. However, doubts remain as to whether dentists are aware of this concept called "biomodification". Therefore, the purpose of this study was to assess the Knowledge, Attitude, and Practices (KAP) of specialists in conservative dentistry regarding the use of cross-linkers. The goal was to gain insights into their practices and enhance the longevity of resin-dentin bonds for

adhesive restorations. Additionally, the authors aimed to correlate their knowledge with years of practice.

MATERIALS AND METHODS

The study was a single-point cross-sectional observational study that involved administering a semi-structured, semi-validated questionnaire. Approval from the Institutional Ethical Committee (IEC NDCH/2022/SEPT/P-76) was obtained. The study, conducted by the Department of Conservative Dentistry at Narayana Dental College in Andhra Pradesh, India, spanned from September 2022 to November 2022.

Inclusion criteria: The study only included dentists who specialised in Conservative Dentistry and were pursuing postgraduate studies in the same field.

Exclusion criteria: Conservative dentists who were neither practicing nor in academics were excluded from the study.

Procedure

It was an online survey, and the responses were collected through Google Forms. The questionnaire was either personally mailed to participants across India or posted in social media groups to reach out to postgraduates. All participants were informed that their participation would be anonymous, and the recorded information would be strictly confidential and used for research purposes only.

Questionnaire: A self-constructed 24-item closed-ended questionnaire [Annexure-1] was created, with only two open-ended questions in the demographic category. A Likert 5-point scale was used to gather practitioners' opinions for the close-ended questions. The questionnaire was divided into four main categories: socio-demographic characteristics, the KAP of dentists using cross-linkers and MMP inhibitors. The questionnaire consisted of twelve questions assessing the knowledge of dental practitioners in conservative dentistry regarding the use of cross-linkers, three questions on their attitude, four questions on their practice towards the use of cross-linkers, and five questions about demographic details [Annexure 1].

Sample size calculation: A sample size of 189 was calculated using 'Sample size calculator' (Calculator.net), with 95% confidence interval and margin of error at 5%. A literature search was conducted to identify if there was any existence of previously validated questionnaire on MMPs or their inhibitors. As there was none, a questionnaire was framed considering the guidelines given by the Red Cross society (CADRIM) and Tsang S et al., [14-16]

A pilot study was conducted among 30 dentists specialising in conservative dentistry to achieve 80% power for testing validity and reliability [17]. After face validation, the questionnaire was analysed, and the difficulty level in understanding, interpreting, and correctly answering the questions was evaluated. Internal consistency was estimated using Cronbach's alpha, resulting in a value of 0.82. The questionnaire items were revised based on the results of the preliminary pilot testing, and this process was repeated multiple times before finalising the questionnaire's final draft.

STATISTICAL ANALYSIS

The received responses were converted into an Excel sheet and analysed using Statistical Package for Social Sciences (SPSS) software, version 21.0. A descriptive analysis was conducted to establish a general understanding of the study population. Categorical variables were reported in frequencies and percentages. The chi-square test was used to assess whether there was any correlation between demographic variables and the participants' responses based on KAP. A p-value less than 0.05 was considered significant.

RESULTS

A total of 181 responses were received from various states.

The age group of the study population ranged from 23 to 57 years, with a mean age of 32.7±8.92 years. The majority (58.3%) of

respondents were aged <35 years. Approximately 68% of the study population was female, and 32% were male. Among the 181 responses, 43.6% were postgraduate students, 33.3% were in both clinical practice and academics, and 8.8% were only in academics [Table/Fig-1]. Most of the participants were from Andhra Pradesh- 74 (41%), followed by Telangana- 36 (20%), Karnataka- 26 (14%), Tamil Nadu- 16 (8.8%), Punjab- 14 (7.3%). Few responses were also received from Kerala- 3 (1.7%), Maharashtra- 5 (2.7%), Madhya Pradesh- 3 (1.6%), Odisha- 1 (0.6%), Chhattisgarh- 1 (0.6%), Delhi- 1 (0.6%), and Gujarat- 1 (0.6%).

Demographic details	Frequency	Percentage
Gender		
Female	123	68
Male	58	32
Type of practice		
Clinical practice	61	33.3
Only academics	16	8.8
Only clinical practice	25	13.8
Postgraduate student	79	43.6
Years of experience		
≤3 years	102	56.4
3-6 years	21	11.6
7-10 years	11	6.1
>10 years	47	26.0

[Table/Fig-1]: Baseline demographic data; Total responses: N=181.

Among the 181 responses received, nearly 143 (79%) agreed that resin dentin bonds are less durable than resin enamel bonds. Approximately 169 (93.3%) respondents agreed that biomodification, which involves the use of biologically active substances to stabilise collagen, is a valid approach [Table/Fig-2]. About 68.2 percent of the study population became aware of biomodification through articles in various journals [Table/Fig-3].

Knowledge based questions	Frequency	Percent
Q6. The resin dentin bonds are less durable than resin enamel bonds		
Agree	84	45.5
Disagree	13	7.2
Neutral	14	7.7
Strongly Agree	59	32.6
Strongly disagree	11	6.1
Q7. Biomodification is a modification of dentin with biologically active substances such as treatment with cross-linkers and stabilising collagen		
Agree	109	60.2
Neutral	9	5.0
Strongly Agree	60	33.1
Strongly disagree	3	1.7
Q11. The bonding agent has to be blamed for the failure of composite resin		
Agree	50	27.6
Disagree	83	45.9
Unsure	48	26.5
Q12. Stabilisation and strengthening of collagen fibers is a potential approach for possibly restoring dentin damaged by dental caries and improving bond		
Agree	103	56.9
Disagree	1	0.6
Neutral	21	11.6
Strongly Agree	50	27.6
Strongly disagree	6	3.3
Q14. What is at risk with the negative effects of MMPs?		
The collagen in dentin	25	13.8

The collagen in the hybrid layer	44	24.3
The collagen that is not infiltrated by resin below the hybrid layer	112	61.9
Q15. When do you think a cross-linker should be applied when using total etch adhesives		
After etching and before the bonding agent application	157	86.7
After the bonding agent application	15	8.3
Before etching	9	5.0
Q16. Apart from cross-linking effect, most of the natural cross-linkers have an inhibitory effect on endogenous proteases (MMPs and Cathepsins)		
Agree	95	52.5
Disagree	11	6.1
Neutral	39	21.5
Strongly agree	31	17.1
Strongly disagree	5	2.8
Q17. Most of the plant-derived cross-linkers are polyphenolic flavonoids		
Agree	103	56.9
Disagree	6	3.3
Neutral	42	23.2
Strongly agree	28	15.5
strongly disagree	2	1.1
Attitude based questions		
Q18. How likely do you think a cross-linker would prolong the durability of the resin dentin bond?		
1	3	1.7
2	2	1.1
3	34	18.8
4	88	48.6
5	54	29.8
Q20. Do you agree that Chlorhexidine (CHX) is the most classic non-specific MMP inhibitor and can be used to increase the durability of the bond?		
Agree	87	48.1
Disagree	8	4.4
Neutral	45	24.9
Strongly agree	36	19.9
Strongly disagree	5	2.8
Practices		
Q21. Have you tried biomodification?		
No	148	81.8
Yes	33	18.2

[Table/Fig-2]: Frequency and percentage of respondents for each question received related to Knowledge, Attitude and practice on the use of cross-linkers during Dentin bonding.
MMP: Matrix metalloproteases

Knowledge based questions	Frequency	Percent
Q8: How did you get to know about biomodification?		
From colleagues	37	21.4
In conference presentations	23	13.3
Through my personal research work	23	13.3
By going through articles in various journals	118	68.2
Never heard about it	7	4
Q9: Cross-linkers are used for which of the following purposes? (can select more than one)		
To improve the mechanical properties of dentin	47	26
For collagen stability	71	39.2
Root caries prevention	12	6.6
To reduce degradation thus preservation of resin dentin bond strength	83	45.9
Inhibition of demineralisation/promotion of remineralisation	17	9.4
All of the above	85	47

Q10: The failure of resin dentin bonding may result in		
Micro leakage	39	21.5
Staining	13	7.2
Recurrent caries	23	12.7
Postoperative sensitivity	22	12.2
All of the above	154	85.1
Q13: What are the factors that influence the durability of the resin dentin bond?		
The technique of bonding (wet/dry)	134	74
The choice of total etch/self-etch	106	58.6
The solvent in the bonding agent	81	44.8
The dentin proteases (MMPs)	134	74
Q19: What are the practices that you follow to prolong the life of a composite restoration		
Invest in newer composites	28	15.5
Invest in newer bonding agents	46	25.4
Follow the etching and bonding procedure meticulously	137	75.7
Use pre-treatment liners such as CHX, Glutaraldehyde, Proanthocyanidin etc.	91	50.3
Use less sensitive materials such as self-etch	43	23.8
Q23: If no, (you have not tried biomodification so far) what is the reason?		
Lack of awareness/knowledge regarding cross-linkers	61	41.2
Biomodification is still not proven successful in trials	19	12.8
Don't believe in the concept of biomodification	5	3.4
Availability or cross-linkers is difficult	44	29.7
Skeptical if it would interfere with bonding	19	12.8
As there is not sufficient literature to support the application of cross-linker, clinically	33	22.3
Others:		
Q24: What actions can be taken in advance to protect the resin dentin bond?		
Application of an MMP inhibitor	123	68
Application of a cross-linker	115	63.5
Acetone based adhesives	62	34.3
Completely dry the preparation and then use water-based adhesives	35	19.3

[Table/Fig-3]: Frequency and percentage of respondents for questions with multiple options related to Knowledge, Attitude and Practice (KAP) on the use of cross-linkers during dental bonding.

Nearly half of the study population (47%) was knowledgeable about using cross-linkers to enhance dentin strength, prevent degradation, preserve resin dentin bonds, inhibit demineralisation, and prevent root caries. Overall, 85.1% of the participants were aware of the consequences of resin dentin bonding failure [Table/Fig-3]. The majority (n=134, 74%) of the study population believed that bonding and dentin proteases (MMPs) influence the durability of resin dentin bonds [Table/Fig-2].

A total of 157 (86.7%) of the study population believed that the cross-linker should be applied after etching and before the bonding agent application when using total-etch adhesives. About 69.6% agreed that natural cross-linkers have an inhibitory effect on endogenous proteases (MMPs and Cathepsins). More than half (68%) of the study population recognised CHX as the most classic non-specific MMP inhibitor. Only 33 (18.2%) of the participants reported practicing biomodification procedures in their dental practice [Table/Fig-2]. Among the various bio-modifying agents, CHX and glutaraldehyde were the most commonly used cross-linkers. Lack of awareness or knowledge about cross-linkers was cited as the most common reason (41.2%) for not trying biomodification. There was no association of knowledge with years of clinical experience in all the questions when the data were analysed using Fisher-exact test [Table/Fig-4].

Questions			Type of practice				Fisher-exact test
			≤3 years	3-6 years	7-10 years	>10 years	
The resin dentin bonds are less durable than resin enamel bonds	Agree	N	46	8	5	25	χ^2 : 11.37 p-value: 0.497
		%	45.1%	38.1%	45.5%	53.2%	
	Disagree	N	10	2	0	1	
		%	9.8%	9.5%	0.0%	2.1%	
	Neutral	N	10	1	2	1	
		%	9.8%	4.8%	18.2%	2.1%	
	Strongly agree	N	29	8	4	18	
		%	28.4%	38.1%	36.4%	38.3%	
	Strongly disagree	N	7	2	0	2	
		%	6.9%	9.5%	0.0%	4.3%	
Biomodification is a modification of dentin with biologically active substances such as treatment with cross-linkers and stabilising collagen	Agree	N	60	11	8	30	χ^2 : 4.52 p-value: 0.87
		%	58.8%	52.4%	72.7%	63.8%	
	Neutral	N	5	2	0	2	
		%	4.9%	9.5%	0.0%	4.3%	
	Strongly agree	N	35	7	3	15	
		%	34.3%	33.3%	27.3%	31.9%	
	Strongly disagree	N	2	1	0	0	
		%	2.0%	4.8%	0.0%	0.0%	
The bonding agent has to be blamed for the failure of composite resin	Agree	N	30	7	2	11	χ^2 : 5.03 p-value: 0.53
		%	29.4%	33.3%	18.2%	23.4%	
	Disagree	N	41	11	7	24	
		%	40.2%	52.4%	63.6%	51.1%	
	Unsure	N	31	3	2	12	
		%	30.4%	14.3%	18.2%	25.5%	
Stabilisation and strengthening of collagen fibers is a potential approach for possibly restoring dentin damaged by dental caries and improving bond	Agree	N	57	9	6	31	χ^2 : 12.32 p-value: 0.42
		%	55.9%	42.9%	54.5%	66.0%	
	Disagree	N	1	0	0	0	
		%	1.0%	0.0%	0.0%	0.0%	
	Neutral	N	16	2	1	2	
		%	15.7%	9.5%	9.1%	4.3%	
	Strongly agree	N	24	8	4	14	
		%	23.5%	38.1%	36.4%	29.8%	
	Strongly disagree	N	4	2	0	0	
		%	3.9%	9.5%	0.0%	0.0%	
What is at risk with the negative effects of MMPs?	The collagen in dentin	N	16	3	2	4	χ^2 : 5.11 p-value: 0.52
		%	15.7%	14.3%	18.2%	8.5%	
	The collagen in the hybrid layer	N	28	2	2	12	
		%	27.5%	9.5%	18.2%	25.5%	
	The collagen that is not infiltrated by resin below the hybrid layer	N	58	16	7	31	
		%	56.9%	76.2%	63.6%	66.0%	
When do you think a cross-linker should be applied when using total etch adhesives	After etching and before the bonding agent application	N	87	20	8	42	χ^2 : 8.49 p-value: 0.20
		%	85.3%	95.2%	72.7%	89.4%	
	After the bonding agent application	N	9	1	3	2	
		%	8.8%	4.8%	27.3%	4.3%	
	Before etching	N	6	0	0	3	
		%	5.9%	0.0%	0.0%	6.4%	
Apart from cross-linking effect, most of the natural cross-linkers have an inhibitory effect on endogenous proteases (MMPs and Cathepsins)	Agree	N	50	10	5	30	χ^2 : 9.14 p-value: 0.69
		%	49.0%	47.6%	45.5%	63.8%	
	Disagree	N	7	1	2	1	
		%	6.9%	4.8%	18.2%	2.1%	
	Neutral	N	24	4	2	9	
		%	23.5%	19.0%	18.2%	19.1%	
	Strongly agree	N	17	5	2	7	
		%	16.7%	23.8%	18.2%	14.9%	

	Strongly disagree	N	4	1	0	0	
		%	3.9%	4.8%	0.0%	0.0%	
Most of the plant-derived cross-linkers are polyphenolic flavonoids	Agree	N	49	13	7	34	χ^2 : 14.35 p-value: 0.268
		%	48.0%	61.9%	63.6%	72.3%	
	Disagree	N	6	0	0	0	
		%	5.9%	0.0%	0.0%	0.0%	
	Neutral	N	29	5	1	7	
		%	28.4%	23.8%	9.1%	14.9%	
	Strongly agree	N	16	3	3	6	
		%	15.7%	14.3%	27.3%	12.8%	
	Strongly disagree	N	2	0	0	0	
		%	2.0%	0.0%	0.0%	0.0%	
How likely do you think a cross-linker would prolong the durability of the resin dentin bond	1	N	2	0	0	1	χ^2 : 3.22 p-value: 0.99
		%	2.0%	0.0%	0.0%	2.1%	
	2	N	2	0	0	0	
		%	2.0%	0.0%	0.0%	0.0%	
	3	N	18	4	2	10	
		%	17.6%	19.0%	18.2%	21.3%	
	4	N	52	10	5	21	
		%	51.0%	47.6%	45.5%	44.7%	
	5	N	28	7	4	15	
		%	27.5%	33.3%	36.4%	31.9%	
Do you agree that CHX (Chlorhexidine) is the most classic non-specific MMP inhibitor and can be used to increase the durability of the bond?	Agree	N	48	9	4	26	χ^2 : 14.61 p-value: 0.26
		%	47.1%	42.9%	36.4%	55.3%	
	Disagree	N	4	3	1	0	
		%	3.9%	14.3%	9.1%	0.0%	
	Neutral	N	22	5	4	14	
		%	21.6%	23.8%	36.4%	29.8%	
	Strongly agree	N	23	4	2	7	
		%	22.5%	19.0%	18.2%	14.9%	
	Strongly disagree	N	5	0	0	0	
		%	4.9%	0.0%	0.0%	0.0%	
Have you tried biomodification	No	N	87	17	10	34	χ^2 : 4.27 p-value: 0.23
		%	85.3%	81.0%	90.9%	72.3%	
	Yes	N	15	4	1	13	
		%	14.7%	19.0%	9.1%	27.7%	

[Table/Fig-4]: Association of the knowledge and years of experience.
Only p-values <0.05 are considered significant

DISCUSSION

Dentin bonding is a cornerstone of conservative dentistry that facilitates the long-term success of restorative procedures. Significant advancements have been made in adhesive systems, including the incorporation of cross-linkers, to enhance bond strength and stability. However, the effective utilisation of these cross-linkers requires a comprehensive understanding of their properties, application techniques, and compatibility with different restorative materials. Furthermore, the Knowledge, Attitudes, and Practices (KAP) of conservative dentistry practitioners play a crucial role in implementing these techniques accurately and consistently. The purpose of this survey was to investigate the current knowledge, attitudes, and practices of conservative dentistry practitioners regarding the use of cross-linkers in dentistry.

This survey specifically targeted ongoing postgraduate students in conservative dentistry or clinical practitioners/academics with master's degrees only in conservative dentistry. The rationale behind this was to standardise the exposure of all participants to the master's degree curriculum. Most participants were postgraduate students, followed by conservative dentists in both clinical practice and academics.

When making decisions about clinical diagnosis, material selection, and treatment planning, the years of experience of dentists play a crucial role. Therefore, the participants' years of clinical practice were inquired about. However, the authors found no association between their level of knowledge regarding biomodification or the use of cross-linkers and their years of experience. This could be attributed to the constantly evolving concepts in adhesive dentistry, which require practicing dentists to keep themselves updated on newly launched products within a short period [18].

While evaluating participants' knowledge regarding cross-linkers during dentin bonding, it was found that a high percentage of dentists (154, 85.1%) knew that resin dentin bonds are unstable and that the breakdown of these bonds can result in microleakage, staining, recurrent caries, and postoperative sensitivity. Over time, due to poor infusion of resin monomers into demineralised dentin, collagen fibrils within the hybrid layer remain denuded, making them susceptible to degradation and denaturation by MMPs and cysteine cathepsins [8,19-21].

The success and failure of composite resins depend on several factors, such as polymerisation shrinkage of composite resins, the state of curing light, the size of the restoration, the technique

used in composite placement, water absorption, shade matching, contamination of the field by moisture, improper technique or bonding agent used, and inadequate finishing and polishing [22]. Therefore, blaming the bonding agent alone for composite failure may not be appropriate. Similarly, almost half of the participants in this study disagreed with the idea that the bonding agent should be solely blamed for the failure of the composite resin. It is important to consider all factors that may contribute to such failures in order to improve the overall success rate of composite restorations. A study by Brunthaler A et al., mentioned that the failure of composite restorations in the first five years is mainly due to technique or material selection issues, and for the next 6-17 years, secondary decay was the reason for replacing the restoration [23].

More than 134 (70%) respondents believed that the bonding technique (wet/dry) and dentin proteases influence the durability of resin dentin bonds. However, variations in the structure and composition of dentin, characteristics of the dentin surface after bur cutting and chemical treatment, and properties of adhesives used also determine the durability of resin dentin bonds [24]. Thus, bonding to dentin is challenging. Meanwhile, other respondents felt that the choice of self-etch/total-etch and the solvent used in the bonding agent were factors that influenced the durability of the resin dentin bond. This statement also holds true as the application of self-etch adhesive displays higher performance in establishing a durable bond with dentin by penetrating the smear layers and partially dissolving hydroxyapatite to form a hybrid layer with the remaining hydroxyapatite crystals, i.e., simultaneous etching and penetration [25,26]. However, self-etch adhesive also activates endogenous MMPs within the dentin matrix and causes collagen degradation over time [27].

During dentin biomodification, cross-linking agents are applied after acid etching so that the exposed collagen fibrils interact with each other and form strong covalent bonds, contributing to the stiffness of the resin-dentin bond [28-30]. Almost 157 (87%) respondents agreed that a cross-linking agent should be applied after acid etching and before bonding. A study by Macedo GV et al., evaluating the effect of the cross-linking agent on dentin bond strength, concluded that applying chemical cross-linking agents to etched dentin before bonding increases the dentin bond strength in both caries-affected and sound dentin [31].

Furthermore, approximately 124 (70%) respondents agreed that CHX is the most classic MMP inhibitor that can be used to increase the durability of bonds. In a systematic review and meta-analysis by Kiuru O et al., CHX inhibited the function of the protease enzyme, thereby protecting the hybrid layer from degradation and increasing the longevity of the resin-dentin bond [32].

It is interesting to note that despite the recommendation of collagen cross-linkers as a dependable approach, only a small percentage of people (n=33, 18%) have actually tried using a collagen cross-linker to enhance bond strength. Among those who have tried it, CHX and glutaraldehyde seem to be the most commonly used cross-linkers, followed by proanthocyanidin. In the present study, dentists attributed the limited usage of cross-linkers to a lack of awareness and knowledge about these agents, followed by difficulty in finding these products in the market. In addition, some participants also felt that there needed to be more literature to support the clinical application of cross-linkers. Moreover, limited clinical studies using cross-linkers and MMP inhibitors have added to the dilemma of whether to include these agents during restorative procedures. This uncertainty can be improved through exposure to evidence-based practices and access to unbiased information on the clinical efficacy of products introduced in the market. Additionally, regular continuing dental education programs can be conducted to update dentists with the latest practices.

The present study is the first to evaluate the KAPs regarding using cross-linkers and MMP inhibitors during dentin bonding procedures

among practitioners specialised in conservative dentistry. Online surveys are usually difficult to follow, and additional email reminders can be easily ignored compared to telephone follow-ups. Research suggests a difference in the response rate of practitioners who respond to papers compared to those who do so online [33]. Further clinical studies are required to substantiate the results of in-vitro studies and emphasise the clinical relevance of using cross-linkers on dentin.

Limitation(s)

The low participation of dentists from all over India and the lack of randomisation of options in the given questionnaire are some of the limitations of this study. Confounding factors such as training and education, geographical location, availability of resources, and research exposure were not accounted for in this survey, which could be limitations influencing the results.

CONCLUSION(S)

It can be concluded that the study participants had knowledge and awareness of the use of cross-linkers and MMP inhibitors during dentin bonding. However, the use of collagen cross-linkers and MMP inhibitors in clinical practice is limited. Further clinical studies are needed to substantiate the results of several in-vitro studies on cross-linkers. These studies would likely motivate more dentists to adopt this procedure in their clinical practice. Additionally, these clinical trials would contribute to the cultivation of more evidence-based approaches among dentists, enabling them to make informed decisions regarding various new procedures, techniques, and materials.

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