ORIGINAL RESEARCH

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Study about mechano-chemical gingival displacement with single-cord technique.

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Abstract
Introduction: Besides abutment preparation, the impression is essential in order to achieve an esthetical and functional prosthetic restoration. Proper gingival displacement and abutment finish line exposure is crucial for the proper impression technique.
The study aims are to investigate the vertical gingival displacement and if the free gingival margin returns to its original position after seven days by using a retraction cord impregnated with different chemical substances.
Materials and method: Our clinical study evaluated on digital photos the modification of the healthy, free gingival margin position on the labial surface of two upper central incisors in the same female patient during the sulcus enlargement with the mechano-chemical method.
Results: Statistically significant differences were obtained by comparing the mean values of vertical gingival displacement obtained using a non-impregnated and an impregnated retraction cord with different chemical at each time of the measurements.
Conclusion: The mechano-chemical technique is an efficient method for gingival displacement regardless the impregnating solution used.
Keywords: retraction cord, gingival displacement, impregnation.

Introduction

Perfectly executed prosthetic rehabilitation is the result of consistent and complex work processes. Besides abutment preparation, the impression is essential to achieve an esthetical and functional prosthetic restoration. Proper gingival displacement and abutment finish line exposure is crucial for the proper impression technique [1,2].

The most commonly used gingival sulcus expansion method is the mechano-chemical method, which also provides a moisture-free area. The chemical used for gingival displacement must be carefully selected because, in addition to their positive effect can cause irreversible damage to the gingiva [3,4].

The study aims are to investigate the vertical gingival displacement and if the free gingival margin returns to its original position after seven days by using a retraction cord impregnated with different chemical substances.

Material and methods

Our clinical study evaluated on digital photos the modification of the healthy, free gingival margin position on the labial surface of two upper central incisors in the same female patient during the sulcus enlargement with the mechano-chemical method.

For the single-cord gingival displacement technique, the 0 sized, non-impregnated Easy Cord retraction cord was used. The cord was impregnated every week with different hemostatic agents and vasoconstrictors. The impregnating solutions (ferric sulfate: 15.5%, 20%, aluminum chloride: 20%, 25%, aluminum sulfate: 25%, epinephrine: 8%) were prepared at the Department of Biochemistry of the George Emil Palade University of Medicine, Pharmacy, Science and Technology of Târgu Mureș (Figure 1).The free gingival margin's position vertical modification was studied weekly during seven weeks.

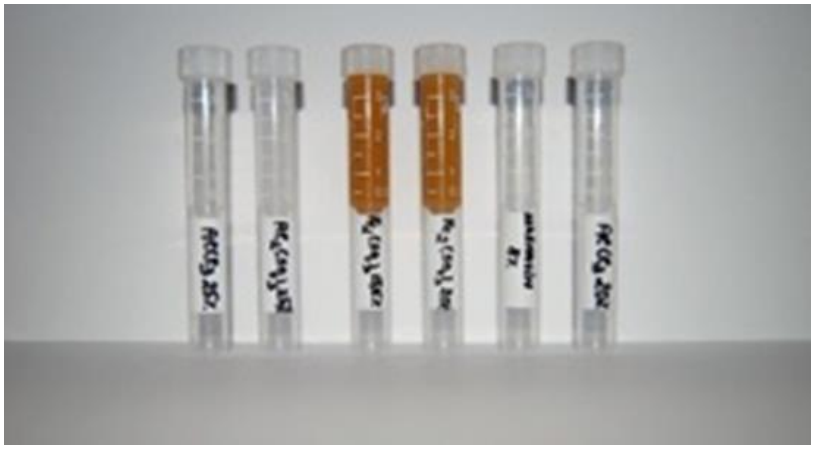

Figure 1. Impregnating chemicals

A thin dental spatula was used to insert the retraction cord in the sulcus. The removal of the cord was performed after five minutes in all cases. Photographs were taken before and immediately after the insertion; at five minutes from the insertion; immediately, and respectively at one, two, five, and ten minutes after removing the cord from the sulcus.

During the photo session, a custom-made bite-fork with an acrylic bite template was used to maintain in the same position's head and teeth (Figure 2). A millimeter-scale was placed on the incisal area of the bite template to calibrate the pictures. The photos were taken using a Nikon D750 digital camera (Nikkor, 60mm, f 2.8) mounted on a tripod. The camera's macro lenses were placed every time at the same distance and perpendicular to the central incisors' labial surface.

Figure 2. Custom-made bite fork with acrylic bite template

The free gingival margin position was determined in the digital photographs in the following moments: before- (T1), immediately- (T2), at five minutes (T3) after the cord placement; immediately (T4)-, and at one (T5), two (T6), five (T7), ten minutes (T8) after removing the cord.

On day seven, the clinical healing and the free gingival margin position were examined on a photograph.

The workflow:

- The working area was isolated by using cotton rolls.
- A control photo was taken to determine the initial position of the free gingival margin.

- For the proper choice of the adequately sized retraction cord, the gingival sulcus depth was measured with a periodontal probe.
- For the impregnation of the cord, different chemicals were used every week. The cord was soaked a few seconds in the impregnating solution and kept on a dry surface until it was inserted.
- In the first week, a non-impregnated (NI) cord was placed in the sulcus. In the second week, 25% aluminum chloride (AlCl3) was used, 25% aluminum sulfate (Al(SO4)3) in the third week, 15.5% ferrous sulfate (Fe2(SO4)3) at week four, in the fifth week, 20% ferrous sulfate (Fe2(SO4)3), the sixth week 8% epinephrine (E), and in the last, seventh week, 20% aluminum chloride (AlCl3).
- The cord was placed in the sulcus from mesial to distal.
- The second photo was taken immediately after inserting the cord. After waiting five minutes, the third photo was taken, and the cord was removed. The next four pictures were taken according to the protocol established at the beginning of the workflow. The last photo was taken after a week to evaluate the healing of the free gingival margin.
- The Digimizer software was used for the measurements of the free gingival margin's position vertical modification. The millimetric-scale, attached to the bite template, was used to calibrate the digital measuring program's ruler. Each measurement was performed three times, in mm, perpendicular to the gingival margin from the same reference points of the millimetric-scale.

Figure 3. The Digimizer photo analysis software – determination of the free gingival margin's position

- The data obtained were processed in Microsoft Excel.
- The statistical analysis was performed by using GraphPad Prism 8 for macOS version 8.4.3. software. The statistical significance was set at $p < 0,05$. The mean (M), median (Me), and standard deviation (SD) were calculated. Confidence interval was established at 95%. The used test: Kruskal Wallis followed by Dunn's multiple variance analysis, Mann-Whitney (non-Gaussian distribution).

Results

The moments of the measurements of vertical modification of the gingival margin's position after displacement with retraction cord impregnated with different chemicals are presented in Figure 4 and 5.

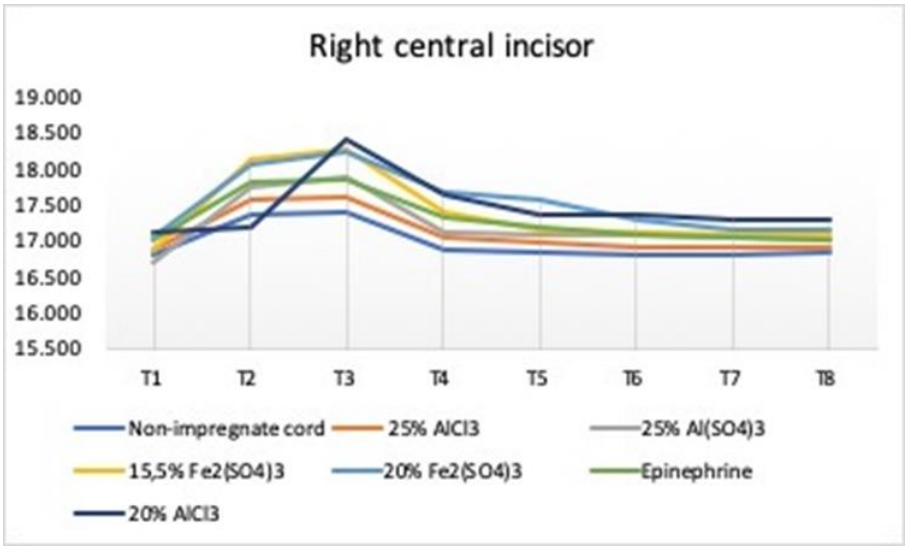

Figure 4. The vertical gingival displacement obtained with the different chemicals in different moments - right central incisor

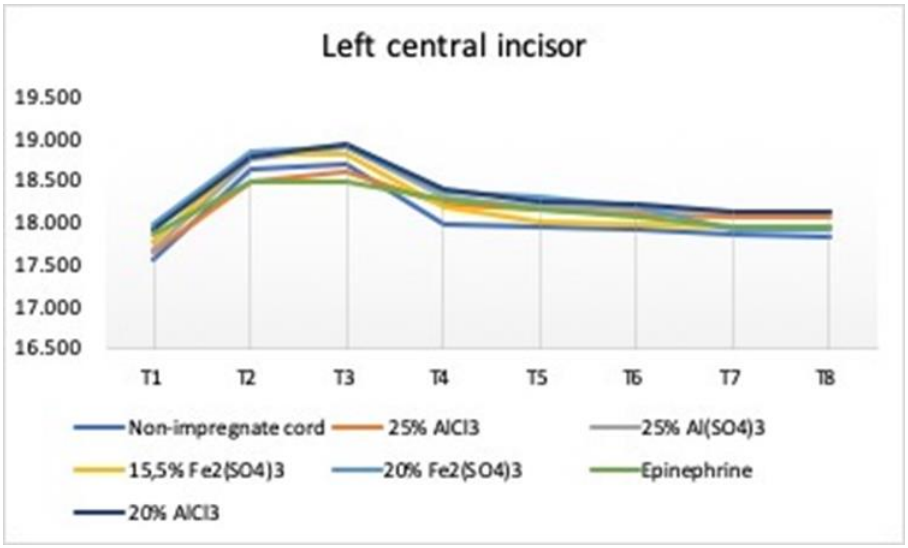

Figure 5. The vertical gingival displacement obtained with the different chemicals in different moments - left central incisor

Comparing the mean values recorded each time, the level of the free gingival margin's position was measured before insertion of the retraction cords, no statistical differences were obtained from one week to another (Mann-Whitney test) (Table 1).

Table 1. Mann-Whitney test results

Period	Gingival displacement method	Mean values	SD	Minimum	Maximum	
Week 1vs 2	NI 25% $AlCl_3$	16.824 17.544	0.004359 1.157	16.819 16.875	16.827 18.880	
Week 2 vs 3	25%$AlCl_3$ $Al(SO_4)_3$	17.544 16.695	1.157 0.002646	16.875 16.692	18.880 16.697	**p>0,05**
Week 3 vs 4	$Al(SO_4)_3$ 15.5% $Fe_2(SO_4)_3$	16.695 16.895	0.002646 0.002646	16.692 16.893	16.697 16.898	
Week 4 vs 5	15.5% $Fe_2(SO_4)_3$ 20% $Fe_2(SO_4)_3$	16.895 17.039	0.002646 0.002646	16.893 17.036	16.898 17.040	

Week 5 vs 6	20% $Fe_2(SO_4)_3$ Epinephrine	17.039 17.007	0.002646 0.001732	17.036 17.005	17.041 17.008	
Week 6 vs 7	Epinephrine 20% $AlCl_3$	17.007 17.129	0.001732 0.002646	17.005 17.127	17.008 17.132	

Statistically significant differences (p=0.0047 – T2, p=0.0036 – T3, p=0.0036 – T4, p=0.0037 – T5, p=0.0038 – T6, p=0.0036 – T7, p=0.0036 – T8) were obtained by comparing the mean values of vertical gingival displacement obtained using a non-impregnated and an impregnated retraction cord with different chemical at each time of the measurements. (Kruskal-Wallis followed Dunn's multiple variance analysis tests) (Table 2-8).

Table 2. Dunn's multiple variance analysis test – T2

Immediately after inserting the cord – T2				
	Right central incisor		Left central incisor	
Comparison	Difference	p-value	Difference	p-value
NI vs 25% $AlCl_3$	0.000	p>0.05	15.000	p>0.05
NI vs 25% $Al(SO_4)_3$	-11.000	p>0.05	3.000	p>0.05
NI vs 15.5% $Fe_2(SO_4)_3$	-14.000	p>0.05	6.000	p>0.05
NI vs 20% $Fe_2(SO_4)_3$	-8.000	p>0.05	12.000	p>0.05
NI vs epinephrine	-5.000	p>0.05	**18.000**	**p<0.01
NI vs 20% $AlCl_3$	3.000	p>0.05	9.000	p>0.05
25% $AlCl_3$ vs 25% $Al(SO_4)_3$	-11.000	p>0.05	-12.000	p>0.05
25% $AlCl_3$ vs 15.5% $Fe_2(SO_4)_3$	-14.000	p>0.05	-9.000	p>0.05
25% $AlCl_3$ vs 20% $Fe_2(SO_4)_3$	-8.000	p>0.05	-3.000	p>0.05
25% $AlCl_3$ vs epinephrine	-5.000	p>0.05	3.000	p>0.05
25% $AlCl_3$ vs 20% $AlCl_3$	3.000	p>0.05	-6.000	p>0.05
25% $Al(SO_4)_3$ vs 15.5% $Fe_2(SO_4)_3$	-3.000	p>0.05	3.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	3.000	p>0.05	9.000	p>0.05
25% $Al(SO_4)_3$ vs epinephrine	6.000	p>0.05	15.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $AlCl_3$	14.000	p>0.05	6.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	6.000	p>0.05	6.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs epinephrine	9.000	p>0.05	12.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	**17.000**	***p<0.05**	3.000	p>0.05
20% $Fe_2(SO_4)_3$ vs epinephrine	3.000	p>0.05	6.000	p>0.05
20% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	11.000	p>0.05	-3.000	p>0.05
Epinephrine vs 20% $AlCl_3$	8.000	p>0.05	-9.000	p>0.05

* - significant p ≤ 0,05; ** - very significant p ≤ 0,01

Table 3. Dunn's multiple variance analysis test – T3

Five minutes after retraction cord insertion – T3				
	Right central incisor		Left central incisor	
Comparison	Difference	p-value	Difference	p-value
NI vs 25% $AlCl_3$	-1.000	p>0.05	9.000	p>0.05
NI vs 25% $Al(SO_4)_3$	-8.000	p>0.05	-3.000	p>0.05
NI vs 15.5% $Fe_2(SO_4)_3$	**-17.000**	***p<0.05**	3.000	p>0.05
NI vs 20% $Fe_2(SO_4)_3$	-11.000	p>0.05	12.000	p>0.05
NI vs epinephrine	-5.000	p>0.05	15.000	p>0.05
NI vs 20% $AlCl_3$	-14.000	p>0.05	6.000	p>0.05
25% $AlCl_3$ vs 25% $Al(SO_4)_3$	-7.000	p>0.05	-12.000	p>0.05
25% $AlCl_3$ vs 15.5% $Fe_2(SO_4)_3$	**-16.000**	***p<0.05**	-6.000	p>0.05
25% $AlCl_3$ vs 20% $Fe_2(SO_4)_3$	-10.000	p>0.05	3.000	p>0.05
25% $AlCl_3$ vs epinephrine	-4.000	p>0.05	6.000	p>0.05
25% $AlCl_3$ vs 20% $AlCl_3$	-13.000	p>0.05	-3.000	p>0.05
25% $Al(SO_4)_3$ vs 15.5% $Fe_2(SO_4)_3$	-9.000	p>0.05	6.000	p>0.05

25% $Al(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	-3.000	p>0.05	15.000	p>0.05
25% $Al(SO_4)_3$ vs epinephrine	3.000	p>0.05	**18.000**	****p<0.01**
25% $Al(SO_4)_3$ vs 20% $AlCl_3$	-6.000	p>0.05	9.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	6.000	p>0.05	9.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs epinephrine	12.000	p>0.05	12.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	3.000	p>0.05	3.000	p>0.05
20% $Fe_2(SO_4)_3$ vs epinephrine	6.000	p>0.05	3.000	p>0.05
20% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	-3.000	p>0.05	-6.000	p>0.05
Epinephrine vs 20% $AlCl_3$	-9.000	p>0.05	-9.000	p>0.05

* - significant p ≤ 0,05; ** - very significant p ≤ 0,01

Table 4. Dunn's multiple variance analysis test – T4

	Immediately after removing the cord – T4			
	Right central incisor		Left central incisor	
Comparison	Difference	p	difference	p
NI vs 25% $AlCl_3$	-1.000	p>0.05	-6.333	p>0.05
NI vs 25% $Al(SO_4)_3$	-8.000	p>0.05	-9.333	p>0.05
NI vs 15.5% $Fe_2(SO_4)_3$	-11.000	p>0.05	5.667	p>0.05
NI vs 20% $Fe_2(SO_4)_3$	**-17.000**	***p<0.05**	8.667	p>0.05
NI vs epinephrine	-5.000	p>0.05	2.333	p>0.05
NI vs 20% $AlCl_3$	-14.000	p>0.05	-3.333	p>0.05
25% $AlCl_3$ vs 25% $Al(SO_4)_3$	-7.000	p>0.05	-3.000	p>0.05
25% $AlCl_3$ vs 15.5% $Fe_2(SO_4)_3$	-10.000	p>0.05	12.000	p>0.05
25% $AlCl_3$ vs 20% $Fe_2(SO_4)_3$	**-16.000**	***p<0.05**	15.000	p>0.05
25% $AlCl_3$ vs epinephrine	-4.000	p>0.05	8.667	p>0.05
25% $AlCl_3$ vs 20% $AlCl_3$	-13.000	p>0.05	3.000	p>0.05
25% $Al(SO_4)_3$ vs 15.5% $Fe_2(SO_4)_3$	-3.000	p>0.05	15.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	-9.000	p>0.05	**18.000**	****p<0.01**
25% $Al(SO_4)_3$ vs epinephrine	3.000	p>0.05	11.667	p>0.05
25% $Al(SO_4)_3$ vs 20% $AlCl_3$	-6.000	p>0.05	6.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	-6.000	p>0.05	3.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs epinephrine	6.000	p>0.05	-3.333	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	-3.000	p>0.05	-9.000	p>0.05
20% $Fe_2(SO_4)_3$ vs epinephrine	12.000	p>0.05	-6.333	p>0.05
20% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	3.000	p>0.05	-12.000	p>0.05
Epinephrine vs 20% $AlCl_3$	9.000	p>0.05	-5.667	p>0.05

* - significant p ≤ 0,05; ** - very significant p ≤ 0,01

Table 5. Dunn's multiple variance analysis test – T5

	One minute after removing the cord – T5			
	Right central incisor		Left central incisor	
Comparison	Difference	p	Difference	p
NI vs 25% $AlCl_3$	-1.000	p>0.05	-6.000	p>0.05
NI vs 25% $Al(SO_4)_3$	-14.000	p>0.05	-3.000	p>0.05
NI vs 15.5% $Fe_2(SO_4)_3$	-10.833	p>0.05	12.000	p>0.05
NI vs 20% $Fe_2(SO_4)_3$	**-17.000**	***p<0.05**	3.500	p>0.05
NI vs epinephrine	-5.000	p>0.05	9.000	p>0.05
NI vs 20% $AlCl_3$	-8.167	p>0.05	5.500	p>0.05
25% $AlCl_3$ vs 25% $Al(SO_4)_3$	-13.000	p>0.05	3.000	p>0.05
25% $AlCl_3$ vs 15.5% $Fe_2(SO_4)_3$	-9.833	p>0.05	**18.000**	****p<0.01**
25% $AlCl_3$ vs 20% $Fe_2(SO_4)_3$	**-16.000**	***p<0.05**	9.500	p>0.05
25% $AlCl_3$ vs epinephrine	-4.000	p>0.05	15.000	p>0.05
25% $AlCl_3$ vs 20% $AlCl_3$	-7.167	p>0.05	11.500	p>0.05
25% $Al(SO_4)_3$ vs 15.5% $Fe_2(SO_4)_3$	3.167	p>0.05	15.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	-3.000	p>0.05	6.500	p>0.05

25% $Al(SO_4)_3$ vs epinephrine	9.000	p>0.05	12.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $AlCl_3$	5.833	p>0.05	8.500	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	-6.167	p>0.05	-8.500	p>0.05
15.5% $Fe_2(SO_4)_3$ vs epinephrine	5.833	p>0.05	-3.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	2.667	p>0.05	-6.500	p>0.05
20% $Fe_2(SO_4)_3$ vs epinephrine	12.000	p>0.05	5.500	p>0.05
20% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	8.833	p>0.05	2.000	p>0.05
Epinephrine vs 20% $AlCl_3$	-3.167	p>0.05	-3.500	p>0.05

* - significant p ≤ 0,05; ** - very significant p ≤ 0,01

Table 6. Dunn's multiple variance analysis test – T6

	Two minutes after removing the cord – T6			
	Right central incisor		Left central incisor	
Comparison	Difference	p	Difference	p
NI vs 25% $AlCl_3$	-1.000	p>0.05	-3.000	p>0.05
NI vs 25% $Al(SO_4)_3$	**-17.000**	***p<0.05**	-6.000	p>0.05
NI vs 15.5% $Fe_2(SO_4)_3$	-8.333	p>0.05	12.000	p>0.05
NI vs 20% $Fe_2(SO_4)_3$	-14.000	p>0.05	8.500	p>0.05
NI vs epinephrine	-5.000	p>0.05	6.500	p>0.05
NI vs 20% $AlCl_3$	-10.667	p>0.05	3.000	p>0.05
25% $AlCl_3$ vs 25% $Al(SO_4)_3$	**-16.000**	***p<0.05**	-3.000	p>0.05
25% $AlCl_3$ vs 15.5% $Fe_2(SO_4)_3$	-7.333	p>0.05	15.000	p>0.05
25% $AlCl_3$ vs 20% $Fe_2(SO_4)_3$	-13.000	p>0.05	11.500	p>0.05
25% $AlCl_3$ vs epinephrine	-4.000	p>0.05	9.500	p>0.05
25% $AlCl_3$ vs 20% $AlCl_3$	-9.667	p>0.05	6.000	p>0.05
25% $Al(SO_4)_3$ vs 15.5% $Fe_2(SO_4)_3$	8.667	p>0.05	**18.000**	****p<0.01**
25% $Al(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	3.000	p>0.05	14.500	p>0.05
25% $Al(SO_4)_3$ vs epinephrine	12.000	p>0.05	12.500	p>0.05
25% $Al(SO_4)_3$ vs 20% $AlCl_3$	6.333	p>0.05	9.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	-5.667	p>0.05	-3.500	p>0.05
15.5% $Fe_2(SO_4)_3$ vs epinephrine	3.333	p>0.05	-5.500	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	-2.333	p>0.05	-9.000	p>0.05
20% $Fe_2(SO_4)_3$ vs epinephrine	9.000	p>0.05	-2.000	p>0.05
20% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	3.333	p>0.05	-5.500	p>0.05
Epinephrine vs 20% $AlCl_3$	-5.667	p>0.05	-3.500	p>0.05

* - significant p ≤ 0,05; ** - very significant p ≤ 0,01

Table 7. Dunn's multiple variance analysis test – T7

	Five minutes after removing the cord – T7			
	Right central incisor		Left central incisor	
Comparison	Difference	p	Difference	p
NI vs 25% $AlCl_3$	-1.000	p>0.05	-3.000	p>0.05
NI vs 25% $Al(SO_4)_3$	**-17.000**	***p<0.05**	-6.000	p>0.05
NI vs 15.5% $Fe_2(SO_4)_3$	-14.000	p>0.05	6.000	p>0.05
NI vs 20% $Fe_2(SO_4)_3$	-8.000	p>0.05	12.000	p>0.05
NI vs epinephrine	-5.000	p>0.05	9.000	p>0.05
NI vs 20% $AlCl_3$	-11.000	p>0.05	3.000	p>0.05
25% $AlCl_3$ vs 25% $Al(SO_4)_3$	**-16.000**	***p<0.05**	-3.000	p>0.05
25% $AlCl_3$ vs 15.5% $Fe_2(SO_4)_3$	-13.000	p>0.05	9.000	p>0.05
25% $AlCl_3$ vs 20% $Fe_2(SO_4)_3$	-7.000	p>0.05	15.000	p>0.05
25% $AlCl_3$ vs epinephrine	-4.000	p>0.05	12.000	p>0.05
25% $AlCl_3$ vs 20% $AlCl_3$	-10.000	p>0.05	6.000	p>0.05
25% $Al(SO_4)_3$ vs 15.5% $Fe_2(SO_4)_3$	3.000	p>0.05	12.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	9.000	p>0.05	**18.000**	****p<0.01**
25% $Al(SO_4)_3$ vs epinephrine	12.000	p>0.05	15.000	p>0.05

25% $Al(SO_4)_3$ vs 20% $AlCl_3$	6.000	p>0.05	9.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	6.000	p>0.05	6.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs epinephrine	9.000	p>0.05	3.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	3.000	p>0.05	-3.000	p>0.05
20% $Fe_2(SO_4)_3$ vs epinephrine	3.000	p>0.05	-3.000	p>0.05
20% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	-3.000	p>0.05	-9.000	p>0.05
Epinephrine vs 20% $AlCl_3$	-6.000	p>0.05	-6.000	p>0.05

*- significant p ≤ 0,05; **- very significant p ≤ 0,01

Table 8. Dunn's multiple variance analysis test – T8

	Ten minutes after removing the cord – T8			
	Right central incisor		Left central incisor	
Comparison	Difference	p	Difference	p
NI vs 25% $AlCl_3$	-1.000	p>0.05	-3.000	p>0.05
NI vs 25% $Al(SO_4)_3$	**-17.000**	***p<0.05**	-6.000	p>0.05
NI vs 15.5% $Fe_2(SO_4)_3$	-14.000	p>0.05	6.000	p>0.05
NI vs 20% $Fe_2(SO_4)_3$	-8.000	p>0.05	12.000	p>0.05
NI vs epinephrine	-5.000	p>0.05	9.000	p>0.05
NI vs 20% $AlCl_3$	-11.000	p>0.05	3.000	p>0.05
25% $AlCl_3$ vs 25% $Al(SO_4)_3$	**-16.000**	***p<0.05**	-3.000	p>0.05
25% $AlCl_3$ vs 15.5% $Fe_2(SO_4)_3$	-13.000	p>0.05	9.000	p>0.05
25% $AlCl_3$ vs 20% $Fe_2(SO_4)_3$	-7.000	p>0.05	15.000	p>0.05
25% $AlCl_3$ vs epinephrine	-4.000	p>0.05	12.000	p>0.05
25% $AlCl_3$ vs 20% $AlCl_3$	-10.000	p>0.05	6.000	p>0.05
25% $Al(SO_4)_3$ vs 15.5% $Fe_2(SO_4)_3$	3.000	p>0.05	12.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	9.000	p>0.05	**18.000**	****p<0.01**
25% $Al(SO_4)_3$ vs epinephrine	12.000	p>0.05	15.000	p>0.05
25% $Al(SO_4)_3$ vs 20% $AlCl_3$	6.000	p>0.05	9.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $Fe_2(SO_4)_3$	6.000	p>0.05	6.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs epinephrine	9.000	p>0.05	3.000	p>0.05
15.5% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	3.000	p>0.05	-3.000	p>0.05
20% $Fe_2(SO_4)_3$ vs epinephrine	3.000	p>0.05	-3.000	p>0.05
20% $Fe_2(SO_4)_3$ vs 20% $AlCl_3$	-3.000	p>0.05	-9.000	p>0.05
Epinephrine vs 20% $AlCl_3$	-6.000	p>0.05	-6.000	p>0.05

*- significant p ≤ 0,05; **- very significant p ≤ 0,01

Discussions

During dental rehabilitation, the abutment's accurate impression represents one of the most critical clinical steps. The 0.5–1 mm subgingivally placed crown margins are desired when restoring esthetics in the frontal area [5,6]. The gingival enlargement around the abutment is essential to obtain visibility and access to the finish line during the preparation and the impression.

Several mechanical, chemical, mechano-chemical, and surgical gingival displacement procedures have been described in the literature [7,8]. Nowadays, the "classical" mechano-chemical technique is most frequently used [5,9]. The method presented in our study uses the retraction cord and different chemicals (hemostatic and vasoconstrictor) to obtain a moisture-free, accessible sulcus. The gingival displacement was obtained using the single cord technique, which is used more frequently for single-tooth restorations in healthy gingival tissue. It involves inserting a proper size single retraction cord in the gingival sulcus, which is soaked in various chemicals and then removed carefully [10].

Chandra et al. demonstrated this technique's efficiency by obtaining the desired width, which is maintained in the first minute after removing the cord and is lost progressively in time until the free gingival margin returns to its initial position [8]. Considering that the different elastomeric impression materials' setting time is between two to seven minutes [11], we considered essential to evaluate the vertical modification of the free gingival

margin immediately and at one to ten minutes after removing the retraction cord.

According to Baharav et al., to achieve optimal enlargement is recommended to keep the cord in the sulcus for four minutes [12]. In our case, the cord was maintained in the sulcus for five minutes.

After cord removal, the best gingival enlargement (mean values) was achieved using 25% aluminum sulfate (0.53 mm) followed by 20% aluminum chloride (0.50 mm), 20% ferrous sulfate (0.49 mm), 15.5% ferrous sulfate (0.46 mm), and epinephrine (0.36 mm), which are in concordance with researches of Hansen et al., demonstrating why the most commonly used chemicals nowadays are the aluminum sulfate and the aluminum chloride [13].

In the literature, there are only a few studies regarding the vertical displacement of the gingival margin. Gajbhiye et al. obtained a mean value of 0.299 mm with a 25% aluminum chloride impregnated retraction cord [7], a lower value than our measurements, but Thimmappa et al. obtained a higher mean value of 1.24 mm with a non-impregnated retraction cord [14].

In our study, the lowest value was obtained for the non-impregnated cord. Our findings are similar to Cloyd et al. 's results. The impregnation of the cord is important to obtain good results [15]. According to our and some other authors' research, aluminum chloride is the least irritating hemostatic agent and astringent, without contraindications and minimal local and systemic side effects [16].

Unfortunately, it can modify the polyvinyl siloxane impression materials setting reaction, like the aluminum sulfate [17].

Tarighi and Khoroushi [18] have shown that rinsing the preparation boundary with water after removing the cord can reduce the interaction with the impression materials. Machado and Guedes refute the direct, adverse effect of the aluminum chloride on impression materials [19].

The ferrous sulfate above, a 15% concentration, causes significant gum irritation and sensitivity [20]. As demonstrated in our experiment, gingival sensitivity and gingivitis occurred after using both concentrations of our solutions.

The most easily inserted cord has been with epinephrine, an effective vasoconstrictor, and hemostatic agent [17]. According to its systemic side effects, especially in patients with cardiovascular diseases [21], its use is not widespread today.

To avoid the gingival lesions during the cord's removal, Pelzner et al. recommend being moisturized [22].

During our research, the free gingival margin did not return to the original position after a week. However, no statistically significant differences were found between the different positions of the gingival margins during the seven weeks of examination. One week is not enough for complete gingival recovery in case of gingival displacement with retraction cords, how Prasad et al. and Reddy et al. demonstrated in their studies [23, 24]. Alternative methods can be used to obtain faster healing. The carefully handled displacement pastes can be less injurious to the marginal gingiva's health than the retraction cords [25]. According to Andreiuolo et al., retraction with cords usually requires local anesthesia and is time-consuming. Instead of cords, for better results, these clinicians recommend the different astringent pastes [26].

The limitations of this study: the lack of standardization of the landmarks used to perform the measurements does not allow an accurate assessment of the vertical gingival displacement. The clinical use of the single-cord technique has limitations. The double-cord technique is an effective alternative that can result in a different gingival enlargement.

The knitted retraction cord was used for the gingival displacement. Another cord type can result in different modifications. The interpretation of the results did not consider the gingival phenotype. The obtained values can differ for the thin biotype.

Conclusions

Within this study's limitation, the mechano-chemical technique is an efficient method for gingival displacement regardless the impregnating solution used. The use of aluminum chloride as an impregnation solution has proven to be the most efficient gingival displacement method.

The full recovery of the free gingival

margin's position is not completed in a week regardless of whether an impregnated or non-impregnated retraction cord is used.

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