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·基础研究·

原花青素对漂白后牙本质与复合树脂粘接强度的影响

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【摘要】 目的 探讨原花青素对过氧化脲漂白后牙本质与复合树脂粘接强度的影响。**方法** 按照牙本质粘接界面不同处理方法，将120颗人离体第三磨牙随机分为12组（n = 10）；W组（无漂白+去离子水）、Wa组（无漂白+去离子水+老化）、WT1组（无漂白+5%原花青素1 min）、WT1a组（无漂白+5%原花青素1 min+老化）、WT2组（无漂白+5%原花青素5 min）、WT2a组（无漂白+5%原花青素5 min+老化）、C组（过氧化脲+去离子水）、Ca组（过氧化脲+去离子水+老化）、CT1组（过氧化脲+5%原花青素1 min）、CT1a组（过氧化脲+5%原花青素1 min+老化）、CT2组（过氧化脲+5%原花青素5 min）、CT2a组（过氧化脲+5%原花青素5 min+老化）；上述各组在即刻或冷热循环老化后，万能力学试验机测试粘接强度，扫描电镜观察粘接界面微观形貌和纳米渗漏。**结果** CT1组经原花青素处理1 min（P < 0.001）和CT2组经原花青素处理5 min（P < 0.001）的漂白即刻组粘接强度均高于对照组C组，差异具有统计学意义，但CT1与CT2之间差异无统计学意义（P = 1.000）；冷热循环处理后各组粘接强度均下降，W与Wa（P < 0.001）、C与Ca（P < 0.001）的差异具有统计学意义，但CT1与CT1a（P = 0.052）、CT2与CT2a（P = 0.053）之间的差异无统计学意义。“漂白”（P < 0.001）、“老化”（P < 0.001）、“原花青素”（P < 0.001）主效应和二阶交互效应“漂白*原花青素”（P = 0.008）、“漂白*老化”（P = 0.024）、“老化*原花青素”（P < 0.001）均有统计学意义。扫描电镜示即刻组C、CT1和CT2组混合层欠清晰，老化组Ca、CT1a和CT2a组混合层局部破坏崩解，背散射模式下Ca组混合层存在大量硝酸银颗粒，CT1a、CT2a组混合层残留银离子减少。**结论** 5%原花青素预处理1 min即可提高过氧化脲漂白后牙本质与复合树脂的即刻粘接强度并改善粘接耐久性。

【关键词】 原花青素；牙齿漂白；过氧化脲；牙本质粘接；复合树脂；粘接强度；微观形貌；纳米渗漏；粘接耐久性
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Effects of applying procyanidins on the bond strength of bleached dentin to composite resin

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【Abstract】 Objective To study the influence of procyanidins on the bonding strength of dentin bleached by carbamide peroxide to composite resin. **Methods** By applying different treatments to dentin bonding interfaces, 120 human third molars were randomly divided into 12 groups (n = 10): W group (no bleaching+deionized water), Wa group (no bleaching+deionized water+aging), WT1 group (no bleaching+5% procyanidins for 1 min), WT1a group (no bleaching+5% procyanidins for 1 min+aging), WT2 group (no bleaching+5% procyanidins for 5 min), WT2a group (no bleaching+5% procyanidins for 5 min+aging), C group (carbamide peroxide+deionized water), Ca group (carbamide per-

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oxide+deionized water+aging), CT1 group (carbamide peroxide+5% procyanidins for 1 min), CT1a group (carbamide peroxide+5% procyanidins for 1 min+aging), CT2 group (carbamide peroxide+5% procyanidins for 5 min), and CT2a group (carbamide peroxide+5% procyanidins for 5 min+aging). The bond strength to composite resin was measured by universal mechanical testing machine, microstructure and the nanoleakages were measured by scanning electron microscope immediately or after the thermal cycling aging test. **Results** The immediate bond strength of the bleached groups pretreated with procyanidins for 1 min ($P < 0.001$) and 5 min ($P < 0.001$) was higher than that of Group C, and the difference was statistically significant. Meanwhile, there was no statistically significant difference between Group CT1 and Group CT2 ($P = 1.000$). After the thermal cycles, the bond strength of each group declined. The differences between Group W and Group Wa ($P < 0.001$) and Group C and Group Ca ($P < 0.001$) were statistically significant, but no significant differences between Group CT1 and Group CT1a ($P = 0.052$) or Group CT2 and Group CT2a ($P = 0.053$) were found. The main effects of "aging" ($P < 0.001$), "bleaching" ($P < 0.001$) and "procyanidins" ($P < 0.001$) and the second-order interaction effects of "bleaching * procyanidins" ($P = 0.008$), "bleaching * aging" ($P = 0.024$), and "aging * procyanidins" ($P < 0.001$) were statistically significant. SEM observations showed that the hybrid layers in Groups C, CT1 and CT2 were not clear, and the hybrid layers in Groups Ca, CT1a and CT2a were partially destroyed and disintegrated. Under backscattering mode, it was observed that there were a large number of silver nitrate particles in the hybrid layer of Group Ca, and the residual silver ions in the hybrid layer of Groups CT1a and CT2a were decreased. **Conclusion** Pretreatment with 5% procyanidins for 1 min can improve the immediate bond strength of dentin bleached by carbamide peroxide to composite resin and maintain bonding durability.

【Key words】 procyanidins; tooth-bleaching; carbamide peroxide; dentin adhesive; composite resin; bond strength; microstructure; nanoleakage; bonding durability

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过氧化脲(10%)因其操作方便、低损伤等优点,被广泛应用于居家牙齿美白治疗[1-2]。临床发现过氧化脲能够渗透牙釉质到达牙本质,降低牙本质与树脂的即刻粘接强度[3]。针对该问题,临床常推迟4周再进行漂白后牙体的树脂粘接修复[4]。如何快速、高效地获得漂白后牙齿与树脂的良好粘接强度,对于减少患者就诊次数,提高诊疗效率具有重要意义。相较于目前国内外学者研究较多的抗环血酸钠[5],原花青素作为一种天然抗氧化剂[6],其化学性质稳定,作用迅速,安全性能更高,且原花青素清除自由基的活性是抗坏血酸钠20倍[7]。研究显示原花青素可改善漂白后牙本质粘接强度降低的问题[8],但对于使用时间仍存在争议[9-10]。因此,本实验拟探讨原花青素作用对过氧化脲漂白后牙本质粘接强度的影响,以期为其临床应用提供实验依据。

1　材料和方法

1.1　主要试剂和仪器

10%过氧化脲(皓齿公司,美国);原花青素(solarbio,中国);Adper Single Bond 2(51202,3M公司,美国);无水乙醇(天利公司,中国);复合树脂(Z250,3M公司,美国);35%磷酸(heraeus,德国);场发射扫描电镜(MLA650F,FEI,美国);万能测试机(WDW-D,恒瑞金试验机有限公司,中国);超声震荡仪(VGT-173QTD,广东固特超声有限公司,中国);冷热循环机(TC-501F,苏州威尔实验用品公司,中国);光固化机(G568E24440F2A1,Dentsply,德国);游标卡尺(三本精密仪器有限公司,中国)。

1.2　离体牙收集及原花青素预处理剂的配制

本研究经西南医科大学口腔医学院伦理委员会批准(批号:20191227001),采集120颗近期完整拔除的无龋坏、缺损的阻生第三磨牙,患者均已签署知情同意书。清理牙齿表面附着组织,保存于1%氯胺T溶液中。将原花青素加入无水乙醇中,制备质量体积分数为5%的预处理剂,用标准氢氧化钠滴定至pH=7.2。

1.3　实验分组与试件制备

样本牙随机分为12组(n=10):W组(无漂白+去离子水)、Wa组(无漂白+去离子水+老化)、WT1组(无漂白+5%原花青素1 min)、WT1a组(无漂白+5%原花青素1 min+老化)、WT2组(无漂白+5%

原花青素5 min）、WT2a组（无漂白+5%原花青素5 min+老化）、C组（过氧化脲+去离子水）、Ca组（过氧化脲+去离子水+老化）、CT1组（过氧化脲+5%原花青素1 min）、CT1a组（过氧化脲+5%原花青素1 min+老化）、CT2组（过氧化脲+5%原花青素5 min）、CT2a组（过氧化脲+5%原花青素5 min+老化），具体粘接面处理见表1。牙冠横向切开去除𬌗面0.5 cm厚度牙釉质，W、Wa、WT1、WT1a、WT2、WT2a进行去离子水处理；C、Ca、CT1、CT1a、CT2、CT2a组使用过氧化脲处理8 h，彻底冲洗后，再去除所有试件𬌗面全部牙釉质，暴露中层牙本质，牙本质粘接面使用碳化硅砂纸湿性打磨牙体表面，模拟临床牙本质玷污层，35%磷酸酸蚀15 s，去离子水彻底冲洗30 s。按表1的分组和预处理方式使用去离子水或原花青素处理，再使用去离子水冲洗30 s。均匀涂布Single Bond2，轻吹3 s，光固化5 s，采用分层固化技术通过模具堆塑高为4 mm、直径为4 mm的树脂复合体。

表1　实验分组和粘接面处理

Table 1　Experimental grouping and bonding surface treatment

Group	Bleaching treatment	Pretreatment mode	Immediate/aging
W	Deionized water	Deionized water	Immediate
WT1	Deionized water	Procyanidins 1 min	Immediate
WT2	Deionized water	Procyanidins 5 min	Immediate
C	10% carbamide peroxide	Deionized water	Immediate
CT1	10% carbamide peroxide	Procyanidins 1 min	Immediate
CT2	10% carbamide peroxide	Procyanidins 5 min	Immediate
Wa	Deionized water	Deionized water	Aging
WT1a	Deionized water	Procyanidins 1 min	Aging
WT2a	Deionized water	Procyanidins 5 min	Aging
Ca	10% carbamide peroxide	Deionized water	Aging
CT1a	10% carbamide peroxide	Procyanidins 1 min	Aging
CT2a	10% carbamide peroxide	Procyanidins 5 min	Aging

Immediate: test immediate bond strength; aging: test the bond strength after the cold and hot cycle aging test

1.4　试件储存与冷热循环老化实验

W、WT1、WT2、C、CT1、CT2组检测即刻粘接强度。Wa、WT1a、WT2a、Ca、CT1a、CT2a组试件置于冷热循环机内，冷水浴（5 ℃，1 min）与热水浴（55 ℃，1 min）交替处理样本，循环5 000次。

1.5　粘接强度测试

每组取6个样本进行石膏包埋，固定于万能力学试验机。加载头的加载速度为0.5 mm/min，加载方向平行于粘接面。直至样本断裂时，记录最大剪切力并测量每个试件的实际粘接面积。计算粘接强度：粘接强度（MPa）=最大剪切应力值（N）/样本粘接面积（mm^2）。

1.6　扫描电镜观察粘接界面微观形貌

每组取2颗样本在流水冲洗下，垂直于粘接界面通过慢速切割机，形成约1 mm厚薄片，依次用250、400、600、800、1 000目砂纸流水下抛光切割面，35%磷酸凝胶处理120 s，流水下彻底冲洗，5.25%次氯酸钠溶液浸泡5 min，超声波震荡清洗表面，乙醇梯度脱水，充分干燥，喷金，扫描电镜下观察牙本质粘接界面微观形貌。

1.7　粘接界面纳米渗漏观测

每组取2颗样本流水冲洗下，垂直于粘接界面通过慢速切割机，形成约1 mm厚薄片，超声震荡清洗。待样品完全干燥后，用2层速干指甲油密封距离粘接界面1 mm的牙本质表面。将样品浸入50%含氨硝酸银溶液中避光保存24 h后彻底冲洗。在显影液中进行荧光照射8 h，定影液中浸泡4 h，冲洗，干燥。用400、800、1 000、1 500、2 000、2 500目碳化硅砂纸抛光切割面，超声波清洗表面。充分干燥、喷金、扫描电镜的背散射模式下观察牙本质粘接界面纳米渗漏。

1.8　统计学分析

实验数据用SPSS26.0软件进行Levene's方差齐性检验后，三因素方差分析过氧化脲、原花青素、老化处理对粘接强度的影响，各组老化前后及有无漂白处理使用t检验两两比较，不同预处理方式使用Bonferroni检验两两比较，检验水准α为0.05。

2　结　果

2.1　粘接强度测试结果

各组粘接强度测试结果见表2，不同预处理方式的Bonferroni检验结果见表3，三因素方差分析见表4，漂白+原花青素、老化+原花青素之间的牙本质粘接强度分析分别见表5、表6。

老化：老化后各组粘接强度均下降，其中W与Wa、C与Ca的差异具有统计学意义（$P<0.05$），而WT1与WT1a、WT2与WT2a、CT1与CT1a、CT2与CT2a之间差异无统计学意义（$P>0.05$）。

漂白：W与C、WT1与CT1、WT2与CT2两两比较，粘接强度差异有统计学意义（$P<0.05$）；Wa与Ca、WT1a与CT1a、WT2a与CT2a两两比较粘接强度差异有统计学意义（$P<0.05$）。

原花青素预处理：W与WT1、W与WT2、WT1与WT2、CT1与CT2之间粘接强度差异均无统计学

意义（$P>0.05$），C与CT1、C与CT2之间粘接强度差异具有统计学意义（$P<0.05$）；老化后粘接强度WT1a与WT2a、CT1a与CT2a之间差异均无统计学意义（$P>0.05$），Wa与WT1a、Wa与WT2a、Ca与CT1a、Ca与CT2a之间的差异具有统计学意义（$P<0.05$）。

交互效应："漂白"、"老化"、"原花青素"主效应均有统计学意义（$P<0.05$），二阶交互效应中"老化*原花青素"、"漂白*老化"、"漂白*原花青素"均具有统计学意义（$P<0.05$）。对于拮抗漂白和老化两个作用因素，原花青素预处理5 min均优于原花青素预处理1 min，但差异无统计学意义（$P>0.05$），原花青素预处理1、5 min均优于无原花青素预处理，差异具有统计学意义（$P<0.05$）。

2.2　微观形貌观察

各组试件微观形貌观察见图1。W、WT1、WT2混合层结合严密，树脂密集且较长，规则排列，C、CT1和CT2组混合层结构欠清晰，树脂突相对较短较细；Wa、WT1a、WT2a、Ca、CT1a、CT2a组混合层出现不同程度的裂纹，其中WT1a和WT2a组混合层结构较清晰，裂纹最少，Wa组牙本质-粘接界面上可见数个狭窄裂隙，Ca、CT1a和CT2a组混合层局部破坏崩解，树脂突排列稀疏杂乱。

2.3　纳米渗漏观察

各组试件纳米渗漏观察见图2。图像显示各组牙本质-粘接剂界面均出现不同程度纳米泄漏，Wa、Ca组混合层存在大量硝酸银颗粒，经原花青素处理后WT1a、WT2a、CT1a、CT2a组混合层残留银离子显著减少，且原花青素预处理1 min和5 min

表2　各组粘接强度测试结果

Table 2　The bond strength results of each group　$\bar{x} \pm s$, MPa

Group	Bond strength	Group	Bond strength	t	P
W[a]	23.00 ± 1.89	Wa[d]	12.74 ± 0.71	11.23	< 0.001
WT1[a]	23.69 ± 0.55	WT1a[e]	21.73 ± 2.22	2.54	0.064
WT2[a]	24.58 ± 0.55	WT2a[e]	22.62 ± 1.74	2.61	0.060
C[b]	13.80 ± 1.55	Ca[f]	8.29 ± 2.34	12.63	< 0.001
CT1[c]	19.52 ± 1.69	CT1a[g]	18.04 ± 1.94	2.73	0.052
CT2[c]	20.50 ± 1.61	CT2a[g]	19.44 ± 2.22	2.71	0.053

Experimental grouping and bonding surface treatment as shown in Table 1. a, b, c: compared with group W, WT1, WT2, C, CT1 and CT2, the two groups with different symbols have statistical significance ($P<0.05$). d, e, f, g: compared with group Wa, WT1a, WT2a, Ca, CT1a and CT2a, the two groups with different symbols have statistical significance ($P<0.05$)

表3　不同预处理方式的Bonferroni检验结果

Table 3　Results of Bonferroni test for different pretreatment methods

	Deionized water		Bleaching	
	Immediate	Aging	Immediate	Aging
Deionized water *vs.* 1 min procyanidins	1.000	< 0.001	< 0.001	< 0.001
Deionized water *vs.* 5 min procyanidins	0.166	< 0.001	< 0.001	< 0.001
1 min procyanidins *vs.* 5 min procyanidins	0.762	1.000	1.000	0.987

表4　三因素方差分析表结果

Table 4　Three factors analysis of variance

Source	SS	ds	MS	F	P
Intercept	21 649.36	1	21 649.36	7 497.84	< 0.001
Bleaching	345.12	1	345.12	119.53	< 0.001
Procyanidins	628.56	2	314.28	108.85	< 0.001
Aging	206.02	1	206.02	71.35	< 0.001
Bleaching * procyanidins	31.13	2	15.57	5.39	0.008
Bleaching * aging	15.69	1	15.69	5.43	0.024
Aging * procyanidins	131.09	2	65.55	22.70	< 0.001
Bleaching * aging * procyanidins	13.79	2	6.89	2.39	0.103

表5　漂白与原花青素对牙本质粘接强度简单效应分析

Table 5　Simple effect analysis of bleaching and procyanidins on dentin bond strength

Bleaching	Procyanidins pretreatment (I)	Procyanidins pretreatment (J)	Difference of mean (I−J)	P
Deionized water	Deionized water	Procyanidins 1 min	−4.84	< 0.001
		Procyanidins 5 min	−5.73	< 0.001
	Procyanidins 1 min	Deionized water	4.84	< 0.001
		Procyanidins 5 min	−0.89	0.739
	Procyanidins 5 min	Deionized water	5.73	< 0.001
		Procyanidins 1 min	0.89	0.739
10% carbamide peroxide	Deionized water	Procyanidins 1 min	−7.74	< 0.001
		Procyanidins 5 min	−8.92	< 0.001
	Procyanidins 1 min	Deionized water	7.74	< 0.001
		Procyanidins 5 min	−1.19	0.375
	Procyanidins 5 min	Deionized water	8.92	< 0.001
		Procyanidins 1 min	1.19	0.375

表6　老化与原花青素对牙本质粘接强度简单效应分析
Table 6　Simple effect analysis of aging and procyanidins on dentin bond strength

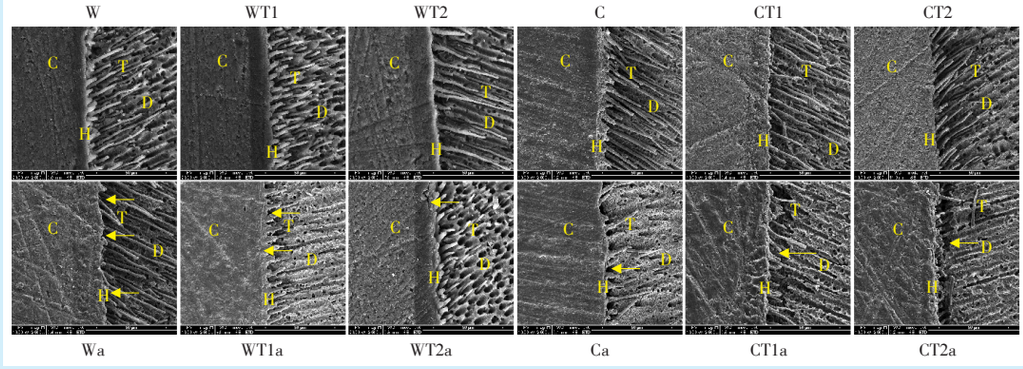
	Procyanidins pretreatment (I)	Procyanidins pretreatment (J)	Difference of means (I-J)	*P*
Immediate	Deionized water	Procyanidins 1 min	−3.21	< 0.001
		Procyanidins 5 min	−4.14	< 0.001
	Procyanidins 1 min	Deionized water	3.21	< 0.001
		Procyanidins 5 min	−0.94	0.674
	Procyanidins 5 min	Deionized water	4.14	< 0.001
		Procyanidins 1 min	0.94	0.674
Aging	Deionized water	Procyanidins 1 min	−9.37	< 0.001
		Procyanidins 5 min	−10.51	< 0.001
	Procyanidins 1 min	Deionized water	9.37	< 0.001
		Procyanidins 5 min	−1.14	0.416
	Procyanidins 5 min	Deionized water	10.51	< 0.001
		Procyanidins 1 min	1.14	0.416

的粘接界面残留银离子量相近。

3　讨　论

漂白后的牙本质即刻粘接强度低是一个临床难题，这与过氧化脲分解产生的不稳定自由基易在牙本质中残留有关[11]。而抗氧化剂含有多个电子供体位点，可有效中和牙本质中残留的氧自由基，迅速恢复牙本质粘接强度[12]。原花青素作为一种天然抗氧化剂[8]，其作用迅速，安全性能高，成为近年研究的热点。

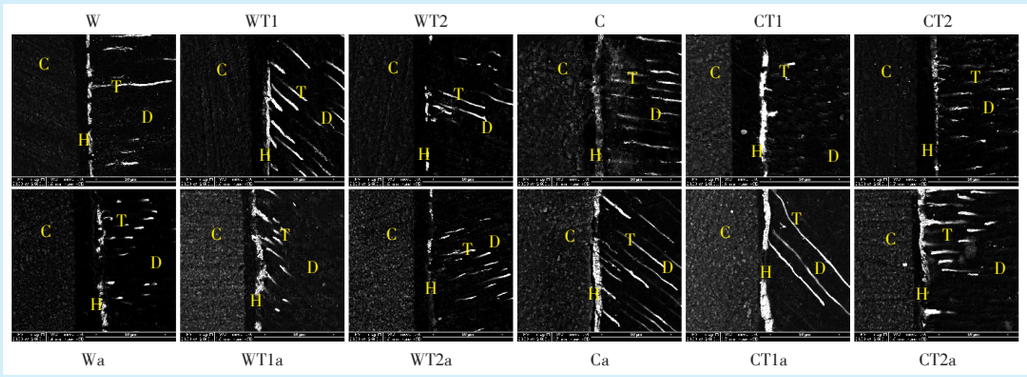
本研究结果提示漂白处理后牙本质即刻粘接强度与无漂白处理组比较，差异具有统计学意义，表明漂白术后会出现牙本质与复合树脂即刻粘接强度降低，这与Cavalli等[13]学者的研究结果一致。这可能因为残留的自由基会干扰树脂粘接剂的渗透附着和聚合[14]。临床面对该问题，为了避免推迟修复时间，国外学者一直在尝试使用抗氧化剂提升即刻粘接强度。本研究结果表明，使用5%原花青素预处理漂白后牙本质，相比于无原花青素预处理的漂白组，粘接强度明显升高，且漂白*原花青素有交互作用，说明原花青素对提升漂白后牙本质即刻粘接强度具有积极作用。原花青素通过提供氢原子，与自由基结合，阻断自由基链式反应，从而逆转粘接强度的下降[15]。关于原花青素作用时间上，不同学者观点有所差异，Nair等[8]认为至少需要10 min，Lai等[10]则认为至少需要3 h，而Freire等[9]认为1 min也能改善粘接效果。本实验中，经原花青素处理1 min和5 min的漂白组，即刻粘接强度提升均具有统计学意义，分析其原因可能与实验采取的过氧化脲浓度差异有关。Vaz等[16]曾提出漂白后牙本质残留的过氧化物与漂白剂浓度呈正相关，本实验中过氧化脲浓度为10%，组织中残留氧较少，对树脂渗漏和聚合影响小。本实验中，原花青素作用1 min后即可显著提升牙本质粘接强度，但随着时间延长，即使作用时间达到5 min，粘接强度与1 min相比差异无统计学意义。Freire等[17]学者对抗氧化剂反应动力学的研



Experimental grouping and bonding surface treatment as shown in Table 1. C: composite resin; H: hybrid layer; T: resin tag; D: dentin; arrows: crack; In immediate Group W, WT1 and WT2, the hybrid layers were tightly bonded. The resin tags were dense and long and arranged regularly. While in Groups C, CT1 and CT2, the structure of the hybrid layers was not clear, and the resin tags were relatively short and thin. After aging, the hybrid layers of Wa, WT1a, WT2a, Ca, CT1a, CT2a had cracks in different degrees. Among them, the structure of hybrid layers of Group WT1a and WT2a was clear and the number of cracks was the least. Several narrow cracks were found on the dentin-bonding interface of Group Wa. The hybrid layers of Ca, CT1a and CT2a were partially destroyed and disintegrated, and the resin tags were sparse and disorderly

Figure 1　Observation results of the microstructure of the bonding interface (×2 500)

图1　粘接界面微观形貌观察结果(×2 500)



Experimental grouping and bonding surface treatment as shown in Table 1. C: composite resin; H: hybrid layer; T: resin tag; D: dentin; The images showed that the dentin-adhesive interface of each group had different degrees of nano-leakage. After aging, there were a lot of silver nitrate particles in the hybrid layers of Group Wa and Ca , and the residual silver ions in Group WT1a, WT2a, CT1a and CT2a hybrid layers were obviously reduced after procyanidins treatment. Moreover, the amount of residual silver ions in the bonding interface of procyanidins pretreatment for 1 min and 5 min was similar in appearance

Figure 2　Observation results of the nanoleakage of the bonding interface(×2 500)

图2　粘接界面纳米渗漏观察结果(×2 500)

究提示,虽然原花青素和牙本质之间的接触时间越长,氧化剂和抗氧化剂之间的反应时间就越长,但还原反应速度约在1 min内即可达到峰值,之后还原反应速度显著下降。此外,原花青素使用浓度和漂白次数是否会引起预处理时间的差异,有待进一步探讨。

漂白剂的氧化性、酸性及试件的老化将触发基质金属蛋白酶(matrix metallo proteinase,MMP)的自我催化[18],导致混合层中胶原纤维发生水解变性,降低粘接耐久性[5, 19]。本实验通过冷热循环5 000转发现:未使用原花青素预处理的漂白组中,即刻与老化的粘接强度差异具有统计学意义,而使用原花青素预处理(1、5 min)预处理的漂白组中,即刻与老化组的粘接强度差异无统计学意义,说明原花青素对漂白后牙本质粘接耐久性具有重要意义。抗氧化剂原花青素能够快速清除过氧化物,截断MMP生成途径,从而提高混合层的质量[20]。同时原花青素还可以发挥其良好的交联能力,不仅可以增加胶原分子间交联度,维持胶原纤维网架结构,还能诱导MMP三维结构构象变化,并阻挡分子移动,这对于抑制MMP活性具有显著作用[21-22]。

本实验粘接界面纵剖面微观形貌显示,即刻组粘接界面混合层完整均匀,老化组混合层不均,且出现不同程度裂隙,其中不经原花青素预处理的漂白老化组裂隙最大。Van Meerbeek等[23]认为混合层质量决定了牙本质粘接的强度和耐久性,这与本实验结果一致。Betancourt等[24]认为,粘接剂并不能完全渗漏牙本质脱矿层,这些未封闭结构将形成纳米渗漏通道,成为水解牙本质中胶原蛋白的途径。本实验中,漂白组可以明显看到在混合层及牙本质中存在大量银离子。在使用了原花青素处理后的混合层中银离子明显减少,说明原花青素在提高混合层质量,恢复牙本质粘接强度具有积极意义。这可能由于原花青素处理后去除了抑制树脂聚合和渗透的过氧化物,另外原花青素通过抑制基质金属蛋白酶从而保证了完整的混合层结构,使得混合层中未封闭结构减少,纳米渗漏通道明显减少。

综上,5%原花青素预处理对牙本质粘接具有积极作用,能够提高漂白后即刻粘接强度,不能提高无漂白处理组即刻粘接强度,但均能改善二者的粘接耐久性,且5%原花青素预处理1 min即可达到较理想的效果。因此,原花青素对于当临床上不能等待过氧化脲被消除,需要即刻修复的患者具有积极的应用前景。

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