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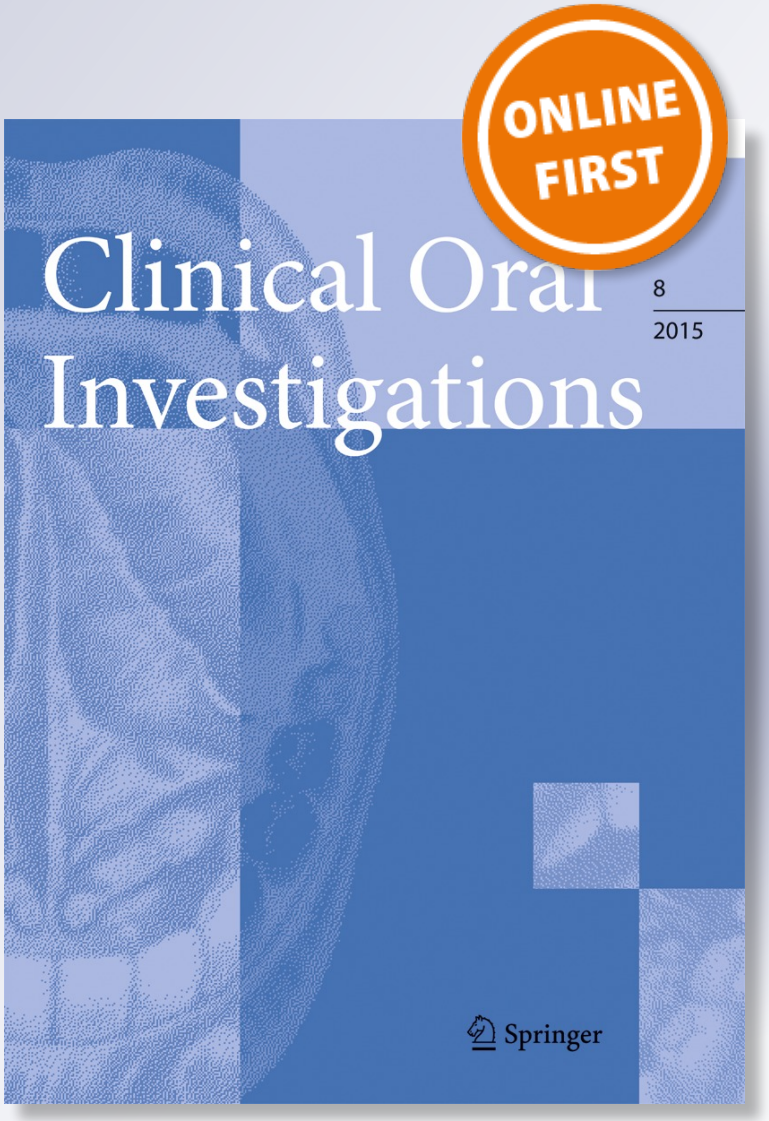

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ORIGINAL ARTICLE

Periodontal response to two different subgingival restorative margin designs: a 12-month randomized clinical trial

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Abstract
Objectives Subgingival margin placement is sometimes required due to different reasons and is often associated with adverse periodontal reactions. The purpose of this study was to determine if a single restoration with subgingival margin on a tooth, in the maxillary anterior zone, would affect its periodontal soft tissue parameters, and whether or not a deep chamfer preparation has a different influence in the periodontium when compared to a feather edge preparation.
Material and methods Plaque and gingival indexes, periodontal probing depth, bleeding on probing, and patient's biotype were registered. One hundred six teeth were prepared with a deep chamfer, while 94 were prepared with a feather edge finishing line. Twelve months after the restoration delivery, the same parameters were evaluated. Repeated measure one-way analysis of variance (ANOVA) (α=0.05) was used.
Results A statistically significant difference between the baseline and the 12-month follow-up is present in regard to plaque index, gingival index, and periodontal probing depth, but no statistically significant difference between chamfer and feather edge finishing lines. There is a statistically significant difference between the baseline and the 12-month follow-up in regard to bleeding on probing. Feather edge preparation presents significantly more bleeding on probing and less gingival recession than the chamfer.
Conclusions Subgingival margins do influence the periodontal soft tissue response. Statistically significant difference exists between feather edge and chamfer finishing lines in regard to bleeding on probing and gingival recession.
Clinical relevance Subgingival margins should be carefully selected, especially when feather edge finishing line is utilized.

Keywords Subgingival margin · Periodontal response · Recession · Bleeding on probing · All-ceramic restoration

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Introduction

Every full-coverage restoration should restore the prepared tooth to its initial form in order to address certain mechanical and biological requirements, including maximum surface area, adequate thickness of the restorative material, conservation of tooth structure, establishment of anatomic contours, and proper location of the finishing line [1]. Furthermore, if the restoration is located in the anterior zone, the esthetic

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requirements should be fulfilled as well, especially if the patient has a high lip line [2]. Therefore, adequate thickness of porcelain is required along with equi- or subgingival margin placement [3, 4]. Additional reasons for subgingival margin placement include removal of previous restorations or dental caries, crown fracture, abfraction, abrasion, chemical erosion, susceptibility to root caries, enhancement of retention and resistance form, development of a ferrule effect when a post and core is utilized, or provision of a better crown contour if needed [5–10].

Subgingival restorative margin placement should be very cautiously used and should be limited only in the labial area, from one proximal point to the other. It has been demonstrated in the past that the use of subgingival margins is associated with adverse inflammatory periodontal reactions due to the defective tooth-restoration interface [11–16], restoration overcontouring [17–19], difficulty in application of oral hygiene measures [20, 21], increased pathogenicity of the subgingival dental plaque [22, 23], and violation of the biologic width [24, 25].

Clinical and histological studies suggest that subgingival restorative margins may cause undesired tissue effects, even if bacterial plaque is well controlled [21, 26–29]. Localized gingival inflammation and increased plaque, gingival index scores, as well as probing depths have been recorded around prostheses with subgingival margins compared to natural dentition or prostheses with supragingival margins [30–34]. Additionally, an in vivo study by Waerhaug has concluded that subgingival restorations are associated with attachment loss. These findings have been confirmed with additional studies [35–38]. Two studies, one in cast gold, metal-ceramic, and metal-acrylic restorations and another one in all-ceramic restorations have demonstrated that subgingival margin placement presented greater chances of bleeding than the supragingival finishing lines [39, 40]. Furthermore, the restorations with subgingival margins exhibited a gingival recession, especially when these were placed in patients with a thin gingival biotype [33, 36, 39, 41–48]. Therefore, although subgingival margins are many times preferred by many clinicians, due to patients' esthetic concerns, it is highly unlikely that these margins will stay subgingivally over time. In addition, it has been demonstrated that a greater mean attachment loss is associated with subgingival margins when compared to supragingival ones [49].

Although the benefits of supragingival margin placement are well documented, intracrevicular restorative finishing lines are often unavoidable [37]. In those cases, establishment of a healthy periodontium seems to be of utmost importance, as healthy gingival tissues are stable and less likely to be affected by future recession [6]. Since the healthy gingival sulcus is very shallow, subgingival placement of the restorative finishing line should be performed extremely cautiously, respecting the junctional epithelium [25]. Therefore, placement of the restorative margin should be no deeper than 0.5–0.7 mm into the gingival crevice in order to minimize the deleterious effects caused by even minimal encroachment on the subgingival tissues [50]. Furthermore, an animal study has demonstrated that in that depth a meticulous toothbrushing can effectively remove dental plaque [51].

Although the literature is clear that whenever possible subgingival margins should be avoided, it does not supply a definitive indication as to which type of restorative margin—i.e., chamfer, shoulder, feather edge—should be selected when a subgingival margin is placed. Recently, the utilization of vertical tooth preparation with a biologically oriented technique has been suggested [52]. The authors present this as a method with potential benefits on soft tissue stability of the natural gingival architecture both in short- and long-term. However, the literature lacks scientific evidence comparing different types of subgingival margins as regards to various periodontal indexes.

The purpose of this study was to determine if placement of a single restoration with subgingival margin on a tooth in the maxillary anterior zone would affect its periodontal soft tissue parameters, and whether or not a deep chamfer preparation has a different influence in periodontal soft tissue parameters, when compared to a feather edge preparation. The null hypothesis was that the examined periodontal indexes would not be affected by neither placement of a restoration nor of the type of preparation utilized.

Materials and methods

Study design

This was a prospective randomized controlled double blind clinical trial, enrolling a sample of patients who needed a single full-coverage restoration in the anterior maxilla. Patient recruitment took place in the School of Dentistry of the University of Padova, Italy. It started in July 1, 2013, and was completed in November 29, 2013.

Patients were screened by both a prosthodontist (GP) and a periodontist (LG) for possible inclusion in this study. The criteria used for including patients were as follows: (i) ≥18 years of age, (ii) dentate patients planned for a single full-coverage restoration in the area between the first bicuspids, (iii) periodontal probing depths ≤4 mm, (iv) full mouth plaque (FMPS) and bleeding (FMBS) scores ≤20 %, and (v) >2 mm of keratinized tissue. Patients satisfying the abovementioned criteria were not included in the study if one or more of the following conditions were met: (i) smoking (>10 cigarettes/day), (ii) substance abuse history, (iii) severe clenching or bruxing habits, (iv) local or systemic disease (endocrine, renal, hematologic, hepatic, immunosuppressive), (v) current steroid/chemotherapy, (vi) head and neck

irradiation, (vii) pregnancy, and (viii) inability or unwillingness to return for follow-up visits [53–57].

This prospective study was performed in accordance with the guidelines of the Declaration of Helsinki, and the research protocol was approved by the Ethics Committee of the University of Padova (2737P/2013), prior to patient enrollment. Additionally, this clinical study was registered at the US National Institutes of Health Clinical Trials Registry (NCT02276586). Patients were notified that their data would be collected and used for a statistical analysis. A signed informed consent was obtained from all patients enrolled in this study.

Randomization and allocation concealment procedure

All teeth planned for full-coverage restorations were randomly allocated to one of the two different treatment groups, according to a computer-generated randomization list. The teeth allocation was concealed by means of sealed envelopes until the moment of preparation. The randomized treatment code (group 1 or 2) was available in closed non-transparent envelopes that were opened before teeth preparation. Patients were assigned to group 1 (horizontal finishing line) or to group 2 (vertical finishing line).

Treatment procedures

The time sequence of all procedures is depicted in Fig. 1. After recruitment, a periodontal prophylaxis was performed by a periodontist and then oral hygiene instructions were given to the patients in order to establish optimal plaque control and gingival health. One week later, the following periodontal measurements were registered by experienced periodontists (LG and DL) [58]: (i) periodontal probing depth (PPD), at three different facial sites (mesial, midpoint, distal) with the utilization of a periodontal probe (UNC periodontal probe, Hu-Friedy, Chicago, IL), rounding the measurements to the nearest millimeter; (ii) plaque index (PI), according to Sillness and Loe [59], rounded at the highest score; (iii) gingival index (GI), according to Löe and Silness [60], rounded at the highest score; and (iv) gingival bleeding on probing (BOP), according to Ainamo and Bay [54]. Additionally, each patient's gingival biotype was assessed and recorded [61].

All restorative procedures were performed by one experienced prosthodontist (GP) under local anesthesia (articaine with 1:100.000 epinephrine). A classic preparation for an all-ceramic full-coverage restoration was employed for all teeth, with an initial depth of 0.8 mm and a final depth of 1 mm axially and 1.5 mm incisally [1]. The chamfer diamond burs used for the initial preparation of teeth in group 1 had a grit size of 151 μ (6881; Komet, Milan, Italy), while a grit size of 25 μ (881 EF; Komet, Milan, Italy) was used for the finishing procedures. The same grit sizes were employed for group 2. However, long flame-shaped diamond burs were used (6862 and 862EF; Komet, Milan, Italy) for the second group. Finally, the tooth surface was polished with ultrasonic devices (Komet SF1LM, Komet Italia). The facial restorative margin was initially prepared equi-gingivally and was then placed 0.5 mm below the gingival margin, using a 40.000-rpm speed (Expertmatic E25L; KAVO GmbH, Biberach, Germany) and a ×4.5 magnification (EyeMag Pro F; Zeiss GmbH, Oberkochen, Germany). All provisional restorations were fabricated with heat-polymerizing polymethylmethacrylate (PMMA) acrylic resin (C&B V Dentine; Major Prodotti Dentari, Moncalieri, Italy) and were then relined with auto-polymerizing PMMA acrylic resin (Jet; Lang Dental Mfg Co, Wheeling, IL, USA), in order to minimize the adverse effects of free monomer excess and heat transfer to the tooth and the surrounding tissues [62, 63]. The facial restorative margin of second group restorations was finalized and carefully positioned 0.5 mm below the gingival margin. Patients were dismissed and advised to use a 0.2 % chlorhexidine gluconate solution for 10 days, before returning 12 weeks later for the impression procedures [64, 65].

The zirconia-ceramic restorations (Lava, 3 M ESPE, Seefeld, Germany) fabricated for all teeth were cemented with a resin luting agent (RelyX Unicem; 3 M ESPE, St. Paul, MN, USA). Cement excess was carefully removed, and occlusion was adjusted. Oral hygiene instructions were given to the patients, including the use of dental floss and proxabrushes. Patients were recalled 2 weeks later and then 3 and 6 months after, for evaluation and oral hygiene measures enforcement.

Twelve months after the cementation of the restorations, the same clinical measurements registered before the initiation of the treatment were taken again by two experienced periodontists (LG and DL). An additional parameter registered at 12 months was the restorative margin in relation to the gingival margin. This was classified as follows: (i) subgingival (not visible), (ii) equi-gingival (slightly visible), and (iii) supragingival (visible).

An intra-examiner calibration took place before initiation of the study by examination of ten patients twice, 24 h apart. The sequence of examiners was random. Measurements were accepted as calibrated, if 90 % of the recordings could be reproduced within a difference of 1 mm. The inter-examiner agreement for the assessment of the variables was determined with the Intraclass Correlation Coefficient (ICC). For the two examiners, the t test (α=0.05) revealed no statistically significant differences.

Repeated measure one-way analysis of variance (ANOVA) (level of significance, α=0.05) was used to determine statistically significant differences between different restorative finishing lines and periodontal parameters. All analyses were performed using statistics software (SPSS 22.0; IBM Corp, Armonk, NY, USA).

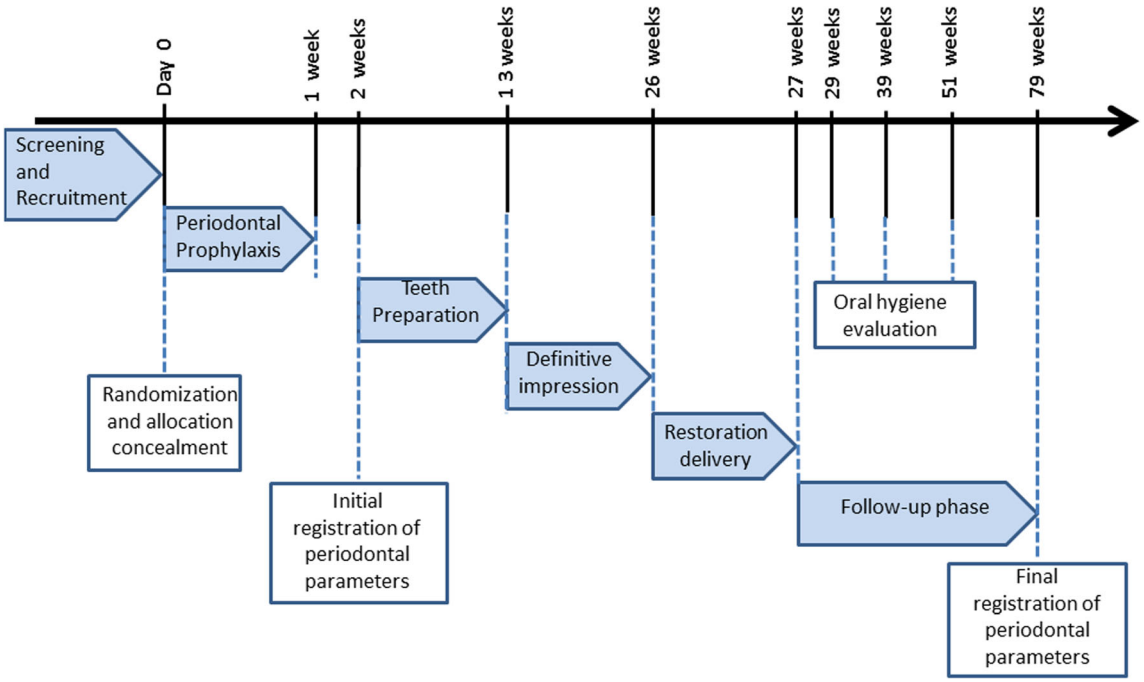

Fig. 1 Time sequence of interventions and examinations

Results

Fifty-eight patients (27 males and 31 females, aged 30–64 years, mean age 50.3 years) received 200 full-coverage restorations, of which 106 were included in group 1 and 94 in group 2. All participants completed the 12-month follow-up period. However, four restorations were lost due to either fracture of the root (n=2) or the restoration (n=2), prior to the 12-month follow-up. The fractured roots were removed and implants were placed, while the fractured restorations were replaced with new ones. Nevertheless, these four sites were not included in the statistical analysis. Therefore, 196 restorations were included in the statistical analysis. Plaque and gingival indexes, gingival recession, BOP, and PPD were analyzed in relation to different finishing lines and patient's biotype.

Plaque index

At baseline, all sites had a plaque index of 0. Twelve months after, 14.4 % of the restorations in group 1 presented an increase from 0 to 1, while 3.8 % presented an increase from 0 to 2. In group 2, the increase from 0 to 1 was 17.4 %. No restorations presented a plaque index of 2 in group 2. There was a statistical significant difference between the baseline and the 12-month follow-up (p<0.001), regarding plaque index. However, no statistical significant differences were revealed between the two types of preparation (p=0.148) (Table 1).

Gingival index

Similarly, at baseline, all sites had a gingival index of 0. Twelve months post-treatment, 33.7 % of the restorations in group 1 increased from 0 to 1, 11.5 % presented an index of 2, while 1.9 % increased from 0 to 3. In group 2, the increase from 0 to 1 was 31.5 %, while 9.8 % presented an index of 2. No restorations presented a gingival index of 3 in group 2. There was a statistical significant difference between the baseline and the 12-month follow-up (p<0.001), regarding gingival index. Nevertheless, no statistical significant differences were found between the two types of preparation (p=0.518) (Table 2).

PPD

Periodontal probing depths increased at mesial and distal sites, while a reduction was noted at the facial (mid-distance) site from baseline to the 12-month follow-up (Table 3). One-way ANOVA revealed statistical significant differences for all registered sites (p<0.001), while the combined effect of "*PPD measurement differences* × *preparation type*" was not statistically significant for none of the measured sites (p=0.467, p=0.486, p=0.833).

BOP

At baseline, all tested sites were free of bleeding on probing. One-way ANOVA revealed statistically significant

Table 1 Plaque index score scores in relation to margin design features (12-month data)

Plaque index		0	1	2	3	Total
Horizontal (H)	Number of crowns	85	15	4	0	104
	Percentage of crowns	81.7	14.4	3.8	0.0	100
Vertical (V)	Number of crowns	76	16	0	0	92
	Percentage of crowns	82.6	17.4	0.0	0.0	100
Total	Number of crowns	161	31	4	0	196
	Percentage of crowns	82.1	15.8	2.0	0.0	100

differences ($p<0.001$) between the two preparation types. ANOVA also demonstrated that the combined effect of "*BOP measurement differences× preparation type*" was also statistically significant ($p=0.028$). An important finding was that 52.2 % of the restorations with a vertical finishing line presented bleeding on probing, while only 36.5 % of the restorations with a horizontal finishing line presented bleeding on probing at the 12-month follow-up (Tables 4 and 5).

Gingival recession

All restorative finishing lines were positioned 0.5 mm subgingivally. The position of the margins in relation to the gingival level was re-evaluated at the 12-month follow-up and is reported on Table 6. A statistically significant difference was found between the types of preparation ($p=0.03$). No gingival recession was noted in 96.7 % of the restorations prepared with a vertical margin design compared to 88.5 % of the restorations prepared with a horizontal margin design.

Biotype

Patients' biotype did not have an influence on the PPD and on BOP, as the combined effect of "*PPD measurement differences× biotype*" was not statistically significant for none of the measured sites (mesial $p=0.951$, facial $p=0.193$, distal $p=0.390$). Furthermore, the combined effect "*PPD measurement differences× preparation type× biotype*" did not present statistical significance either (mesial $p=0.548$, facial $p=0.922$, distal $p=0.382$). Regarding the BOP, the combined effect "*BOP measurement differences× biotype*" was not statistically significant ($p=0.08$). Additionally, the combined effect "*BOP measurement differences× preparation type× biotype*" did not present statistical significance either ($p=0.181$).

Table 3 PPD in relation to margin design features and different sites (12-month data)

	Sample number	Mean PPD (mm)
Mesial site		
Horizontal (H)	104	2.3
Vertical (V)	92	2.5
Total (H+V)	196	2.4
Facial site		
Horizontal (H)	104	1.9
Vertical (V)	92	2.0
Total (H+V)	196	2.0
Distal site		
Horizontal (H)	104	2.2
Vertical (V)	92	2.4
Total (H+V)	196	2.3

Discussion

The results of the present randomized clinical trial suggest that placement of a single restoration in the maxillary anterior zone affects the periodontal soft tissue parameters. Therefore, the first part of the null hypothesis has to be rejected. Instead, the type of the restorative finishing line presented a statistically significant influence only on BOP and recession.

Although there is some controversy in the literature, as to whether or not subgingivally placed restorative materials (i.e., amalgam, glass ionomer, composite resin) may or may not adversely affect the periodontal clinical parameters [66, 67], a 26-year longitudinal study has demonstrated that full-coverage restorations with subgingivally placed finishing

Table 2 Gingival index scores in relation to margin design features (12-month data)

Gingival index		0	1	2	3	
Horizontal (H)	Number of crowns	55	35	12	2	104
	Percentage of crowns	52.9	33.7	11.5	1.9	100
Vertical (V)	Number of crowns	54	29	9	0	92
	Percentage of crowns	58.7	31.5	9.8	0.0	100
Total	Number of crowns	109	64	21	2	196
	Percentage of crowns	55.6	32.7	10.7	1.0	100

Table 4 Bleeding on probing score and margin design features (chi-square 4.846, *p* value 0.028)

Bleeding on probing		H (Horizontal)	V (Vertical)	Total
No	Number of crowns	66	44	110
	%	63.5	47.8	56.1
Yes	Number of crowns	38	48	86
	%	36.5	52.2	43.9
Total	Number of crowns	104	92	196
	%	100.0	100.0	100.0

Table 5 One-way ANOVA for BOP from baseline to 12 month follow-up

Tests of within-subject contrasts

Source	Type III sum of squares	*df*	Mean square	*F*	Significance
Baseline to 12-month follow-up	19.209	1	19.209	158.334	<0.001
Baseline to 12-month follow-up × preparation type	0.597	1	0.597	4.918	0.028
Error (baseline to 12-month follow-up)	23.536	194	0.121		

lines have a detrimental effect on periodontal health [68]. Moreover, that study confirmed that the deterioration of the clinical periodontal parameters was evident 1 to 3 years after the delivery of the restorations. Previous studies have also reported on this issue [23, 32, 49, 69]. It has been suggested that the negative effect of subgingivally placed margins is associated to inflammation due to plaque increase [23, 70]. Furthermore, it has been advocated that there is a change in the subgingival microflora from a profile related with health to one associated to disease, namely Gram-negative anaerobic bacteria, black-pigmented Bacteroides, and increased anaerobe [22]. Besides the defective margins which can create an environment favoring changes in subgingival microflora, other factors influencing gingival inflammation include the following: (a) improper emergence profile, (b) lack of attached gingiva, and (c) violation of the biologic width [37, 70]. Every effort was made so that these factors could be ruled out, in order not influence the clinical outcome of the present study. In particular, every definitive impression captured the surface of the prepared tooth below the finishing line, and the dies were trimmed by the same laboratory master technician under a microscope in order to preserve the anatomy of the root immediately below the margin. The second factor was eliminated by including in the study only patients who had more than 2 mm of attached keratinized gingiva. The third factor was taken care of by carefully measuring the sulcus depth before treatment and placing the finishing line only 0.5 mm below the gingival margin, as suggested by Nevins and Skurow [25], with the help of ×4.5 magnification loops.

Plaque and gingival indexes presented a slight increase at the 12-month evaluation, with no statistically significant differences between the two types of finishing lines. This finding is consistent with the results presented by Flores-de-Jacoby et al., who found that 1-year post-delivery subgingival margins presented increased plaque, gingival index scores, and probing depths [23]. Additionally, in that study, subgingival margins were associated with an increase in spirochetes, rods, fusiforms, and filamentous bacteria. It should be mentioned however that all-ceramic restorations present a smaller plaque index than metal-ceramic crowns, natural teeth, cast gold restorations, and acrylic resin veneer crowns [71]. Therefore, the increase in plaque and gingival indexes registered in the patients of the present study are probably associated with the restorative procedures and the subgingival margin placement than with the all-ceramic material used.

As already mentioned in the results, an increase in the PPD index was found for the mesial and distal sites, while a decrease was noted for the facial (mid-distance). This finding could be related to patient's difficulty to clean effectively the interproximal surfaces, as compared to the facial one. Furthermore, the restorative procedures—i.e., preparation, impression, and removal of luting agent's excess—are more difficult in these areas [72, 73]. It has been demonstrated in the past that plaque accumulation and gingivitis are more evident in proximal areas with well-adapted subgingival amalgam restorations compared to non-restored tooth surfaces [72]. It has also been stated that restorations with subgingival margins can contribute to plaque accumulation, especially in areas that are hard to be efficiently treated with scaling instruments [74, 75].

Regarding BOP, the results of the present study are in accordance with the majority of the studies reporting on that subject [30–34], but they are in contrast with those reported by Loi et al. [10]. A statistically significant higher rate of BOP was associated with the vertical finishing line when compared to the horizontal one. As discussed earlier in this paper, these findings are probably associated with technical difficulties

Table 6 Restorative margin design in relation to gingival margin position (p=0.03)

Margin design	Baseline	12-month follow-up	
	Subgingival margin	Subgingival margin	Equa- or supragingival
Horizontal (H)	106 (100 %)	92 (88.5 %)	12 (11.5 %)
Vertical (V)	94 (100 %)	89 (96.7 %)	3 (3.3 %)
Total (H+V)	200 (100 %)	181 (92.3 %)	15 (7.7 %)

encountered during the fabrication of restorations on teeth prepared with a feather edge finishing line, including a possible improper emergence profile at the provisionalization phase, technician's inability to visualize the exact position of the margin, difficult communication between clinician and technician in determining the exact finishing line position, as well as overcontouring of the definitive restoration in order to improve the gingival scalloping and also to increase the strength of the ceramic material at the cervical area. In addition, Dragoo and Williams have demonstrated that beveled margins are associated with a compromised healing, when compared to shoulder preparations [76, 77]. Although the finishing line associated with increased BOP in the present study was not a bevel by definition, it can be understood that the feather edge preparation can be considered as a long bevel. Thus, with teeth prepared with feather edge, by establishing a new emergence profile with increased contour, potential problems might be expected. This has been proven to be an important factor for the presence or absence of gingival health, as a study has demonstrated that as the facial and lingual cervical contours of an artificial crown are increased, so does the plaque and subgingival microflora [37, 70, 78, 79].

Subgingival margin placement presents a problem not only for the periodontal health but also for soft tissue stability, as well [28–30]. In a clinical study, Valderhaug et al. have examined crowns with subgingival margins for a mean period of 4 to 12 years and found that gingival recession occurred in 34 % of the restorations, while it affected only 6 % of the crowns with supragingival margins [33]. Similarly, a longitudinal study with a 15-year follow-up has demonstrated that crowns with subgingival margins had a 2.65 times higher chance of gingival recession when compared with the contralateral teeth [39]. The present clinical research confirmed this risk, since 12 months after delivery of the restorations, 7.7 % of them presented a gingival recession which exposed the restorative margins. It should be mentioned however that, in the present clinical trial, only 1.5 % of the restorations presented supragingival margins at least in one portion of their facial aspect, at the 12-month follow-up examination [44, 45]. The gingival recession registered was in the range of 0.5 mm and was associated with the horizontal (chamfer) finishing line. This finding seems to favor the vertical (feather edge) finishing line in regard to gingival recession. However, a closer look to the results reveals that vertical finishing line demonstrated increased BOP, which along with edema is a sign of inflammation [80, 81]. This may be the explanation as to why the restorations with feather edge preparation did not present a gingival recession.

The importance of gingival biotype in treatment planning and in the final esthetic outcome has been discussed by several authors in the past [82–86]. It has been demonstrated that different periodontal biotypes respond in a different way to surgical and restorative procedures. Siebert and Lindhe have categorized the gingiva into "thin-scalloped" and "thick-flat," while Becker et al. suggested three distinct periodontal biotypes, namely "flat," "scalloped," and "pronounced scalloped" [84, 85]. Besides the differences in their morphologic characteristics, "thin-scalloped" biotypes are not considered as resistant, since they respond to surgical trauma or restorative procedures with recession, while the "thick-flat" type is resistant to trauma and responds with infra bony defect and pocket formation. Patients' gingival biotype was also registered, using Kan classification, in an effort to reveal its potential influence on the measured clinical parameters [61]. However, a relationship between the gingival biotype and the clinical outcome could not be established by the present study. A larger sample size is maybe required to reveal whether or not such a relationship exists.

The results of the present study may be considered as preliminary, as a bigger sample size and longer observational periods are probably needed in order to establish possible unidentified correlations between the examined parameters.

Conclusions

Within the limitations of the present randomized clinical trial, the following conclusions can be drawn:

1. Subgingival margins should be carefully selected and managed, as there is a statistically significant difference between the baseline and the 12-month follow-up in regard to plaque index, gingival index, and periodontal probing depth but there is no statistically significant difference between chamfer and feather edge finishing lines in regard to these parameters.
2. Vertical tooth preparations could represent a potential risk for periodontal tissues and need particular care when selected during tooth preparation, provisional restoration fabrication, impression procedures, and cementation, as there is a statistically significant difference between the baseline and the 12-month follow-up in regard to bleeding on probing. Feather edge preparation presents significantly more bleeding on probing than the chamfer.
3. Vertical tooth preparation might be preferred when soft tissue level has a crucial esthetic impact, as a statistically significant difference exists between feather edge and chamfer finishing lines in regard to gingival recession. Increased recession was noticed around chamfer preparation.
4. A correlation between gingival biotype, periodontal probing depth, bleeding on probing, and the two finishing lines could not be established.

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Compliance with ethical standards This prospective study was performed in accordance with the guidelines of the 1964 Declaration of Helsinki, and the research protocol was approved by the Ethics Committee of the University of Padova (2737P/2013), prior to patient enrollment. Additionally, this clinical study was registered at the US National Institutes of Health Clinical Trials Registry (NCT02276586). Patients were notified that their data would be collected and used for a statistical analysis. A signed informed consent was obtained from all patients enrolled in this study. This article does not contain any studies with animal performed by any of the authors.

Conflict of interest The authors declare that they have no competing interests.

References

1. Rosenstiel S, Land M, Fujimoto J (2006) Contemporary fixed prosthodontics, 4th edn. Mosby Elsevier, St. Louis, pp 209-257, 544-546
2. Rufenacht CR (1990) Fundamentals of esthetics. Quintessence, Chicago, p 77
3. Conrad HJ, Seong WJ, Pesun IJ (2007) Current ceramic materials and systems with clinical recommendations: a systematic review. J Prosthet Dent 98:389–404
4. Paniz G, Kang K, Kim Y, Kumagai N, Hirayama H (2013) Influence of coping design on the cervical color of ceramic crowns. J Prosthet Dent 110:495–500
5. Naylor WP, Beatty MW (1992) Materials and techniques in fixed prosthodontics. Dent Clin N Am 36:665–692
6. Chiche GJ, Pinault A (1994) Esthetics of anterior fixed prosthodontics. Quintessence, Chicago, pp 75-89, 143-159
7. Goodacre CJ, Campagni WV, Aquilino SA (2001) Tooth preparations for complete crowns: an art form based on scientific principles. J Prosthet Dent 85:363–376
8. Tan PL, Aquilino SA, Gratton DG, Stanford CM, Tan SC, Johnson WT, Dawson D (2005) In vitro fracture resistance of endodontically treated central incisors with varying ferrule heights and configurations. J Prosthet Dent 93:331–336
9. Kois JC (1994) Altering gingival levels: the restorative connection part I: biologic variables. J Esthet Dent 6:3–9
10. Loi I, Di Felice A (2013) Biologically oriented preparation technique (BOPT): a new approach for prosthetic restoration of periodontically healthy teeth. Eur J Esthet Dent 8:10–23
11. Waerhaug J, Philos D (1968) Periodontology and partial prosthesis. Int Dent J 18:101–107
12. Silness J, Hegdahl T (1970) Area of the exposed zinc phosphate cement surfaces in fixed restorations. Scand J Dent Res 78:163–177
13. Jones JC (1972) The success rate of anterior crowns. Br Dent J 132: 399–403
14. Saltzberg DS, Ceravolo FJ, Holstein F, Groom G, Gottsegen R (1976) Scanning electron microscope study of the junction between restorations and gingival cavosurface margins. J Prosthet Dent 36: 517–522
15. Janenko C (1979) Anterior crowns and gingival health. Aust Dent J 24:225–230
16. Silness J (1980) Fixed prosthodontics and periodontal health. Dent Clin N Am 24:317–329
17. Perel ML (1971) Axial crown contours. J Prosthet Dent 25:642–649
18. Perel ML (1971) Periodontal considerations of crown contours. J Prosthet Dent 26:627–630
19. Weisgold AS (1977) Contours of the full crown restoration. Alpha Omegan 70:77–89
20. Marcum J (1967) The effect of crown marginal depth upon gingival tissue. J Prosthet Dent 17:479–487
21. Newcomb GM (1974) The relationship between the location of subgingival crown margins and gingival inflammation. J Periodontol 45:151–154
22. Lang NP, Kiel RA, Anderhalden K (1983) Clinical and microbiological effects of subgingival restorations with overhanging or clinically perfect margins. J Clin Periodontol 10:563–578
23. Flores-de-Jacoby L, Zafiropoulos GG, Ciancio S (1989) The effect of crown margin location on plaque and periodontal health. Int J Periodontics Restorative Dent 9:197–205
24. Maynard JG Jr, Wilson RD (1979) Physiologic dimensions of the periodontium significant to the restorative dentist. J Periodontol 50: 107–174
25. Nevins M, Skurow HM (1984) The intracrevicular restorative margin, the biologic width, and the maintenance of the gingival margin. Int J Periodontol Rest Dent 4:30–49
26. Tarnow D, Stahl SS, Magner A, Zamzok J (1986) Human gingival attachment responses to subgingival crown placement marginal remodelling. J Clin Periodontol 13:563–569
27. Brandau HE, Yaman P, Molvar M (1988) Effect of restorative procedures for a porcelain jacket crown on gingival health and height. Am J Dent 1:119–122
28. Koth DL (1982) Full crown restorations and gingival inflammation in a controlled population. J Prosthet Dent 48:681–685
29. Jameson LM (1979) Comparison of the volume of crevicular fluid from restored and nonrestored teeth. J Prosthet Dent 41:209–214
30. Kent LK, Campbell SD (2000) Periodontal tissue responses after insertion of artificial crowns and fixed partial dentures. J Prosthet Dent 84:492–498
31. Felton DA, Kanoy BE, Bayne SC, Wirthman GP (1991) Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent 65:357–364
32. Muller HP (1986) The effect of artificial crown margins at the gingival margin on the periodontal conditions in a group of periodontally supervised patients treated with fixed bridges. J Clin Periodontol 13:97–102
33. Valderhaug J, Ellingsen JE, Jokstad A (1993) Oral hygiene, periodontal conditions and carious lesions in patients treated with dental bridges. A 15-year clinical and radiographic follow-up study. J Clin Periodontol 20:482–489
34. Schätzle M, Land NP, Anerud A, Boysen H, Burgin W, Loe H (2001) The influence of margins of restorations of the periodontal tissues over 26 years. J Clin Periodontol 28:57–64
35. Bader J, Rozier RG, McFall WT Jr (1991) The effect of crown receipt on measures of gingival status. J Dent Res 70:1386–1389
36. Koke U, Sander C, Heinecke A, Mller HP (2003) A possible influence of gingival dimensions on attachment loss and gingival recession following placement of artificial crowns. Int J Periodontics Restor Dent 23:439–445
37. Padbury A Jr, Eber R, Wang HL (2003) Interactions between the gingiva and the margin of restorations. J Clin Periodontol 30:379–385
38. Giollo MD, Valle PM, Gomes SC, Rosing CK (2007) A retrospective clinical, radiographic and microbiological study of periodontal conditions of teeth with and without crowns. Braz Oral Res 21:348–354

39. Orkin DA, Reddy J, Bradshaw D (1987) The relationship of the position of crown margins to gingival health. J Prosthet Dent 57: 421–442
40. Gemalmaz D, Ergin S (2002) Clinical evaluation of all-ceramic crowns. J Prosthet Dent 87:189–196
41. Müller HP, Heinecke A, Schaller N, Eger T (2000) Masticatory mucosa in subjects with different periodontal phenotypes. J Clin Periodontol 27:621–626
42. Miller PD Jr (1985) A classification of marginal tissue recession. Int J Periodontics Restor Dent 5:8–13
43. Kao RT, Pasquinelli K (2002) Thick vs. thin gingival tissue: a key determinant in tissue response to disease and restorative treatment. J Calif Dent Assoc 30:521–526
44. Stetler KJ, Bissada NF (1987) Significance of the width of keratinized gingival on the periodontal status of the teeth with submarginal restorations. J Periodontol 58:696–700
45. Valderhaug J (1980) Periodontal conditions and carious lesions following the insertion of fixed prostheses: a 10-year follow-up study. Int Dent J 30:296–304
46. Wennstrom J, Lindhe J (1983) Role of attached gingival for maintenance of periodontal health. Healing following excisional and grafting procedures in dogs. J Clin Periodontol 10:206–221
47. Wennstrom J, Lindhe J (1983) Plaque-induced gingival inflammation in the absence of attached gingival in dogs. J Clin Periodontol 10:226–276
48. Tao J, Wu Y, Chen J, Su J (2014) A follow-up study of up to 5 years of metal-ceramic crowns in the maxillary central incisors for different gingival biotypes. Int J Periodontics Restorative Dent 34:e85–e92
49. Valderhaug J, Birkeland JM (1976) Periodontal conditions in patients 5 years following insertion of fixed prostheses. J Oral Rehabil 3:237–243
50. Shavell HM (1988) Mastering the art of tissue management during provisionalization and biologic final impressions. Int J Periodontics Restovative Dent 8:25–43
51. Waerhaug J (1981) Effect of toothbrushing on subgingival plaque formation. J Periodontol 52:30–34
52. Loi I, Di Felice A (2013) Biologically oriented preparation technique (BOPT): a new approach for prosthetic restoration of periodontally healthy teeth. Eur J Esthet Dent 8:10–23
53. Mühlemann HR, Son S (1971) Gingival sulcus bleeding—a leading symptom in initial gingivitis. Helv Odontol Acta 15:107–113
54. Ainamo J, Bay I (1975) Problems and proposals for recording gingivitis and plaque. Int Dent J 25:229–235
55. Brunette DM, Hornby K, Oakley C (2007) Critical thinking. Understanding and evaluating dental research, 2nd edn, Quintessence, Chicago, pp. 231-244
56. Hackshaw A, Paul E, Davenport E (2006) Evidence-based dentistry. An introduction, Blackwell Munksgaard, Oxford, pp. 68-100, 172-185
57. Richards D, Clarkson J, Matthews D, Niederman R (2008) Evidence-based dentistry: managing information for better practice. Quintessence, London, pp 77–91
58. Badersten A, Nilveus R, Egelberg J (1981) Effect of nonsurgical periodontal therapy I. Moderate and advanced periodontitis. J Clin Periodontol 8:57–72
59. Sillness J, Löe H (1964) Periodontal disease in pregnancy. II Correlation between oral hygiene and periodontal condition. Acta Odontal Scand 22:121–135
60. Löe H, Silness J (1963) Periodontal disease in pregnancy. I Prevalence and severity. Acta Odontal Scand 21:533–551
61. Kan JY, Morimoto T, Rungcharassaeng K, Roe P, Smith DH (2010) Gingival biotype assessment in the esthetic zone: visual versus direct measurement. Int J Periodontics Restor Dent 30: 237–243
62. O'Brien WJ (2002) Dental materials and their selection, 3rd edn. Quintessence, Chicago, pp 121–122
63. Michalakis K, Pissiotis A, Hirayama H, Kang K, Kafantaris N (2006) Comparison of temperature increase in the pulp chamber during the polymerization of materials used for the direct fabrication of provisional restorations. J Prosthet Dent 96:418–423
64. Pontoriero R, Carnevale G (2001) Surgical crown lengthening: a 12-month clinical wound healing study. J Periodontol 72: 841–848
65. Ruel J, Schuessler PJ, Malament K, Mori D (1980) Effect of retraction procedures on the periodontium in humans. J Prosthet Dent 44: 508–515
66. Albandar JM, Buischi YA, Axelsson P (1995) Caries lesions and dental restorations as predisposing factors in the progression of periodontal diseases in adolescents. A 3-year longitudinal study. J Periodontol 66:249–254
67. Paolantonio M, D'Ercole S, Perinetti G, Tripodi D, Catamo G, Serra E, Brue C, Piccolomini R (2004) Clinical and microbiological effects of different restorative materials on the periodontal tissues adjacent to subgingival class V restorations. J Clin Periodontol 31: 200–207
68. Schatzle M, Land NP, Anerud A, Boysen H, Burgin W, Loe H (2001) The influence of margins of restorations of the periodontal tissues over 26 years. J Clin Periodontol 28:57–64
69. Newcomb G (1974) The relationship between the location of subgingival crown margins and inflammation. J Periodontol 45: 151–154
70. Reeves WG (1991) Restorative margin placement and periodontal health. J Prosthet Dent 66:733–736
71. Chan C, Weber H (1987) Plaque retention on teeth restored with full ceramic crowns: a comparative study. J Prosthet Dent 56:666–671
72. Renggli HH, Regolati B (1972) Gingival inflammation and plaque accumulation by well-adapted supragingival and subgingival proximal restorations. Helv Odontol Acta 16:99–101
73. Mörmann W, Regolati B, Renggli HH (1974) Gingival reaction to well-fitted subgingival proximal gold inlays. J Clin Periodontol 1: 120–125
74. Waerhaug J (1980) Temporary restorations: advantages and disadvantages. Dent Clin N Am 24:305–306
75. Nayak RP, Wade AB (1977) The relative effectiveness of plaque removal by the proxabrush and rubber cone stimulator. J Clin Periodontol 4:128–133
76. Dragoo MR, Williams GB (1981) Periodontal tissue reactions to restorative procedures. Part I. Int J Periodont Restor Dent 2: 8–29
77. Dragoo MR, Williams GB (1982) Periodontal tissue reactions to restorative procedures. Part II. Int J Periodont Restor Dent 2:34–42
78. Yuodelis RA, Weaver JD, Sapkos S (1973) Facial and lingual contours of artificial complete crown restorations and their effects on the periodontium. J Prosthet Dent 29:61–66
79. Silva NRFA, Bonfante EA, Martins LM, Valverde GB, Thompson VP, Coelho PG (2012) Reliability of reduced-thickness and thinly veneered lithium disilicate crowns. J Dent Res 91:305–310
80. Hodges K (1998) Concepts in nonsurgical periodontal therapy. Delmar, New York, pp 57–58
81. Liu KZ, Xiang XM, Man A, Sowa MG, Cholakis A, Ghiabi E, Singer DL, Scott DA (2009) In vivo determination of multiple indices of periodontal inflammation by optical spectroscopy. J Periodontol Restor 44:117–124
82. Ochsenbien C, Ross S (1969) A re-evaluation of osseous surgery. Dent Clin N Am 13:87–102

83. Claffey N, Shanley D (1986) Relationship of gingival thickness and bleeding to loss of probing attachment in shallow sites following nonsurgical periodontal therapy. J Clin Periodontol 13:654–657
84. Lindhe J (1989) Esthetics and periodontal therapy. Munksgaard, Copenhagen, pp 477–514
85. Becker W, Ochsenbien C, Tibbetts L, Becker BE (1997) Alveolar bone anatomic profiles as measured from dry skulls. Clinical ramifications. J Clin Periodontol 24:727–731
86. Kao RT, Pasquinelli K (2002) Thick vs thin gingival tissue: a key determinant in tissue response to disease and restorative treatment. J Calif Dent Assoc 30:521–526