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A Comparative Analysis of Post-Retraction Changes in Gingival Height after Conventional and Surgical Gingival Displacement: Rotary Curettage, Diode and Er:YAG Laser Troughing

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Abstract: The current article aims to assess post-retraction gingival height changes after six different types of gingival displacement methods – conventional and surgical. A comparative analysis of the post-retraction changes in the gingival height of 263 teeth (23 patients) was performed. The following retraction methods were applied – three classic (single-cord technique, retraction paste Expasyl, and retraction paste Astringent) and three surgical (ceramic bur rotary curettage, Er:YAG laser troughing and diode laser troughing). The recovery of the free gingival margin height on gypsum models, scanned with an intraoral scanner in the first and second week after retraction, was examined. All retraction methods tested, except for the ceramic bur rotary curettage, resulted in clinically insignificant gingival recession levels.

Keywords: gingival displacement; gingival retraction; laser troughing; pre-impression troughing; laser retraction; laser displacement; diode laser; Er:YAG laser; rotary curettage; ceramic bur

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1. Introduction

Gingival retraction (gingival displacement) is the process of a reversible displacement or removal of the inner surface of the gingival sulcus to let the impression material cover or the intraoral scanner scan the prepared and unprepared part of the tooth. According to the Glossary of Prosthodontic Terms, 2017, it is 'the deflection of the marginal gingiva away from a tooth' [1].

The aim is to perform adequate reversible gingival displacement and manipulation of the gingival tissues, to make a precise reproduction of the finish line and the intact unprepared tooth structure apically, as well as to provide a dry field for the impression material or the intraoral scanner while preserving the contour, position, and periodontal health of the gingiva. The main gingival displacement methods can be divided into two main groups: conventional mechanical, chemical and mechano-chemical, and surgical (troughing).

The current article aims to assess post-retraction gingival height changes after six different types of gingival displacement methods – conventional and surgical.

2. Materials and Methods

After six different retraction methods, a comparative analysis of post-retraction changes in gingival height was performed.

Object of observation:

The changes in the gingival height after each one of the retraction methods.

Units of observation:

Retracted gingiva in 263 teeth of 23 patients.

Parameters of observation:

1. Factor variables:
   - The six tested retraction methods.
   - Sex.
   - Age.
   - Group of teeth (frontal, premolars and molars).
   - Time of gingival recovery (first week and second week).
2. Resultant variables:
   - Presence of gingival recession.
   - Hyperplasia of the free gingival margin level.

Venue of observation:

- Department of Prosthetic Dentistry, Faculty of Dental Medicine, CAD/CAM Center of Dental Medicine, Research Institute, Medical University – Plovdiv (RIMUP)
- Department of Periodontology and Oral Mucosa Diseases, Laser Dental Center, Faculty of Dental Medicine, Research Institute, Medical University—Plovdiv, Bulgaria (RIMUP)

Criteria for inclusion in the study:

- Patients should not have systemic diseases. They may lead to inflammation and/or bleeding, compromising the results [2].
- They should not have taken medications in the last three months. Some medications may cause inflammation and/or bleeding, compromising the results [2].
- The Löe and Silness gingival index should be 0. The index assesses the prevalence and severity of gingivitis in populations, groups, and individuals. A score from 0.1 to 1.0 signifies mild inflammation, 1.1 to 2.0 moderate inflammation, and 2.1 to 3.0 severe inflammation [2].

Criteria for exclusion from the study:

- Patients with systemic diseases [3].
- Patients with psychological disorders.
- Patients with periodontal diseases.
- The presence of inaccurate obturations can interfere with the biological width.

- Teeth with periodontal probing depth (PPD) above 3 mm.

The study was approved with a statement by the Committee of Scientific Ethics at Medical University – Plovdiv, reference number P-7350/01.10.2015. Patients signed informed consent and received a document about the study and the possible risks.

Entry of primary data:

The reported gingival height (in mm) with the Trios CAD/CAM intraoral scanner (3Shape, Denmark) was also registered by photo documentation, as the photographic material was analyzed according to the tested variables. The obtained mean values (from the triple measuring of the gingival height) for the first and second weeks and the factor variables were plotted in spreadsheets for further statistical analysis.

Study Design:

A randomized 'split mouth design' study was conducted. The dentition was divided into four quadrants, and the gingival retraction of the opposite quadrants was performed using one of the six analyzed methods: mechano-chemical (three classic approaches) or surgical (three approaches). The choice of which retraction method would be used for a given quadrant was random.

23 patients, subject to fixed restorations in the Departments of Prosthetic dentistry, Faculty of Dental medicine, Medical University – Plovdiv, Bulgaria. were examined (263 teeth in total). The participants were healthy patients that needed crown or bridge restorations. The subjects were instructed in advance to maintain good oral hygiene. The first visit included teeth preparation and impression taking. The finish line was subgingival – chamfer, positioned 0.5 mm apically from the gingival margin. Temporary composite crowns were made and cemented on the prepared teeth.

The distance from the free gingival margin to the center of a sphere, made with a round bur (0.08 mm diameter) on the facial side of the tooth, was measured. Three measurements were made on scanned plaster models cast from the impressions:

- 1st measurement – immediately after the retraction – the value was considered 0.
- 2nd measurement – one week after the procedure.
- 3rd measurement – two weeks after that.

Gingival recovery or occurrence of possible gingival recession (GR) was assessed in the two post-retraction stages of the measurement. The obtained mean values of the gingival height in every retraction method were compared.

Retraction methods used:

1. **Classic mechano-chemical:**

1.1. Retraction cords Elite cord (Zhermack, Italy) in five different sizes (000, 00, 0, 1, 2) depending on the sulcus depth, impregnated with a 5% aluminium chloride solution.

1.2. Retraction paste Expasyl (Pierre Rolland, France).

1.3. Retraction paste Astringent (3M ESPE, Germany).

2. **Surgical:**

2.1. Ceramic bur Soft Tissue Trimmer NTI (Kerr, USA).

2.2. Er:YAG laser with a wavelength of 2940 nm (LiteTouch; Syneron Dental, Israel).

2.3. Diode laser with a wavelength of 810 nm and power 8W (FOX, A.R.C. Lasers GmbH, Germany).

Technique of implementation of the applied gingival displacement methods:

It is established that plaque accumulation can lead to gingivitis and periodontitis, which can compromise the results. The subjects were instructed in advance to maintain good oral hygiene by using contemporary mechanical and chemical methods of plaque control to prevent gingivitis [2]. The plaque index of the patients was 0, indicating no visible plaque [2]. The first visit included teeth preparation and impression taking. The finish line was subgingival – chamfer, positioned 0.5 mm apically from the gingival margin. Temporary composite crowns were made and cemented on the prepared teeth.

1. Retraction cords Elite cord (Zhermack, Italy) in five different sizes (000, 00, 0, 1, 2) depending on the sulcus depth were used for the single-cord technique. The cord was impregnated with a 5% aluminum chloride solution. A smooth packing instrument was carefully used to place the cord in the sulcus to ensure excellent visual access to the finish line. The packing of the cords did not cause hemorrhage or tearing of the marginal gingiva. Right before taking the impression, the cord was watered to prevent gingival tearing and removed, and the sulcus was washed and air-dried.

2. The second type of retraction was performed by using **Expasyl retraction paste** (Pierre Rolland, France) with a special applicator gun and a cannula. The retraction paste contains 15% aluminum chloride and kaolin. It was placed in the sulcus around the circumference filling it to the bottom. After 2 minutes of waiting for volume expansion, it was washed away thoroughly immediately before taking the impression.

3. The third type of retraction was using **Astringent Paste** (3M ESPE, Germany) in a compule with a special applicator gun. The retraction paste contains 15% aluminum chloride. It was placed in the sulcus around the circumference so that it filled it to the bottom. After 2 minutes of waiting for volume expansion, it was washed away thoroughly immediately before taking the impression.

4. The fourth type of retraction was the **ceramic bur NTI Soft Tissue Trimmer** (Kerr, USA) **rotary curettage**. Unlike the classic rotary curettage with a diamond bur, when the preparation is finished, and the sulcus is simultaneously de-epithelized, the ceramic bur cuts soft tissues only. It works with a turbine without water cooling. It slid through the sulcus around the circumference, removing the superficial epithelium. Coagulation, therefore, the gingival tissues' hemostasis was achieved due to the temperature rise. Enough epithelium was removed to leave space for the impression material and to visualize the finish line. Before taking the impression, the sulcus was dried, so the hydrophobic impression material could fill it up.

5. The fifth type of retraction was performed using the **Er:YAG LiteTouch laser** (Syneron Dental, Israel) with a wavelength of 2940 nm. A thin chisel tip was used in contact mode, with an incessant brushing movement and a 15º angle to the root surface. The settings were the following: Soft Tissue Mode, 50 mJ, 10 Hz (0.50 W altogether), with incessant water cooling. Enough epithelium was removed to leave space for the impression material and to visualize the finish line. Before taking the impression, the sulcus was dried, so the hydrophobic impression material could fill it up.

6. The sixth type of retraction was by using a **diode** laser (FOX, A.R.C. Lasers GmbH, Germany) with a wavelength of 810 nm and a maximum power of 8 W. The tip of the fiber was activated by holding it on a special black paper prior to starting the procedure. The retraction always started at lower power. The diode laser was set to a continuous mode with a power of 1.5 W and, if necessary, it could be increased to 2 W. The working mode was Gingivectomy. Tissue charring was a side effect of using the laser and could occur either because of operating at too high a power or because the tip moved too slowly.

The optical tip, held at an angle to the soft tissues and away from the prepared tooth, slid along the gingival sulcus to remove the sulcus epithelium. Constant and stable short brushing moves carefully removed the inner sulcus epithelium to provide a 360-degree trough. The tip was cleaned with wet gauze, and soaked in 3% hydrogen peroxide, to remove the debris and eliminate possible bacterial contamination. Enough epithelium was removed to leave space for the impression material and to visualize the finish line. Before taking the impression, the sulcus was dried, so the hydrophobic impression material could fill it up.

Impression materials:

The following impression materials were used for the study – alginate (Tropicalgin, Zhermack, Italy) for taking preliminary impressions and addition silicones (A-silicones) (Variotime, Heraeus Kulzer, Germany). After taking the preliminary alginate impressions, custom trays from light-cured resins were made to take more precise impressions and save impression material. The final impressions were taken with an A-silicone. The finish line was a subgingival chamfer, positioned 0.5 mm apically from the gingival margin. Temporary composite crowns were made and cemented on the abutment teeth.

The impressions were taken at the same visit as the retraction. An assessment of the gingival configuration was made with the help of the final impressions during the three beforementioned stages of the study.

The facial surface of all prepared teeth was marked at a 3 mm distance from the free gingival margin with a round bur with a fixed diameter (0.08 mm). The final impressions were taken with a custom tray and Variotime A-silicone.

In order to dose and equalize the pressure exerted during impression taking, at least three 'occlusal stops' were made on the custom trays. Two layers of pink wax were adapted to provide the necessary space for the impression material. The wax was cut at the areas of the occlusal stops, and a thin aluminium foil was adapted on top of it. The light-cured resin was then adjusted, the excesses were cut with a knife, and a handle was made using some of them. The impression tray was cured in a light-curing unit.

CAD/CAM system:

Scanning the plaster models using the Trios intraoral scanner (3Shape CAD/CAM system) was performed to measure the free gingival margin level at every stage of the study (Figure 1). In order to obtain optimally accurate results (a total of 3 times the study), a threefold measurement of the free gingival margin was performed, and the values obtained were averaged. The measured length immediately after retraction was considered to be 0, and the next two measurements – at week one and week two – tracked the changes in the free gingival margin height.

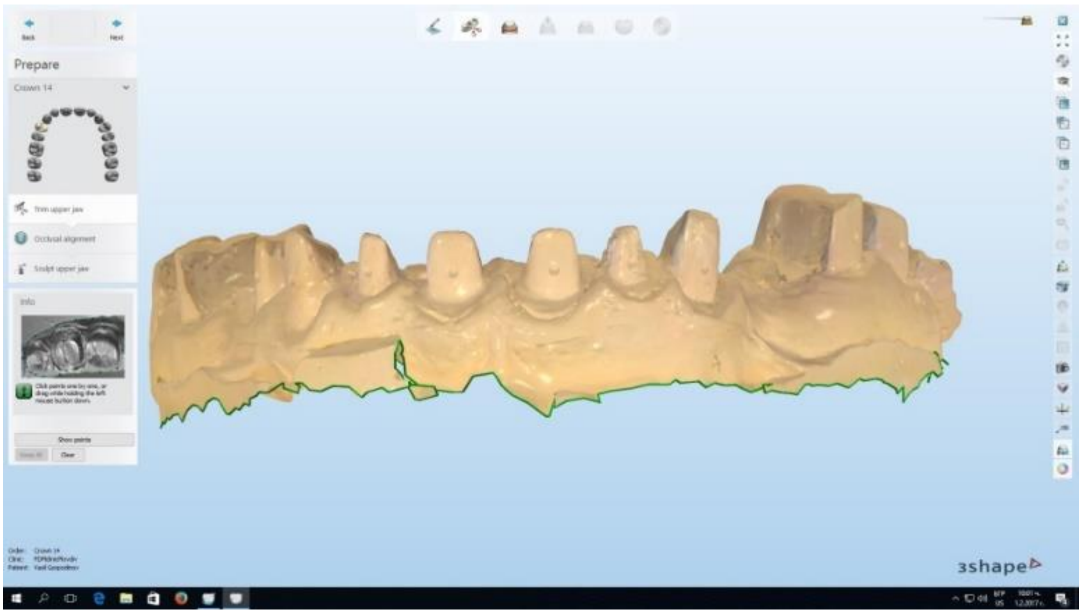

Figure 1. A scanned plaster model using the Trios (3Shape, Denmark) intraoral scanner.

The scanning accuracy of the Trios 3 (3Shape, Denmark) intraoral scanner, according to the American Dental Association (ADA) data, is 6.9±0.9 μm [4].

A total of three impressions were taken: the first one – after the retraction, the second one – on the first week, and the third one – on the second week. Plaster models were cast and then scanned with the Trios intraoral scanner. In order to achieve a three-dimensional accuracy, with the help of the CAD/CAM system, a virtual cut through the middle of the measured tooth along its longitudinal axis was made (Figure 2).

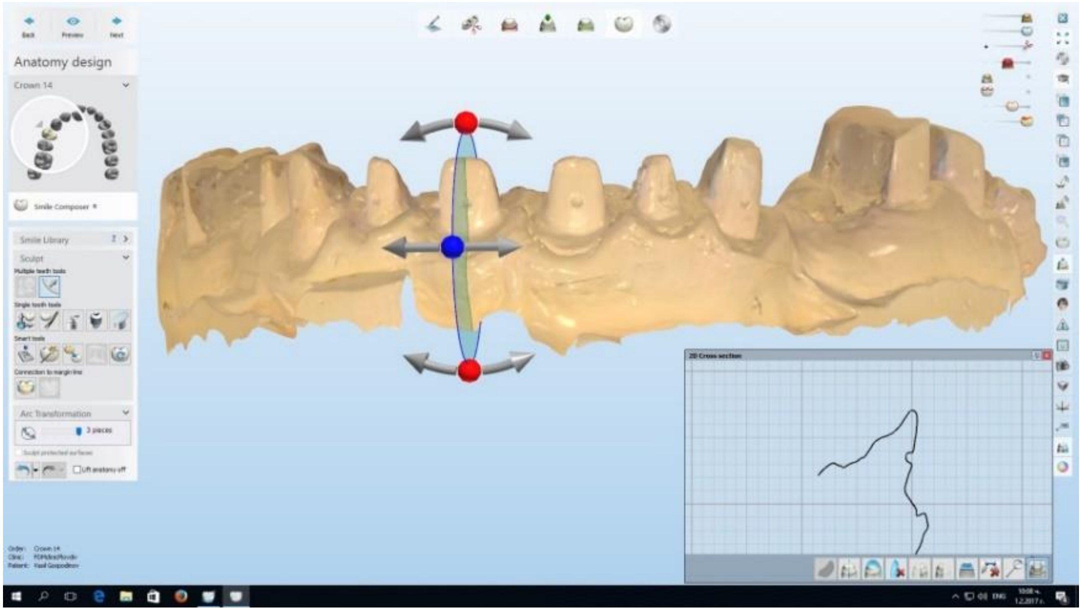

Figure 2. Virtual cut through the middle of the measured tooth. With the help of the vectors the longitudinal axis of the tooth was accurately measured.

The distance between the middle of the mark, made with the 0.08 mm bur on the prepared tooth, and the free gingival margin on the facial surface of the tooth was measured (Figure 3). Thus, possible changes in the gingival height level after the retraction were monitored.

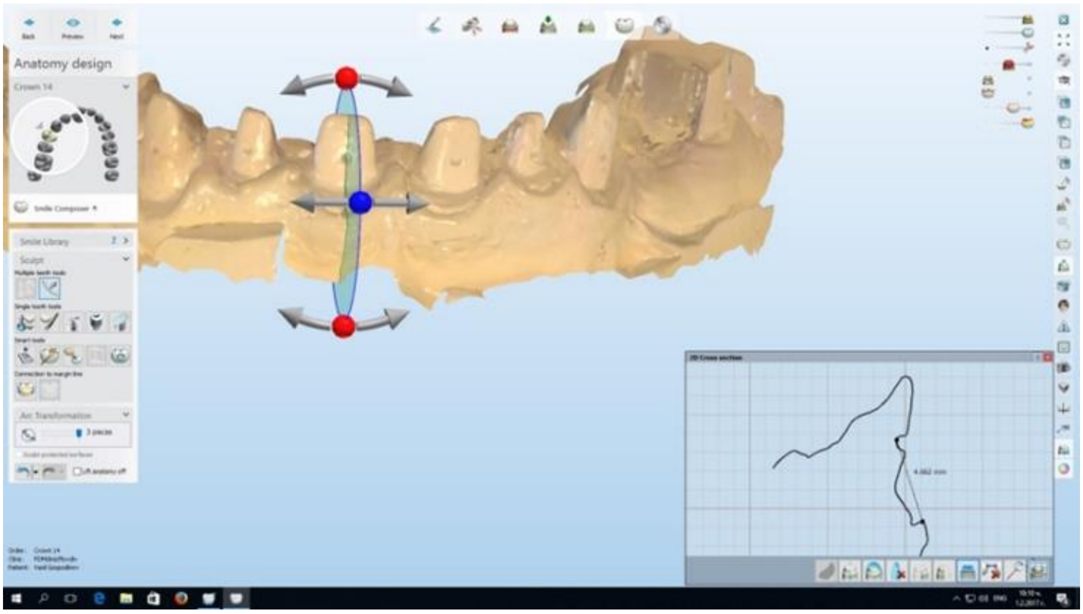

Figure 3. Technique of gingival height measurement.

Statistical methods:

The statistical methods were implemented with the statistical program SPSS version 19, and the results were considered statistically significant at α<0,05.

Statistical analyses applied:

- Descriptive analysis for describing the structures of the given variables.
- X^2-anaysis (Chi-squared test) for establishing dependencies between qualitative variables.
- Mann-Whitney U-Test for comparison between two samples in which the distribution of quantitative variables is not normal.
- Graphical analysis for illustration of the results obtained.

3. Results

3.1. Sample characteristics:

The study compared the obtained mean gingival height levels after retraction with different methods of a total of 263 teeth (of 23 healthy subjects), 44.5% of the analyzed – women (117 teeth), and 55.5% – men (146 teeth).

The average age of the patients was 36.20±6.039 y/o (the youngest was 18 y/o, and the oldest – 56 y/o). The average age of the women was 33.41±4.27 y/o, and men – 38.44±6.32 y/o. The mean difference (5.03 years) was statistically significant (u = 7.369, p = 0.000) – Table 1.

Table 1. Average (mean) age of the studied men and women.

	Sex	Number	Mean	Standard deviation	Standard error	U	p	Mean difference
Age	Men	146	38.44	6.323	0.523	7.369	0.000	5.028
	Women	117	33.41	4.269	0.395			

48.3% (127 teeth) were retracted using the three classic mechano-chemical methods, and 51.7% (136 teeth) were retracted surgically (using three methods).

Figure 4 (Appendix A, Figure A1) shows the structural distribution of teeth retracted with a specific method. The mean number for each method was 42 to 46 teeth.

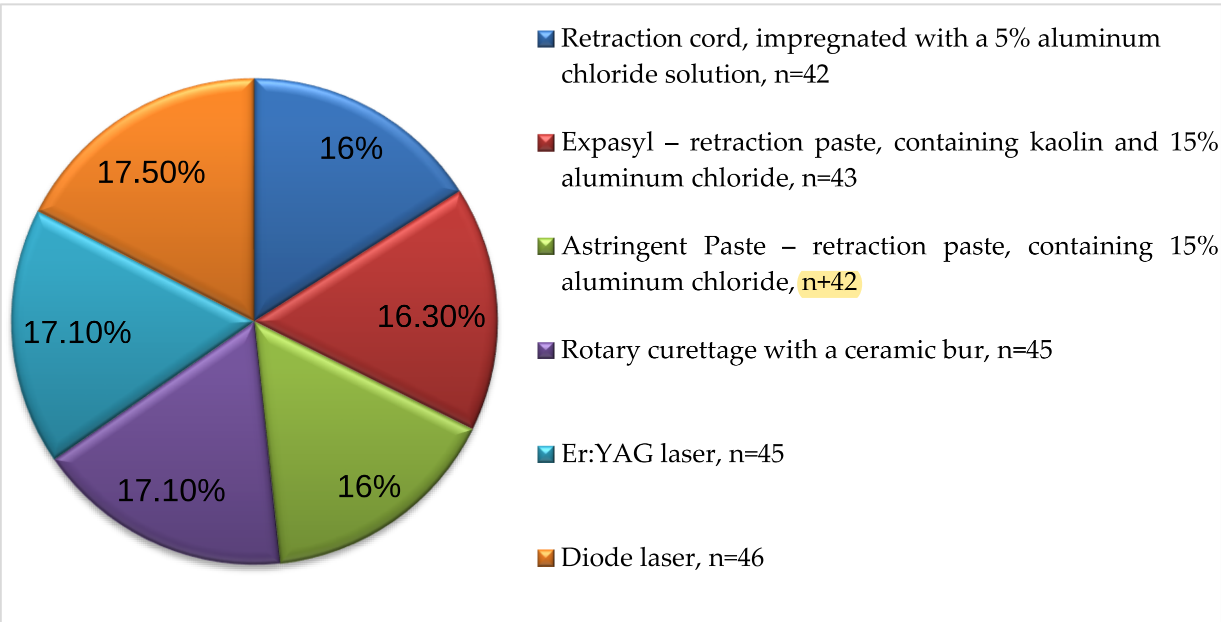

Figure 4. Structural distribution of teeth based on the applied retraction methods.

In Figure 5 (Appendix B, Figure B1), the number and percentage of the examined teeth are presented, depending on whether they are frontal, premolars or molars; the frontal ones represent 48.7% (128 teeth), the premolars – 26.2% (69 teeth), and the molars – 25.1% (66 teeth). A similar number of frontal and distal teeth was sought to be achieved for the sake of the study analyses. Appendix C (Figure C1) shows the structural distribution of the examined teeth in detail.

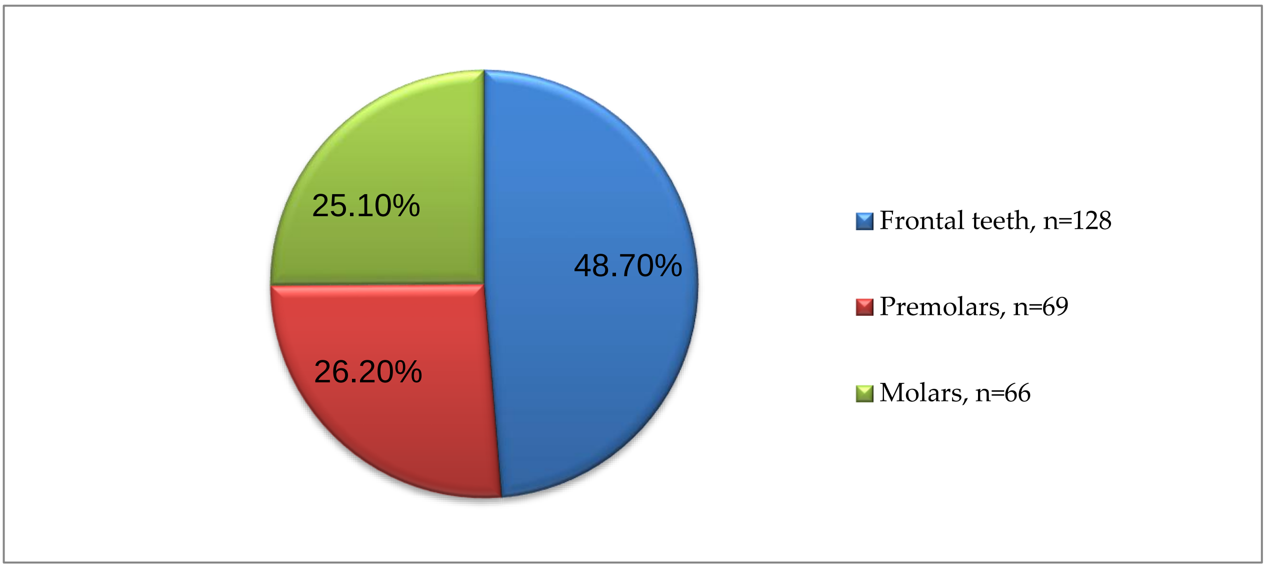

Figure 5. Grouping of the examined teeth.

3.2. Experimental results:

The mean value of the measured gingival recession at the first measurement (the first week after the retraction) for the classic mechano-chemical methods was 0.011±0.17 mm; the surgical methods presented with a more notable, but not clinically significant, recession – 0.23±0.25 mm (Table 2). The intergroup difference between the compared levels of the free gingival margin was 0.24 mm, which was statistically significant – u=8.954, p=0.00.

The measured gingival recession value in the second week after the retraction was 0.02±0.13 mm for the classic mechano-chemical methods and 0.15±0.21 mm – for the surgical ones. The discovered significant difference was 0.14 mm, which was approximately twice less than the difference found between the two methods in the previous measurement.

Table 2. Measured mean values of gingival recession depending on the methods applied.

	Methods	Number	Mean (mm)	Standard deviation	u	p	Mean difference
Values first week after the retraction	Classic mechano-chemical methods	127	**0.011**	0.170	8.954	0.000	**0.239**
	Surgical methods	136	**0.228**	0.251			
Values second week after the retraction	Classic mechano-chemical methods	127	**0.017**	0.127	6.443	0.000	**0.137**
	Surgical methods	136	**0.155**	0.206			

Table 3 presents the mean values of gingival height in the first and second week of the two main methods used, depending on whether they were applied on front teeth, premolars and molars. The differences in gingival height between the two main compared retraction methods were found to be more significant in the premolars and molars than in the frontal teeth.

Table 3. Measured mean total gingival recession values, depending on the main methods applied, when grouping the teeth.

		Methods	Number	Mean (mm)	Standard deviation	u	p	Mean difference
Frontal teeth	Values first week after the retraction	Classic mechano-chemical methods	63	**-0.002**	0.204	4.755	0.000	**0.174**
		Surgical methods	65	**-0.176**	0.209			
	Values second week after the retraction	Classic mechano-chemical methods	63	**-0.031**	0.162	3.022	0.003	**0.091**
		Surgical methods	65	**-0.122**	0.179			
Premolars	Values first week after the retraction	Classic mechano-chemical methods	33	**0.027**	0.154	5.148	0.000	**0.304**
		Surgical methods	36	**-0.277**	0.305			
	Values second week after the retraction	Classic mechano-chemical methods	33	**-0.004**	0.092	4.082	0.000	**0.188**
		Surgical methods	36	**-0.192**	0.249			
Molars	Values first week after the retraction	Classic mechano-chemical methods	31	**0.018**	0.097	6.149	0.000	**0.292**
		Surgical methods	35	**-0.274**	0.248			
	Values second week after the retraction	Classic mechano-chemical methods	31	**-0.004**	0.062	4.570	0.000	**0.173**
		Surgical methods	35	**-0.177**	0.201			

Table 4 presents the mean gingival level at the two measurements. The table demonstrates which methods in particular resulted in gingival recession or an increase of the free gingival margin level. The data showed that the methods with the Astringent Paste (a retraction paste containing 15% aluminum chloride) and the Expasyl paste (a retraction paste containing kaolin and 15% aluminum chloride) resulted in a slight, clinically inexpressible post-retraction gingival hyperplasia.

The other remaining four retraction methods resulted in a different degree of recession, which was clinically significant only for the patients that underwent ceramic bur rotary curettage, respectively 0.45±0.27 mm – for the first week and 0.32±0.23 mm – for the second one (Table 4). The lowest recession levels were recorded at the Er:YAG retraction (0.10±0.13 mm – for the first week and 0.06±0.10 mm – for the second one).

Table 4. Measured mean gingival height values depending on every method applied.

Methods applied		**Values first week after the retraction**	**Values second week after the retraction**
Retraction cord, impregnated with a 5% aluminum chloride solution	Mean (mm)	**-0.148**	**-0.124**
	Number	42	42
	Standard deviation	0.185	0.167
Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	Mean (mm)	**0.116**	**0.057**
	Number	**43**	**43**
	Standard deviation	0.110	0.056
Astringent – retraction paste, containing 15% aluminum chloride	Mean (mm)	**0.062**	**0.013**
	Number	42	42
	Standard deviation	0.047	0.012
Ceramic bur rotary curettage	Mean (mm)	**-0.449**	**-0.307**
	Number	45	45
	Standard deviation	0.269	0.227
Er:YAG laser	Mean (mm)	**-0.100**	**-0.060**
	Number	45	45
	Standard deviation	0.126	0.096
Diode laser	Mean (mm)	**-0.137**	**-0.099**
	Number	46	46
	Standard deviation	0.170	0.180
Total	Mean (mm)	-0.113	-0.088
	Number	263	263
	Standard deviation	0.246	0.185
	F	**62.025**	**0.000**
	P	**33.923**	**0.000**

Because both statistically and clinically significant higher gingival recession levels were obtained after the ceramic bur retraction (surgical method) (Table 5), this method was excluded from the analysis, and the combined mean values of the gingival height for the other two surgical (laser) methods were compared. After the change in Table 4 (the rotary curettage data was excluded), it could be seen that the reported gingival recession levels in the first and second week for the surgical (laser) methods dropped almost twice compared to the data from Table 6. The differences in the gingival recession levels were also twice as low in this comparative approach.

Table 5. Mean gingival height values measured depending on the methods applied (ceramic bur rotary curettage excluded).

	2 main methods (ceramic bur rotary curettage excluded)	**Number**	**Mean (mm)**	**Standard deviation**	**u**	**p**	**Mean difference (mm)**
Values first week after the retraction	Classic mechano-chemical methods	127	0.011	0.170	5.795	0.000	0.130
	Surgical methods	91	-0.118	0.150			
Values second week after the retraction	Classic mechano-chemical methods	127	-0.017	0.127	3.341	0.001	0.062
	Surgical methods	91	-0.080	0.145			

Table 6 presents the specific gingival recession or hyperplasia values when grouping the teeth as frontal, premolars and molars, depending on the specific retraction methods used. It should be noted again that the highest clinically significant gingival recession value was reported in the ceramic bur rotary curettage group. The highest gingival recession level was reported for premolars – 0.56±0.32 mm for the first week and 0.41±0.29 mm – for the second one. The recession levels for this method were slightly lower for the molars – 0.51±0.21 mm and 0.35±0.23 mm for the first and the second week, respectively.

The Er:YAG laser group demonstrated the lowest loss of gingival height levels in every single group of teeth (Table 6). The mean recession level in the diode laser retraction group was twice as low as in the mechano-chemical group (retraction cord) for the frontal teeth. The mean gingival heigh loss after diode laser retraction in the premolars and molars groups was slightly more than after the retraction cord. All the differences found in the gingival height measurement between the compared methods in the three groups of teeth were statistically significant.

Table 6. Mean gingival recession or hyperplasia values, when grouping the teeth as frontal, premolars and molars, and depending on the specific retraction methods used.

			Number	Mean (mm)	Standard deviation	F	p
Frontal teeth	**Values first week after the retraction**	Retraction cord, impregnated with a 5% aluminum chloride solution	21	-0.193	0.237		
		Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	20	0.109	0.115		
		Astringent Paste – retraction paste, containing 15% aluminum chloride	22	0.080	0.048	25.689	0.000
		Ceramic bur rotary curettage	22	-0.361	0.254		
		Er:YAG laser	22	-0.075	0.072		
		Diode laser	21	-0.087	0.105		
		Total	128	-0.090	0.224		
	Values second week after the retraction	Retraction cord, impregnated with a 5% aluminum chloride solution	21	-0.168	0.215		
		Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	20	0.063	0.069		
		Astringent Paste – retraction paste, containing 15% aluminum chloride	22	0.015	0.011	12.099	0.000
		Ceramic bur rotary curettage	22	-0.235	0.170		
		Er:YAG laser	22	-0.057	0.101		
		Diode laser	21	-0.072	0.201		
		Total	128	-0.077	0.176		
Premolars	Values first week after the retraction	Retraction cord, impregnated with a 5% aluminum chloride solution	11	-0.123	0.130		
		Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	12	0.138	0.127		
		Astringent Paste – retraction paste, containing 15% aluminum chloride	10	0.060	0.041	17.774	0.000
		Ceramic bur rotary curettage	11	-0.561	0.317		
		Er:YAG laser	12	-0.132	0.207		
		Diode laser	13	-0.170	0.202		
		Total	69	-0.131	0.287		
	Values second week after the retraction	Retraction cord, impregnated with a 5% aluminum chloride solution	11	-0.090	0.106		
		Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	12	0.058	0.052		
		Astringent Paste – retraction paste, containing 15% aluminum chloride	10	0.015	0.014	12.495	0.000
		Ceramic bur rotary curettage	11	-0.410	0.289		
		Er:YAG laser	12	-0.064	0.124		
		Diode laser	13	-0.125	0.179		
		Total	69	-0.102	0.212		
Molars	Values first week after	Retraction cord, impregnated with a 5% aluminum chloride solution	10	-0.081	0.055		
		Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	11	0.103	0.084		

	Astringent Paste – retraction paste, containing 15% aluminum chloride	10	0.024	0.027	26.708	0.000
	Ceramic bur rotary curettage	12	-0.507	0.208		
	Er:YAG laser	11	-0.114	0.097		
	Diode laser	12	-0.187	0.213		
	Total	66	-0.137	0.241		
Values second week after the retraction	Retraction cord, impregnated with a 5% aluminum chloride solution	10	-0.069	0.056		
	Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	11	0.047	0.039		
	Astringent Paste – retraction paste, containing 15% aluminum chloride	10	0.005	0.013	14.546	0.000
	Ceramic bur rotary curettage	12	-0.343	0.230		
	Er:YAG laser	11	-0.057	0.048		
	Diode laser	12	-0.119	0.151		
	Total	66	-0.095	0.175		

Table 7 demonstrates the mean gingival recession levels, measured in both sexes in the first and second week after the retraction. It should be noted that the measured gingival recession levels in women were higher than in men, and these differences were statistically significant in molars.

Table 7. Mean gingival recession values, when grouping the teeth as frontal, premolars and molars, and depending on the sex.

		Sex	Number	Mean (mm)	Standard deviation	u	p	Mean difference (mm)
Frontal teeth	Values first week after retraction	Man	70	-0.070	0.157			
		Woman	58	-0.115	0.284	1.127	0.262	0.045
	Values second week after retraction	Man	70	-0.063	0.158			
		Woman	58	-0.094	0.196	0.969	0,334	0.030
Premolars	Values first week after retraction	Man	33	-0.135	0.194			
		Woman	36	-0.128	0.355	-0.106	0.916	-0.007
	Values second week after retraction	Man	33	-0.088	0.146			
		Woman	36	-0.116	0.260	0.550	0.584	0.028
Molars	Values first week after retraction	Man	43	-0.096	0.170			
		Woman	23	-0.213	0.328	1.919	0.059	0.117
	Values second week after retraction	Man	43	-0.059	0.109			
		Woman	23	-0.164	0.246	2.424	0.018	0.106

A correlation between age and gingival height after retraction was sought (Table 8). The analyzed data showed that, with a 90% reliability of the results, ageing correlated with a more significant reduction in the free gingival margin level.

Table 8. Correlation between age and the measured gingival height after retraction (for the whole group).

			Values first week after the retraction	Values second week after the retraction
Spearman's rho	Age	Correlation coefficient	-0.107	-0.104
		P	0.083	0.091
		Number	263	263

The subjects were divided by sex, and again a relationship between the free gingival margin level and age in both sexes was sought, considering that the correlations were already statistically significant with a 95% reliability of the results (Table 9). In men, a medium negative correlation was reported in both weeks, indicating that the onset of recession after gingival retraction increased significantly with age. In women, hard-to-explain positive weak correlations between the gingival recession levels and age were reported – e.g., ageing led to the disappearance of recession and the occurrence of hyperplasia. In order to explain this result, the patients were divided into the following age groups: up to 30 y/o, from 30 to 40 y/o, from 40 to 50 y/o and over 50 y/o and were checked whether there was loss of gingival height (Table 9).

Table 9. Correlation between age and the measured gingival height level depending on the sex.

	Sex			**Values first week after retraction**	**Values second week after retraction**
Spearman's rho	**Man**	Age	Correlation coefficient	-0.446**	-0.482**
			P	0,000	,000
			Number	146	146
	Woman	Age	Correlation coefficient	0.252**	0.255**
			P	0.006	0,005
			Number	117	117

Table 10 shows the mean gingival recession levels in the different age groups during the first and the second week. A pronounced tendency for an increase in the gingival recession level with age was established, but the differences found were not statistically significant ($p>0,05$).

Table 10. Mean gingival height values in the subjects depending on age.

		Number	Mean	Standard deviation	F	p
Values first week after the retraction	Up to 30 y/o	13	-0.042	0.056	1.173	0.321
	From 30 to 40 y/o	179	-0.129	0.256		
	From 40 to 50 y/o	46	-0.066	0.276		
	Over 50 y/o	24	-0.123	0.148		
	Total	262	-0.113	0.246		
Values second week after the retraction	Up to 30 y/o	13	-0.023	0.035	1.521	0.209
	From 30 to 40 y/o.	179	-0.097	0.192		
	From 40 to 50 y/o	46	-0.055	0.158		
	Over 50 y/o	24	-0.128	0.225		
	Total	262	-0.089	0.186		

Table 11 shows the gingival recession levels depending on age in both sexes. Men experienced a significant increase in gingival recession levels with age, whereas this tendency in women was observed only up to 40 y/o. After that, clinically expressible hyperplasia of the free gingival margin was reported instead of a recession. The difference in the measured gingival height with the previous decade (from 30 y/o to 40 y/o) for the first week was 0.48 mm and for the second week – 0.29 mm, in favor of the hypertrophic gingiva in women over 40 years of age.

Table 11. Mean values of gingival height in the subjects, depending on sex and age.

Sex			Number	Mean	Standard deviation	F	p
Man	Values first week after retraction	From 30 to 40 y/o	88	-0.048	0.139	9.391	0.000
		From 40 to 50 y/o	34	-0.186	0.217		
		Over 50 y/o	24	-0.123	0.148		
		Total	146	-0.092	0.171		
	Values second week after retraction	From 30 to 40 y/o	88	0.030	0.101	8.374	0.000
		From 40 to 50 y/o	34	-0.121	0.129		
		Over 50 y/o	24	-0.128	0.226		
		Total	146	-0.068	0.142		
Woman	Values first week after retraction	Up to 30 y/o	13	-0.042	0.056	16.194	0.000
		From 30 to 40 y/o	91	-0.207	0.314		
		From 40 to 50 y/o	12	0.271	0.049		
		Total	116	-0.139	0.316		
	Values second week after retraction	Up to 30 y/o	13	-0.023	0.035	11.731	0.000
		From 30 to 40 y/o	91	-0.161	0.233		
		From 40 to 50 y/o	12	0.130	0.038		
		Total	116	-0.116	0.228		

4. Discussion

Several authors focused on the different retraction techniques used and the subsequent degree of undesirable gingival recession [5-20].

Some clinical and technical characteristics of the retraction methods indicate their advantages and disadvantages in dental practice. In the widely used double-cord technique for subgingival tissue displacement, removing the second (upper) cord before injecting the impression material or taking the optical impression ensures thorough finish line reproduction. This time-consuming technique has disadvantages, including possible periodontal ligament damage if excessive force is applied, difficulty in retraction cord removal without rupture of the cord or bleeding, as well as postoperative discomfort [21].

According to the data of our study, in the groups in which the retraction was performed by using: 1. Astringent Paste – retraction paste containing 15% aluminum chloride and 2. Expasyl – retraction paste, containing kaolin and 15% aluminum chloride, the smallest changes in the free gingival margin level occurred. Clinically insignificant gingival hyperplasia was reported, as the values measured in the first and second week were: for the first period – 0.12±0.11 mm and 0.06±0.06 mm, respectively, and for the second period – 0.06±0.05 mm and 0.01±0.01 mm, respectively (Table 4). This extremely low trauma of the gingival tissues, compared to the traditional retraction cords, was noted by other researchers, as well [12, 20, 22]. Moreover, fast recovery within a week after the impression-taking was proven [12, 23].

Ceramic bur rotary curettage was the most traumatic retraction approach for the gingival tissue [18, 24-25]. Our study proved this conclusion, as the most pronounced clinically significant gingival recession was present when performing the ceramic bur rotary curettage – the first week – 0.45±0.27 mm, and the second week – it dropped to 0.31±0.23 mm (Table 4).

Out of the known tissue retraction lasers, the most commonly used ones are the diode lasers, followed by the erbium lasers, and the main advantages of these approaches are lack of subsequent gingival inflammation and minimal to no pain during the procedure, which often does not require anesthesia. Gingival recession and tissue bleeding are less after laser troughing [5, 16].

Stuffken M et al., 2016 examined the gingival recession level after applying two approaches: 1. Double cord, impregnated with 5% aluminum chloride (mechano-chemical retraction), and 2. Diode laser with a wavelength of 810 nm (surgical troughing), observing six patients that needed two crowns on intact teeth each [26]. Randomly, one tooth was retracted with the double cord technique (e.g., number 000 and number 1), impregnated with 5% aluminum chloride, and the other tooth – with the diode laser, respectively. The authors reported that the average recession of the teeth, retracted with the first technique, was 0.26 mm eight weeks after the final crown cementation, with variations between 0.00 mm and 0.72 mm, and the average recession within the second group was 0.27 mm, varying from 0.001 mm and 0.68 mm. The authors considered the observed recession values in the two tested methods comparable and not clinically significant.

It should be noted that, according to our study, the recession values of a single cord, impregnated in 5% aluminum chloride, retraction were twice lower in the first and second week. The recession in the first week was 0.15±0.19 mm and in the second one – 0.12±0.17 mm. Our diode laser data in the present study indicated an even lower degree of gingival recession than in the results by Stuffken M et al. – 0.27 mm (0.001 – 0.68 mm) [26]. Our study's diode laser values for the first week after the retraction were 0,14±0.17 mm, and for the second week – 0.10±0.18 mm.

Our study's lowest gingival recession level was reported in the Er:YAG troughing group: 0,10±0.13 mm – for the first week and 0.6±0.10 mm – for the second one (Table 4). The results from our study did not confirm the established risk of occurring undesired gingival recession by Wilder-Smith P, 1997 [27].

Ruel J et al., 1980 reported that the mean gingival recession value one week after the single-cord retraction technique was 0.2±0.1 mm [5, 28]. This result was completely comparable to our data on the occurrence of gingival recession in the single-cord retraction group.

Azzi R et al, 1983 in their study analyzed three gingival retraction methods – retraction cord, electrosurgery and rotary curettage, concluding that gingival recession was more pronounced and probably of greater clinical significance in the rotary curettage method, minimal – in the electrosurgical method, and non-existent – in the retraction cord method; e.g., the GR was clinically significant only in the rotary curettage group, which was also proven by our study [29]. In contrast to our results, Moskow B, 1964 did not find significant differences in GR between the retraction cord method and the rotary curettage one [30]. According to our study analysis, after excluding the rotary curettage data from the surgical methods, the sum of the mean GR levels from the three classic methods and two laser ones was completely comparable for the first and the second week after the retraction (Table 5).

Qureshi SM et al., 2020 performed an in vivo study evaluating the efficacy of three different retraction methods – gingival displacement using a retraction cord impregnated with a 25% aluminum sulfate solution, gingival displacement with Expasyl retraction paste (Pierre Rolland, France) and gingival displacement with Astringent Paste (3M ESPE, Germany) [31]. The authors took impressions of intact maxillary central incisors on day 1 (without retraction), day 2, day 22 and day 42. The amount of gingival displacement was measured as a horizontal distance from the tooth to the gingival crest using a stereomicroscope. Astringent Paste demonstrated the highest amount of retraction – 0.50 mm, followed by the retraction cord (0.48 mm) and Expasyl (0.34 mm). Different results obtained by Prasanna GS, 2013 – Expasyl exhibited better performance than the classic retraction cord [32]. Shrivastava KJ et al., 2015 conducted similar research and compared three methods – One mechanical (Magic Foam cord, Coltene, Switzerland) and two chemical-mechanical (Expasyl paste and retraction cord impregnated with 15% aluminum chloride) [33]. They discovered that the three methods were clinically effective, providing the necessary for elastomeric impression materials 0.2 mm displacement. According to Thimmappa M et al.'s study (2018) merocel strip provided maximum vertical and horizontal retraction compared to Ultrapak Retraction Cord (Ultradent, USA) and Magic Foam, respectively [34]. Comparative evaluation of non-invasive cordless retraction methods was also performed by other authors, proving that the amount of displacement is sufficient for impression-taking [35-37]

Nasim H et al., 2023 performed a randomized controlled clinical trial and compared the conventional method using a retraction cord with a novel one using polytetrafluoroethylene (PTFE) [38]. They measured the mean horizontal gingival displacement using a stereomicroscope. They also assessed post-displacement bleeding and ease of application. Gingival displacement was similar between the two groups. However, the PTFE group had more bleeding after the retraction and patient discomfort. Further research is needed to improve the biological reaction to PTFE cord.

Gajbhiye V et al., 2019 compared gingival displacement using a retraction cord with such using two new polyvinyl siloxane (PVS) impression materials – Aquasil (Denstsply Sirona, USA) and NoCord VPS one-step self-retracting impression system (Centrix, USA) [39]. The maximum amount of retraction was obtained by using the retraction cord, followed by NoCord and Aquasil, respectively. All three gingival retraction methods resulted in gingival displacement >0.2 mm, sufficient for precise impression taking. Mehta S, 2019 compared gingival retraction with a copper-wire reinforced cord, polyvinyl siloxane foam and vinylpolysiloxane paste and proved that the new systems are not as effective as the conventional ones [40]. Kesari ZI, 2019 attained similar results – they discovered that the best results were gained when using a retraction cord with Racegel (Septodont,France) containing 25% aluminum chloride [41]. However, there was no significant difference between the tested methods – retraction cord with Racegel, Viscostat Clear (Ultradent, USA) containing 25% aluminum chloride, Vasozine eyedrops containing 0.05% tetrahydrozoline and Racegel without cord. Pressure is also a factor in the quality of the impressions [42-43].

Schmitz JH et al., 2020 demonstrated the efficacy of another gingival displacement method – the interim restoration technique [44].

Tao et al., 2018 compared pre-saturated cord and lasers (including diode, Nd:YAG, and Er:YAG)—the most used gingival troughing techniques [45]. This study involved 50 patients and 108 anterior teeth (58 maxillary and 50 mandibular). The four gingival retraction groups were: pre-saturated cord; diode laser; Nd:YAG laser; and Er:YAG laser. Gingival width and GR were measured at three separate intervals: immediately following displacement, one week later, and four weeks later. The gingival sulci were narrower, and the GR was substantially higher ($P < .05$) with the pre-saturated cord than with lasers. Compared to diode and Nd:YAG lasers, Er:YAG laser resulted in the fastest and least uneventful wound healing.

Goutham GB et al., 2018 compared the clinical efficacy of three different gingival retraction systems on gingival sulcus width [46]. The study was performed on either the right or left prepared maxillary central incisor of 45 participants. The three gingival displacement groups were: group I (retraction cord impregnated with aluminum chloride), group II (Magic Foam), and group III (a diode laser with a 400 μm fiber tip, 0.8 W power, 25 kHz frequency, continuous mode). Each one of the three methods was randomly applied to a total of 15 patients. The two-stage double mix impression technique with an addition silicone was used for the pre- and post-displacement impressions. In terms of gender distribution and pre-displacement gingival width, there was no discernible difference between the groups. Group III resulted in more displacement than groups II and I (0.31 mm and 0.09 mm, and 0.44 and 0.11 mm, respectively), with a mean value of 0.48 mm and 0.101 mm. The results were statistically significant. The difference between the post-displacement sulcus width of the retraction cord group and the laser group was not statistically significant. The authors concluded that laser troughing was the most efficient of the three retraction techniques. The choice of a retraction technique depends on the clinical situation and the dentist's choice. Thomas MS et al., 2011 stated that in order to meet specific requirements and obtain predictable results, clinicians needed to modify their armamentarium and gingival displacement techniques [47].

Melilli D et al., 2018 compared two retraction methods– a retraction cord and a diode laser [48]. They measured the clinical crown height of 74 abutment teeth randomly divided into two groups for the two methods. The measurements were as follows: after the tooth preparation, 15 days after the tooth preparation, before exposing the finish line, 10 minutes after that, and 15 days after taking the final impression. The authors evaluated the ease of the technique and patient comfort using the Visual Analogue Scale (VAS). Time needed to perform the technique and bleeding were also assessed. Melilli D et al. concluded that there was no difference between the two methods regarding clinical crown height differences, i.e., the amount of retraction and restoration to the initial situation. However, laser troughing required less time, was easier for the clinician and was more comfortable for the patient.

Kurtzman GM et al., 2017 presented a clinical case report of laser troughing that improves scanning and impression-taking [49]. They stated that the capacity to enhance impressions for restorative procedures was one of the diode laser's therapeutic advantages. It has been proven that diode lasers are safe and efficient and promote good tissue repair. According to Lee EA, 2006 clinicians are becoming increasingly interested in soft tissue lasers, partly because of their potential utility in gingival pre-prosthetic procedures [50]. The ability of soft tissue lasers to control moisture and facilitate hemostasis appears promising for dentists performing esthetic crown lengthening and gingival troughing. These applications will expand as dentists gain more experience with such technologies. For his study, Lee EA used an 810 nm diode laser for perio-restorative treatments in the anterior maxilla [50].

Electrosurgery used as a retraction method in the past, has soft tissue consequences due to the high voltage. In the past, some clinicians have employed electrosurgery to open the sulcular tissue surrounding the preparation to allow better capture of the preparation's margins as an alternative to retraction cords and pastes. Unfortunately, electrosurgery has some soft-tissue consequences documented in the literature due to its high wattage (power at the tip) and deeper cell action [51]. Four Rhesus monkeys were used in a biometric and histometric analysis of electrosurgical gingival "troughing" using a fully rectified current. The procedure caused the free gingival margin to recede statistically significantly, and connective tissue attachment was lost due to the junctional epithelium migrating apically. Burn traces from interactions with the electrodes were seen on the cemental surfaces and in the dentin beneath the enamel close to the cementoenamel junction. The apical migration of the junctional epithelium seen in the experimental teeth may be explained by the fact that the cemental burn marks were typically covered by epithelium. In the experimental locations, there was a little loss of crestal alveolar bone; in one case, a bone sequestrum developed. Secondary dentin was discovered in reaction to electrosurgical contact with the cemental surface. Tissue shrinkage is not a concern when using the diode laser's low power level [49].

Ünalan Değirmenci B et al., 2021 compared the clinical effects of three retraction systems on the gingival tissue – an Ultrapak Retraction Cord, a cordless system containing 15% aluminum chloride hexahydrate – Traxodent (Premier Dental Products Co, USA) and an Er,Cr:YSGG laser device – WaterLase® iPlus (Biolase, USA) [52]. Digital scanning was performed, and the follow-up appointments were on the 1st day, 1st month, 3rd month, 6th month and 1st year. Six periodontal scores were assessed in terms of periodontal health – probing depth (PD), plaque index, gingival index (GI), mobility, sensitivity and bleeding on probing (BOP). The authors concluded that the retraction cord and the cordless system similarly affected the periodontium regarding GI and PD indices. GI tended to decrease on the 1st day up to the 1st month and to increase from the 3rd month up to the, while the PD indices increased in the two groups. Er,Cr:YSGG laser troughing was more sparing to the periodontal tissues with lower PD, GI and BOP indices over the one year.

Within the limitations of our research, frontal teeth presented with 2 to 3 times less pronounced gingival recession after troughing with the two lasers, compared to the recession gained after the single-cord technique, which made laser retraction more suitable for these teeth (Table 6). The mean recession values in premolars and molars for the three compared approaches (retraction cord, erbium laser and diode laser) were comparable, as the GR in the molars after the diode laser troughing was a little bit more pronounced than the one after the single-cord method (Table 6).

Our study sought whether sex and age affected gingival recession levels and whether there was a specific pattern. According to our data, much higher GR was found in women's molars than men's in both the first and second week (Table 9). The gender difference was statistically significant (Table 7). The found differences in the GR levels after retraction in the molars between the two sexes (in women, the recession was twice as high), require additional research on the influence of the female gender on this indicator.

Our data showed that with the increase of age, a more significant GR occurred after retraction, demonstrated by a moderate negative correlation between the gingival recession level and age in men (Table 8, Table 10). The discovered tendencies in the measured levels of the free gingival margin require additional studies and analyses. The data about the influence of age and gender is difficult to compare, as literature sources are scarce. Goutham GB et al., reported no statistical difference between the three retraction groups they examined regarding gender distribution and pr-displacement gingival width. The authors did not report any age correlations [46].

5. Conclusions

All retraction methods tested, except for the ceramic bur rotary curettage, resulted in clinically insignificant gingival recession levels. The lowest post-retraction gingival recession level was reported after the Er:YAG laser troughing, followed by the diode laser troughing and, in the third place (with the highest, but still clinically inexpressible recession) – the single-cord technique. The known significant advantages of lasers (diode and erbium) and the obtained lowest gingival recession levels make dental lasers the most suitable retraction methods, with the leading position being the erbium laser. Ceramic bur rotary curettage troughing led to a clinically expressible and lasting gingival recession, which continued in the second week after the procedure. Post-retraction gingival recession was more pronounced in molars and premolars, which requires careful refinement of the retraction method (rotary curettage to be avoided for this group of teeth). Post-retraction gingival recession was more pronounced in elderly patients.

The conclusions were made within our study's limitations, requiring further investigation.

Appendix A

Figure A1. Structural distribution of teeth depending on the retraction methods used.

		Number	%
Classic	Retraction cord, impregnated with a 5% aluminum chloride solution	42	16.0
Mechano- chemical methods	Expasyl – retraction paste, containing kaolin and 15% aluminum chloride	43	16.3
	Astringent Paste – retraction paste, containing 15% aluminum chloride	42	16.0
Surgical methods	Ceramic bur rotary curettage	45	17.1
	Er:YAG laser	45	17.1
	Diode laser	46	17.5
	Total	263	100.0

Appendix B 594

Figure 1. Grouping of the examined teeth. 595

	Number	%
Front teeth	128	48.7
Premolars	69	26.2
Molars	66	25.1
Total	263	100.0

Appendix C 596

Figure C1. Structural distribution of the examined teeth.

Teeth	Number	%
11	17	6.5
12	14	5.3
13	11	4.2
14	10	3.8
15	8	3.0
16	8	3.0
17	7	2.7
18	2	0.8
21	9	3.4
22	7	2.7
23	8	3.0
24	8	3.0
25	5	1.9
26	7	2.7
27	6	2.3
28	2	0.8
31	15	5.7
32	11	4.2
33	11	4.2
34	12	4.6
35	10	3.8
36	6	2.3
37	7	2.7
38	2	0.8
41	8	3.0
42	9	3.4
43	8	3.0
44	9	3.4
45	7	2.7
46	9	3.4
47	9	3.4
48	1	0.4
Total	263	10.0

Abbreviations

ADA – American Dental Association
A-silicones – addition silicones
BOP – bleeding on probing
GI – gingival index
GR – gingival recession
PD – probing depth
PPD – periodontal probing depth
PTFE – polytetrafluoroethylene
PVS – polyvinyl siloxane

VAS – Visual Analogue Scale

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