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Comparison of Gingival Retraction Materials Using a New Gingival Sulcus Model

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Abstract

Purpose

To investigate the pressure generated by different retraction materials using a novel gingival sulcus model.

Materials and Methods

A gingival sulcus model was made using a polymer frame filled with silicon. A pressure sensor and a sulcus-fluid simulation were embedded into the silicon chamber to evaluate the pressure generated by different retraction materials. Six sizes of Ultrapak retraction cords (Ultradent, sizes #000 - 3), 4 retraction pastes (Expazen, Expasyl, Acteon, Access Edge, Traxodent) and 2 retraction gels (Sulcus Blue, Racegel) were analyzed. The mean and median pressure, interquartile range, and standard deviation (SD) of n = 10 repeated measurements were calculated. Statistical analysis was conducted by Kruskal-Wallis test for differences between the main groups of retraction materials, and Mann-Whitney U-test was performed to analyze differences between the single retraction materials.

Results

Pressure (mean ± SD) generated by retraction cords increased with increasing size (48.26 ± 11.29 kPa, size #000 to 149.27 ± 28.75 kPa for #3). There was a significant difference between sizes ($p < 0.01$), except in #0 versus #1, and #2 versus #3. Retraction pastes generated pressures that ranged from 82.74 ± 29.29 kPa (Traxodent) to 524.35 ± 113.88 kPa (Expasyl). Retraction gels generated pressures from 38.96 ± 14.68 kPa (Racegel) to 95.15 ± 24.18 kPa (Sulcus Blue). Pressure generated by Expasyl was significantly higher than pressure generated by all other tested materials ($p < 0.001$).

Conclusion

Pressure generated by retraction pastes and gels depends on the consistency of the retraction material, while pressure generated by retraction cords increased with increasing size of cords. Expasyl was found to generate the highest pressure compared to all other retraction materials.

The success and longevity of fixed restorations depends highly on the impression process, particularly when the margins of preparations extend subgingivally.[1,2] To record these vital marginal areas in the impression, sufficient space between the tooth and marginal gingiva is necessary.[3] To ensure a sufficient bulk of impression material around the margins of the preparation, a minimum space of 0.15 to 0.20 mm has been recommended.[4] Furthermore, it has shown to be beneficial when the bulk of impression material ends below the preparation line. In addition, this facilitates an easier and safer localization of the preparation line during model trimming.[5] Less space around the margin of the preparation can reduce the marginal accuracy or lead to tearing of the marginal impression material.[4,6] Several gingival retraction materials and techniques are currently in use to obtain a clean, dry, and fully accessible marginal operating area.[7,8]

The methods used for gingival retraction can be divided into 3 categories: (1) mechanical, (2) mechanochemical, and (3) surgical.[1] The latter leads to irreversible soft tissue destruction and can lead to an inflammatory reaction within the soft tissues, cementum, or surrounding bone.[2,9] Mechanical methods are based on physical lateral and vertical displacement of the gingiva usually by plain retraction cords; this method is recommended in patients where fluid seepage or bleeding is not an issue.[10] The mechanochemical retraction method is the most commonly used method.[1,11,12] Mechanochemical methods are pastes, gels, or retraction cords saturated with astringents or hemostatic agents, for example, and can be used in instances where a dry and clean impression is impeded by blood or sulcus fluid.[5,10]

Gingiva retraction by mechanical or mechanochemical methods is similar in that they are physical procedures that generate pressure during displacement. There are only a few investigations in the literature on pressure generated by retraction materials.[13-15] The novelty of the presented gingival sulcus model is the sulcus fluid simulation, which enables an approach to in vivo sulcus scenarios and allows for more realistic measurements.

The aims of the present in vitro study were: (1) The construction and investigation of a gingival sulcus model that simulates the presence of sulcus fluid, and (2) commonly used retraction materials should be analyzed with respect to pressure generation in the sulcus model. The null hypotheses were that (1) there are no differences between retraction materials depending on their physical properties, and (2) when using cords, the pressure generated in the sulcus does not depend on the cord diameter.

Materials and methods

To evaluate the pressure generated in the gingival sulcus during insertion of gingival retraction materials, a pressure gauge model was conceptualized (Figs **1**, **2**). A 4.5 × 9.0 × 2.0 mm polymer frame (FuturaGen; Schütz-Dental Group, Rosbach, Germany) was filled with silicon (Profisil 15; Kettenbach GmbH & Co. KG, Eschenburg, Germany). Four of the 5 polymer-silicon contact surfaces were attached using Mucopren adhesive (Kettenbach GmbH & Co. KG). The fifth contact surface was not attached to create a measurement chamber (Fig **2**).

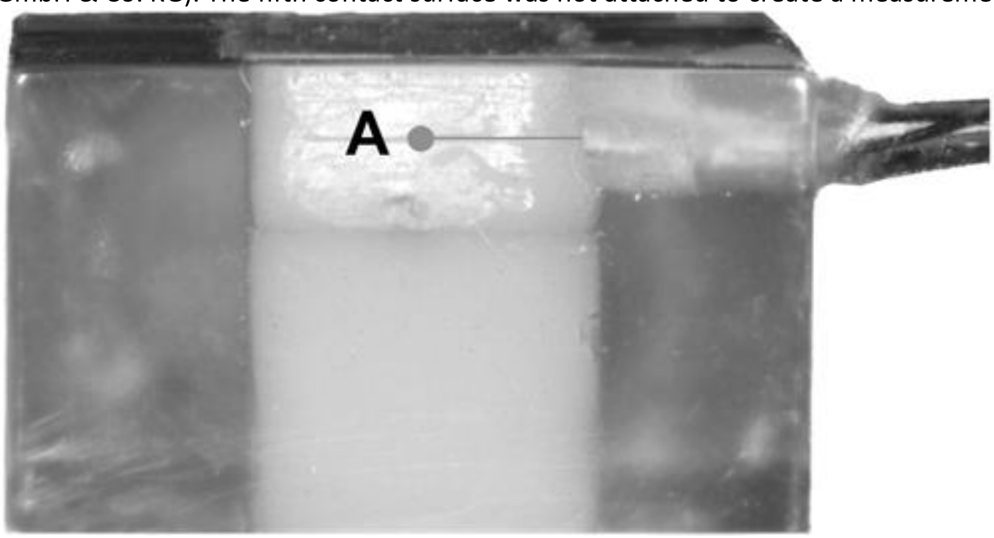

Figure 1 Scheme of the gingival sulcus model (front view). The pressure gauge (A) is positioned at the center of the measurement chamber.

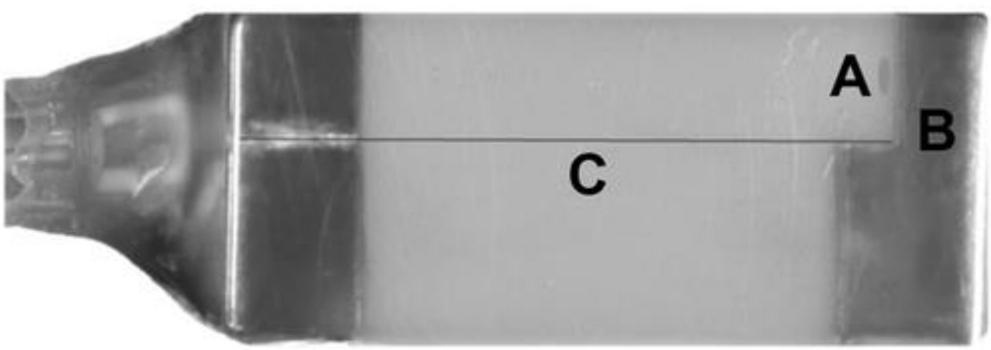

Figure 2 Scheme of the gingival sulcus model (lateral view). The pressure gauge (A) is positioned at the center of the measurement chamber covered with a thin silicon layer. The measurement chamber (B) is a gap-free sulcus between the outer polymer frame and the inner silicon core and can be loaded with retraction materials from the upper side of the model. The gingival fluid simulation was realized by an irrigating cannula (C), which ends at the bottom of the measurement chamber (B).

Investigations by Thomas et al**16** showed a Shore A hardness of sound human soft tissue from 16 to 21 Shore. Following the reports by Thomas et al,**16** Profisil15 silicon was chosen to simulate the gingiva, since its Shore A hardness of 15 Shore allowed for a simulation of human soft tissue as closely as possible.

A sulcus fluid simulation was integrated by including an irrigating cannula (DentsplyMaillefer, Ballaigues, Switzerland) into the bottom of the measurement chamber (Fig **2**). To ensure constant water flow from the bottom of the measurement chamber, a Perfusorcompact (Braun, Melsungen, Germany) with a 20 ml/h flow rate was used. A full bridge active pressure gauge model 105S (Precision Measurements Co., Ann Arbor, MI) was embedded into the silicon next to the measurement chamber (Figs **1**, **2**). Recorded pressures were measured by a Model P3 Strain Indicator and Recorder (Vishay Measurements Group GmbH, Heilbronn, Germany). The pressure recorder was reset to zero after the continuous water flow from the bottom of the chamber started to assure that there was no influence on pressure due to the water flow.

In total n = 12 different materials were investigated. Ten (n = 10) repeated measurements were performed in each group. All tests were performed at room temperature by one operator using a cord packer (GCP113; Hu-Friedy Mfg. Co., LLC, Chicago, IL) to insert the different retraction cords into the measurement chamber (Fig **3**). Cordless retraction materials (pastes and gels) were applied in the technique recommended by the manufacturer. After application, the retraction materials were retained for 10 seconds in the sulcus before the pressure was recorded to avoid erroneous measurements due to manipulations at the pressure gauge during application. Every retraction material was tested 10 times, and the mean pressure as well as standard deviation were first calculated in PSI and converted to kPa.

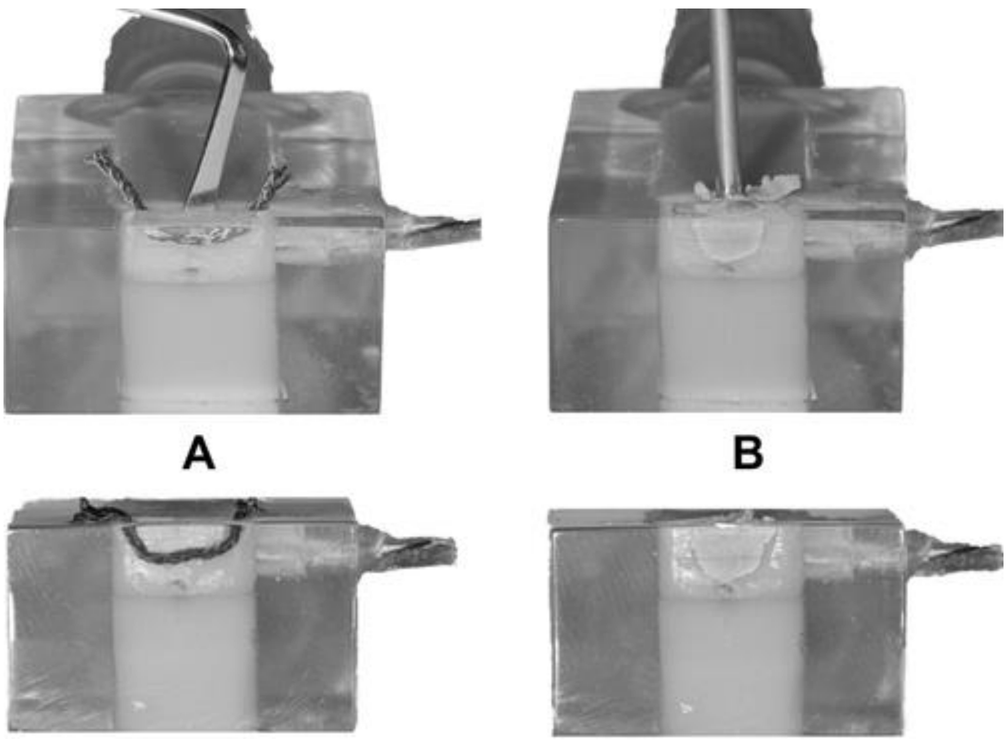

Figure 3 Gingival sulcus model with different retraction materials: Front view on the gingival sulcus model while (A) packing a retraction cord (UP #00) (top left) and with retraction cord in situ (bottom left). (B) Injection of Expasyl into the sulcus model (top right) and Expasyl in situ (bottom right).

The tested retraction cords were Ultrapak cord (UP) (Ultradent Products Inc., South Jordan, UT) sizes #000, #00, #0, #1, #2, and #3. Ultrapak cords are 100% cotton, knitted into loops; this material forms interlocking chains. Ten cord samples of every size were used for testing, each 1.5 cm long.

The following cordless retraction materials (pastes) were tested: (1) Expazen (Acteon Germany GmbH, Mettmann, Germany), which is a tough elastic retraction paste with a haemostyptic effect obtained by the aluminum chloride additive. Expazen is offered in 0.2 g caps and can be applied with normal composite resin applicators. (2) Expasyl (Acteon Germany GmbH), which is a kaolin-based retraction paste with 15% aluminum chloride, colorants, and auxiliary additives. The 1 g capsules can be applied by a manual applicator gun or by a power applicator motorized gun. In the present study the manual applicator gun was used for pressure tests. (3) Access Edge (Centrix Dental Germany, Köln, Germany), which is a kaolin and alumina-based retraction paste with 15% aluminum chloride additive. The retraction paste can be inserted into the sulcus by using a Centrix C-Rsyringe. Access Edge is offered in single-use caps in sizes ‘regular’ or ‘large.’ (4) Traxodent (Premier Dental Products Co., Plymouth Meeting, PA), which is a gel-like retraction paste with 15% aluminum chloride. This retraction paste is offered in a slim 0.7 g syringe with bendable single-use tips. In addition, 2 retraction gels were tested: (1) Sulcus Blue (Acteon Germany GmbH), which is a retraction gel with 15% aluminum chloride and auxiliary additives. The retraction gel is offered in 2 g syringes with changeable single-use application cannulas. (2) Racegel (Septodont GmbH, Niederkassel, Germany) is a haemostyptic retraction gel with 25% aluminum chloride. After application in the warm oral cavity, the viscosity of Racegel increases.**17** This retraction gel is offered in 1.4 g syringes with pre-bent application tips. Racegel can be used either individually or in combination with classic retraction cords. In this study Racegel was used individually.

Data were recorded with MS Excel 2010 (Microsoft, Redmond, WA) and evaluated with SPSS Statistics 24.0 (SPSS Inc., Chicago, IL). The different retraction materials were grouped into retraction pastes, retraction gels, and retraction cords. Potential significant differences between the groups were identified by using Kruskal-Wallis test. Mann-Whitney U-test was used to evaluate significant differences between the groups as well as between the different retraction materials. Level of significance for all tests was set at $p \leq 0.05$. To evaluate the consistency of measurements, the reliability was analyzed by using Cronbach's alpha.

Results

The Kruskal-Wallis test identified significant differences between the groups ($p < 0.001$). The Mann-Whitney U-test revealed that the retraction paste group generated significantly higher pressure compared to the retraction gel and retraction cord groups ($p < 0.001$).

Due to the consistency of the different retraction pastes, the pastes showed the highest interquartile range (IQR) of all groups (Fig **4**). The retraction gel group generated significantly less pressure compared to the other groups ($p < 0.001$).

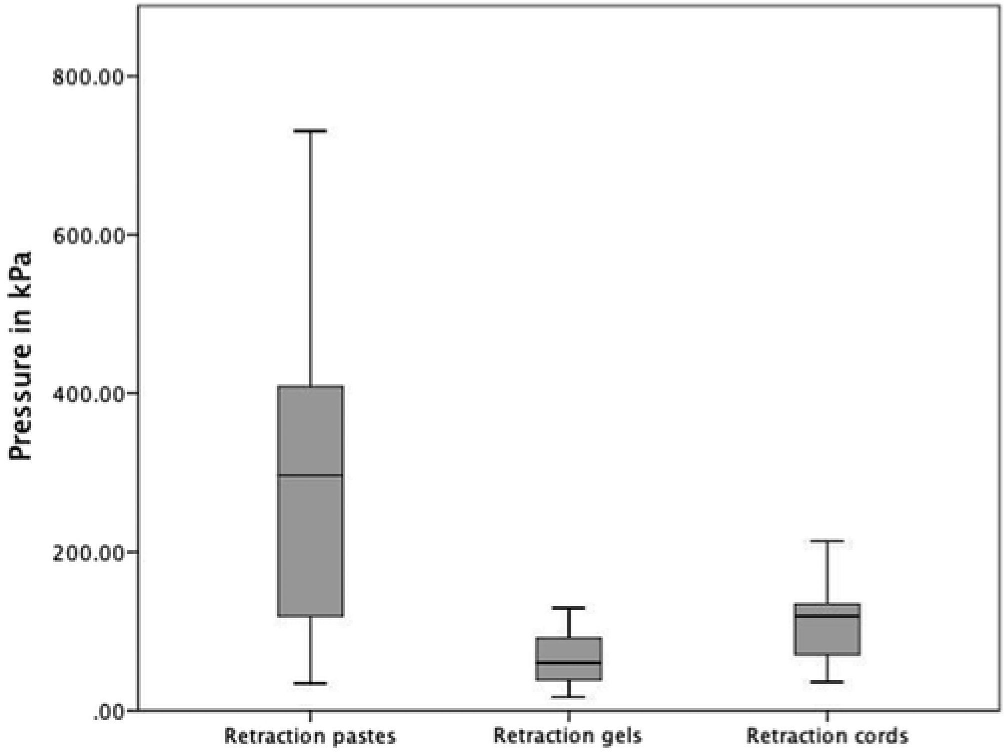

Figure 4 Boxplot projection of the different groups of retraction materials. Retraction pastes were found to generate the highest median pressure with the highest IQR. Retraction gels revealed the lowest median pressure as well as the lowest IQR.

After identifying significant differences between the groups of retraction materials, an inter-group comparison was performed. Therefore, mean ± SD, median and IQR, minimum and maximum pressures were determined and are shown in Table **1**.

Table 1. Mean ± standard deviation (SD), median and IQR, minimum and maximum pressure (kPa) generated by different retraction materials

		Pressure (kPa)			
Retraction material		Mean ± SD	Median (IQR)	Minimum	Maximum
Retraction pastes	Expazen	164.79 ±50.90	158.58 (70.67)	110.32	279.24
	Expasyl	524.35 ± 113.88	491.25 (148.67)	418.86	730.84
	Access Edge	347.15 ± 27.27	343.01 (44.82)	313.71	398.17
	Traxodent	82.74 ± 29.29	86.19 (40.51)	34.47	122.38
Retraction gels	Sulcus Blue	95.15 ± 24.18	91.36 (46.54)	58.61	129.28
	Racegel	38.96 ± 14.68	38.78 (21.12)	17.24	62.05
Retraction cords	UP#000	48.26 ± 11.29	45.68 (19.82)	36.20	70.67
	UP#00	70.67 ± 15.42	69.81 (21.55)	46.54	94.80
	UP#0	112.56 ± 11.72	115.49 (21.12)	94.80	127.55
	UP#1	119.28 ± 15.37	120.66 (20.25)	87.91	141.34
	UP#2	140.31 ± 13.38	140.48 (21.98)	118.93	158.58
	UP#3	149.27 ± 28.75	142.20 (42.66)	118.93	213.74

Mean pressures ± SD generated by retraction pastes ranged from 82.74 ± 29.29 kPa (Traxodent) to 524.35 ± 113.88 kPa (Expasyl), while mean pressures generated by retraction cords ranged from 48.26 ± 11.29 kPa

(UP#000) to 149.27 ± 28.75 kPa (UP#3). Retraction gels generated lower pressure in comparison to retraction pastes and cords (Racegel: 38.96 ± 14.68 kPa; Sulcus Blue: 95.15 ± 24.18 kPa). The highest mean pressure was found in Expasyl compared to all other retraction materials. The pressure generated by Expasyl was significantly higher in comparison to the other groups ($p < 0.001$; Table **2**). The lowest mean pressure of all retraction materials was found in the group of retraction gels; Racegel generated a mean pressure of 38.96 ± 14.68 kPa (Table **1**).

Table 2. Results from Mann-Whitney-U test for comparison between the different retraction materials

	Expazen	Expasyl	Access Edge	Sulcus Blue	Traxodent	Racegel	UP#000	UP#00	UP#0	UP#1	UP#2	UP#3
Expazen	–	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.015	0.325	0.650
Expasyl	<0.001	–	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Access Edge	<0.001	<0.001	–	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sulcus Blue	<0.001	<0.001	<0.001	–	0.449	<0.001	<0.001	0.023	0.105	0.035	<0.001	<0.001
Traxodent	<0.001	<0.001	<0.001	0.449	–	0.002	0.017	0.161	0.007	0.003	<0.001	<0.001
Racegel	<0.001	<0.001	<0.001	<0.001	0.002	–	0.143	<0.001	<0.001	<0.001	<0.001	<0.001
UP#000	<0.001	<0.001	<0.001	<0.001	0.017	0.143	–	0.002	<0.001	<0.001	<0.001	<0.001
UP#00	<0.001	<0.001	<0.001	0.023	0.161	<0.001	0.002	–	<0.001	<0.001	<0.001	<0.001
UP#0	0.002	<0.001	<0.001	0.105	0.007	<0.001	<0.001	<0.001	–	0.315	<0.001	0.001
UP#1	0.015	<0.001	<0.001	0.035	0.003	<0.001	<0.001	<0.001	0.315	–	0.005	0.009
UP#2	0.325	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	–	0.631
UP#3	0.650	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.009	0.631	–

Among the investigated retraction cords, the generated pressure increased with increasing size of retraction cords (from #000 to #3). The highest pressure generated by UP was detected for UP #3, with significant differences to all other retraction materials except UP #2 and Expazen (Table **2**).

Cronbach's alpha analyzed for all tested materials (n = 12 materials, with each n = 10 repeated measurements) was 0.981, which shows that the sulcus model delivers reliable measurements.

Discussion

The present study investigated the pressure in the sulcus generated by 6 sizes of retraction cords, 4 retraction pastes, and 2 retraction gels. While pressure generated by retraction cords increased with increasing size of cords, the range of pressure generated by retraction pastes and gels was much wider due to the different consistency of pastes and gels. Retraction pastes showed variable results in generating pressure. Therefore, both null hypotheses, (1) there are no differences between retraction materials depending on their physical properties, and (2) the pressure generated in the sulcus when using cords does not depend on the cord diameter, were rejected.

These findings agree with the results presented by Bennani et al.[14] A recent systematic review on the efficiency of cordless versus cord techniques for gingival retraction by Huang et al concluded that retraction pastes are less traumatic to soft tissues compared to retraction cords.[18] Retraction pastes appear to be useful when minimal retraction and hemostasis control are required. On the other hand, in cases with a thick gingival biotype or deep subgingival preparation margins, the use of retraction cords is suggested to be more effective.[18] Further, it has been reported that dental technicians are able to detect preparation lines easier when cords are used, in comparison to pastes.[19]

Packing of retraction cords can lead to periodontal damage due to physical force applied. This destruction of epithelium can take approximately 1 week to heal.[1] However, Feng et al found a significantly increased level of TNF-α in gingival crevicular fluid after placement of retraction cords, even 28 days after gingival retraction.[20] It can be assumed that a long-term increase of pro-inflammatory cytokines like TNF-α can lead to attachment loss such as that reported for patients with periodontal disease.[20]

Retraction cords are the most used materials for gingival retraction.[1, 8] However, retraction pastes are described to be easier to apply, and due to gingival displacement and astringent and hemostatic effects of most retraction pastes it may be more efficient while enhancing patient comfort.[1] All investigated retraction pastes and gels of the present study used aluminum chloride for hemostatic and additional astringent effect. It should be mentioned that hemostatic agents like aluminum chloride or ferric sulfate, for example, show cytotoxic effects with increasing retention time in the sulcus.[21] To keep the cytotoxic effect as low as possible, a careful washing after gingiva retraction is necessary to remove residual paste or gels from the bottom of deep margins and avoid irreversible damage of periodontal tissue.[21]

Chandra et al investigated gingival displacement at healthy teeth in an in vivo study.[3] After removal of retraction materials, standardized photographs of the sulcus were taken, then the width and closure of the sulcus was assessed.[3] However, clinical trials comparing gingival displacement techniques are challenging to perform due to ethical concerns and/or limitations in standardizing the assessment.[13]

Comparable results were reported in a recent systematic review, including 10 studies dealing with gingival retraction methods.[11] However, the lack of heterogeneous methodology made appropriate comparisons between the studies very difficult.[11] Three of 10 studies included in the review compared the amount of gingiva retraction achieved by using Ultrapak retraction cords and Expasyl retraction paste. The present study revealed the highest generated mean pressures by 3 retraction pastes (Expasyl, Expazen, Access Edge).

In accordance with the present study, 2 studies revealed a higher amount of gingival retraction when using Expasyl instead of Ultrapak cords,[22, 23] while another study found higher gingiva retraction when using Ultrapak cords than when using Expasyl.[24] However, a comparison between the studies and the results of the present investigation is limited, since the authors used saturated cords in their studies. The effect of astringents on gingiva retraction were not evaluated in the present study. Nevertheless, in vitro studies seem to be an ideal alternative to collect standardized data.

An adequate pressure during the gingival displacement process is necessary to widen the gingival sulcus enough for a dry, clean, and fully accessible marginal region to generate a highly precise impression.[1] The construction of the gingival sulcus model allowed an easy application of retraction materials into the measurement sulcus. The hard polymer frame on the one side and the soft silicon on the other side in combination with the sulcus fluid simulation from the bottom of the measurement sulcus represented the components of a human gingival sulcus as accurately as possible. The reliability of the present measurements was analyzed with Cronbach's alpha. A Cronbach's alpha of 0.981 exemplifies stable and consistent results during measurements. Therefore, the constructed gingival sulcus model appears appropriate to generate valid data; however, there are several limitations: excessive packing of retraction cords can lead to periodontal damage, which cannot be simulated in an in vitro study. Furthermore, some retraction pastes have chemical characteristics that cannot be applied in in vitro studies. For instance, the viscosity of Racegel increases after application in the warm oral cavity.**17** Racegel contains 25% aluminum chloride, more than all other tested retraction pastes. The astringent effect of the aluminum chloride causes a gingiva retraction without generating excessive pressure. On the other hand, the low viscosity of Racegel at the moment of injection simplifies the injection process. The manufacturers of some retraction materials recommend the use of compressive caps. These cotton caps work synergistically with the retraction pastes or gels. The caps cause an additional vertical compression on the marginal tissue and help the retraction material to keep into the sulcus and adsorb fluids.**25** In the present investigation no auxiliary materials like compressive caps were used. The construction of the gingival model does not allow the detection of additional vertical forces or the detection of vertical mechanical retraction.

Another aspect is the differences in handling of the injection process. For example, the injection tip of Expasyl has a diameter of 1.5 mm. The injection tip was set flat on the upper side of the measurement sulcus of the model. Then, Expasyl was injected into the sulcus (Fig **3**). The human marginal gingiva and its complex surface structure can cause more difficulties when injecting Expasyl into the sulcus.

Another restriction was the use of water to simulate gingival fluid flow. While the model can be considered as an open system, since it allowed the flow from the bottom of the crevice to the top, the liquid simulation could be further modified. To create a more realistic model of the human gingival sulcus interface, the use of artificial saliva or serum with a higher viscosity and that contains electrolytes, for example, could be of interest to examine the effect of saliva or blood flow on the effects of retraction materials.

Furthermore, the retraction materials were retained for 10 seconds in the sulcus before pressure was recorded. In clinical practice, retraction materials are retained for a longer time into the sulcus before the impression process starts. Further investigations would be of interest to survey the effect of a prolonged retention of retraction materials into the sulcus.

Finally, a limited number of retraction materials were investigated. To generate more comparable data, further research with further retraction materials is suggested.

Conclusions

Gingival retraction is an indispensable procedure for achieving an accurate impression in the marginal preparation region. The generated pressure inside a sulcus during gingival retraction is of interest when comparing different mechanical and mechanochemical retraction materials regarding their displacement properties. The proposed new gingival sulcus model with sulcus fluid simulation was suitable to analyze pressure generated by retraction materials. An increased size of retraction cords resulted in an increase of pressure. Pressure generated by retraction pastes and gels depended highly on the consistency of pastes or gels, whereby retraction pastes or gels with higher consistency generate higher pressure. Expasyl generated the highest pressure compared to all other retraction materials.

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References

1Phatale S, Marawar P, Byakod G, et al: Effect of retraction materials on gingival health: a histopathological study. *J Ind Soc Periodontol* 2010; **14**: 35- 39

2Goldberg PV, Higginbottom FL, Wilson TG: Periodontal considerations in restorative and implant therapy. *Periodontol 2000* 2001; **25**: 100- 109

3Chandra S, Singh A, Gupta K, et al: Effect of gingival displacement cord and cordless systems on the closure, displacement, and inflammation of the gingival crevice. *J Prosthet Dent* 2016; **115**: 177- 182

4Baharav H, Kupershmidt I, Laufer B, et al: The effect of sulcular width on the linear accuracy of impression materials in the presence of an undercut. *Int J Prothodont* 2004; **17**: 585- 589

5Singh D, Gupta P, Bhatnagar A: Gingival displacements options in prosthodontics: a critical review on recent advances. *J Adv Res Dent Oral Health* 2016; **1**: 13- 21

6Al Hamad KQ, Azar WZ, Alwaeli HA, et al: A clinical study on the effects of cordless and conventional retraction techniques on the gingival and periodontal health. *J Clin Periodontol* 2008; **35**: 1053- 1058

7Bennani V, Schwass D, Chandler N: Gingival retraction techniques for implants versus teeth: current status. *J Am Dent Assoc* 2008; **139**: 1354- 1363

8Ahmed SN, Donovan TE: Gingival displacement: Survey results of dentists' practice procedures. *J Prosthet Dent* 2015; **114**: 81- 85

9Nixon KC, Adkins KF, Keys DW: Histological evaluation of effects produced in alveolar bone following gingival incision with an electrosurgical scalpel. *J Periodontol* 1975; **46**: 40- 44

10Harrison JD: Effect of retraction materials on the gingival sulcus epithelium. *J Prosthet Dent* 1961; **11**: 514- 521

11Tabassum S, Adnan S, Khan FR: Gingival retraction methods: a systematic review. *J Prosthodont* 2017; **26**: 637- 643

12Labban N: A simple technique to reduce the risk of irreversible gingival recession after the final impression. *J Prosthodont* 2019; **28**: e896- e901

13Bennani V, Aarts JM, He LH: A comparison of pressure generated by cordless gingival displacement techniques. *J Prosthet Dent* 2012; **107**: 388- 392

14Bennani V, Inger M, Aarts JM: Comparison of pressure generated by cordless gingival displacement materials. *J Prosthet Dent* 2014; **112**: 163- 167

15Bennani V, Aarts JM, Schumayer D: Correlation of pressure and displacement during gingival displacement: an in vitro study. *J Prosthet Dent* 2016; **115**: 296- 300

16Thomas VJ, Patil KM, Radhakrishnan S, et al: The role of skin hardness, thickness, and sensory loss on standing foot power in the development of plantar ulcers in patients with diabetes mellitus—a preliminary study. *Int J Low Extrem Wounds* 2003; **2**: 132- 139

17 Septodont: Case studies collection: Hess LA: Racegel: gel retraction material increasing the success and predictability of fixed prosthodontic. 2013; **6**: 4- 6. http://www.septodont.de/sites/default/files/Case%20Studies%20Collection%206.pdf. Accessed 6/10/18

18Huang C, Somar M, Li K, et al: Efficiency of cordless versus cord techniques of gingival retraction: a systematic review. *J Prosthodont* 2017; **26**: 177- 185

19Einarsdottir ER, Lang NP, Aspelund T, et al: A multicenter randomized, controlled clinical trial comparing the use of displacement cords, an aluminum chloride paste, and a combination of paste and cords for tissue displacement. *J Prosthet Dent* 2018; **119**: 82- 88

20Feng J, Aboyoussef H, Weiner S, et al: The effect of gingival retraction procedures on periodontal indices and crevicular fluid cytokine levels: a pilot study. *J Prosthodont* 2006; **15**: 108- 112

21Labban N, AlOtaibi H, Mokeem A, et al: The direct cytotoxic effects of different hemostatic agents on human gingival fibroblasts. *J Prosthodont* 2019; **28**: e896- e901

22Prasanna GR, Reddy K, Kumar RN, et al: Evaluation of efficacy of different gingival displacement materials on gingival sulcus width. *J Contemp Dent Pract* 2013; **14**: 217- 221
23Yang J-C, Tsai C-M, Chen M-S, et al: Clinical study of a newly developed injection-type gingival retraction material. *Chin Dent J* 2005; **24**: 147- 151
24Kazemi M, Memarian M, Loran V: Comparing the effectiveness of two gingival retraction procedures on gingival recession and tissue displacement: clinical study. *J Biol Sci* 2009; **4**: 335- 339
25 Premier: TraxodentHemodent Paste Retraction System Brochure. https://www.premusa.com/wp-content/uploads/2015/09/Traxodent-Brochure.pdf. Accessed 6/10/18