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5-year retrospective evaluation of direct composite restorations in orthodontically treated patients

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Abstract

Objectives
In patients affected by dimensional discrepancy between size of anterior maxillary and mandibular teeth, orthodontic therapy could be necessary to solve occlusal problems. However, anterior restorations are indicated to finalize the aesthetic aspect of the therapy. The aim of the present retrospective clinical study was to evaluate the long-term outcomes of direct additive composite restorations performed to correct anterior teeth discrepancies persisting after orthodontic treatment.

Methods
Patients with dimensional teeth discrepancy, subjected to a combined orthodontic-restorative treatment, between January 2009 and January 2019, were recalled for the present retrospective evaluation and divided in two groups according to the restoration performed: G1) diastema closure; G2) tooth shape modification. All patients, after ortho therapy, were subjected to a standardized restorative rehabilitation of the anterior area. All restorations were performed by a single experienced operator employing the same materials. During recall visits, two calibrated examiners evaluated the restorations and recorded USPHS data. Kaplan-Meier estimator and Cox-regression analysis were performed. Statistical significance was set for $p < 0.05$.

Results
53 patient were included, with a total of 169 restoration (G1:110;G2:59). The mean study time period was 5 year (ranging from 6 month to 10 years). The overall survival rate of additive restoration was 2,59% (G1:2,07%; G2:0,47 $p < 0.05$). Chipping of the material was the most frequent adverse event (G1:13,64%; G2:1,69), followed by composite wear (G1:9,09%; G2:5,17).

Conclusions
Based on the obtained results, good clinical performances were shown at a 5-year interval. A low number of failures were collected and most of them were classified as reparable. Only few cases needed complete reintervention.

Clinical Significance
Showing that a direct approach in restoring anterior teeth for diastema closure or shape modification is a valid alternative in terms of durability and aesthetics to more invasive procedure such as indirect restorations.

Keywords: Direct restoration, Composite, Additive, Anterior teeth.

1. Introduction

Many clinical conditions in anterior teeth, such as diastema; peg-shaped or cone-shaped teeth; agenesis or amelogenesis imperfecta; alterations in shape and colour; or asymmetry in the composition of the smile, may require aesthetic treatment. Indeed, patients affected by dimensional discrepancy of anterior teeth (Bolton discrepancy) [1], who undergo orthodontic therapy to resolve malposition, are a population in which anterior restorations are mostly indicated to complete the aesthetic aspect of the therapy.
There are different possibilities for treating all these aesthetic imperfections, such as direct composite restorations and direct or indirect aesthetic veneers. The indirect protocol is effective in terms of aesthetic results but demanding in terms of tooth structure sacrifice [2,3]. In a modern and more conservative approach, additive direct restorations without preparing sound tissues seem to have promising clinical performances [4]. Previous studies have shown that the direct approach with micro-hybrid composites could be considered an aesthetic, functional, and biologically sound treatment option for recontouring teeth and closing diastema with clinically promising survival rates [5,6]. Lempel et al. showed in a recent *in vivo* study that microhybrid and nanofilled direct composite restorations had an acceptable clinical durability with repairable failures in anterior additive restorations with a 1.43 % annual failure rate (AFR) after 7 years of clinical function. Therefore, tooth shape correction and diastema closure could be recommended after an orthodontic treatment when minimally invasive or non-invasive procedures on healthy teeth are indicated [7].
However, long-term aesthetical performance of resin composites could be critical due to material composition. In recent years, to overcome aesthetic problems related to microhybrid composites, nanofilled resins were developed to get comparable wear resistance and mechanical strength with improved aesthetics due to their excellent ability to be polished, polish retention, and lustrous appearance [8,9]. Concerning mechanical properties, nanoclusters seem to have a higher damage tolerance combined with an improved clinical performance [10]. For most dental resin composites, the main cause of mechanical failure is the breakdown of the resin matrix and/or the interface between the filler and the resin matrix. It appears that failure during the first five years of clinical function is a restoration issue, mostly related to the technique or material selection, while failure after that period is due to secondary decay [11]. Given that secondary caries and fractures are the two primary reasons for composite restoration replacement [12], research keeps pursuing improvements in strength and toughness as well as shrinkage and its accompanying stresses. However, when a composite is in the oral environment, it is exposed to plaque acids, foods, and salivary enzymes that can cause material softening and mechanical properties worsening [[13], [14], [15], [16]]. The significant evolution of composites for direct tooth restorations led to improvement of the restoration's resistance to degradation in the oral environment [17], even if the choice of the type of composite is still left to the clinician [18].
In the literature, there are few clinical data concerning the efficacy of nano-hybrid composites in direct additive restorations of anterior teeth with shape or position alteration. Therefore, the aim of this retrospective study was to evaluate the performance of direct composite additive restorations on anterior teeth in correcting form and position in patients that underwent previous orthodontic treatment and showed a Bolton discrepancy. The hypothesis tested was that direct composite additive restorations represents a reliable and long-lasting approach in diastema or shape modification treatment in anterior teeth.

2. Materials and methods

2.1. Study characteristics, participants and design

This retrospective clinical study was conducted in the Department of Cariology and Operative Dentistry, University of …. All patients who received additive composite restorations in anterior maxillary teeth by the last author (N.S.) after an orthodontic treatment were selected for this

retrospective analysis. All patients were contacted by phone or mail. Those patients who were able to participate in the study signed a written, informed consent form prior to the start of the clinical evaluation. This retrospective protocol has been led in accordance with the recommendations of the Declaration of Helsinki as revised in Fortaleza (2013) for investigations with human subjects. The ethical committee of the … approved the study protocol (DS_00071_2018)

2.2. Inclusion and exclusion criteria

For this retrospective clinical evaluation, patients meeting the following inclusion criteria were recruited: any systemic disease; age between 14–30 years; good oral hygiene (FMPS < 20 %), no active periodontal or pulpal disease; inter-arch tooth size discrepancies (Bolton discrepancy) after orthodontic treatment; slight discrepancy of symmetry between upper and lower midline after orthodontic treatment; presence of single or multiple diastema between upper anterior teeth; and malformed teeth (such as peg laterals) requiring reshaping.

Exclusion criteria were systemic disease; uncontrolled parafunction; insufficient oral hygiene leading to multiple caries during orthodontic treatment; periodontal and gingival disease; endodontically treated teeth; absence of antagonist teeth; elements with decay; or previous restorative treatments.

A total of 53 patients (19 male and 34 female patients) between the age of 14 and 25 years (mean age, 18.50 ± 3.59 years) were included in the study. After undergoing orthodontic treatment, the patients altogether received 169 direct composite restorations; 59 were performed in order to recontour tooth form and/or position because of tooth shape abnormalities. Teeth recontouring was performed without teeth preparation except for the facial surface and cusp angle of the canines, which were re-shaped to make them appear like lateral incisors when they were congenitally missing. The remaining 110 restorations were performed to treat diastema by closing interdental spaces.

2.3. Pretreatment and treatment protocols

Orthodontists and restorative dentists evaluated patients before and after orthodontic treatment to check and establish proper anterior teeth position. When orthodontic treatment was completed, a pre-operative phase was performed for all patients, consisting of radiographic evaluation, a session of professional oral hygiene, instruction, and motivation.

Diagnostic models were obtained via a maxillary and mandibular impression; a wax-up was then made to create a silicone guide for clinic procedures and, eventually, to realize a mock-up.

All restorations were performed with the same nanohybrid composite (ClearFil Majesty ES-2, Kuraray, Tokyo, Japan) and the same three-step, etch-and-rinse adhesive system (Optibond FL, Kerr, USA) by the same experienced operator. With regard to diastema closure and tooth recontouring, build-ups were performed symmetrically as much as possible.

2.4. Restorative procedure

All restorations were performed following a standardized procedure according to manufacturer instructions: colour selection through a personalized shade guide; rubber dam placement to isolate anterior region; teeth surface cleaning using pumice; enamel surface sandblasting with 50 µm alumina oxide particles and generous water rinsing; 30 s enamel etching with 37 % phosphoric acid; generous water rinsing for 1 min and drying; bonding resin application (Optibond FL, Kerr) on demineralized enamel and 40 s light-curing with a polywave LED-unit (Valo, Ultradent, South Jordan, UT, USA); composite layering using a transparent silicon matrix with a natural layering technique; application of a hydrophobic coating and 20-second light-curing; contouring and finishing with a flame coarse to fine grit diamond bur (8859.314.014. 8368.204.023 Komet, Gebr. Brasseler, Lemgo, Germany) and abrasive disks with decreasing grain Sof-Lex (3 M/ESPE, St. Paul, MN, USA) on a low-speed handpiece; rubber dam removal; and polishing and finishing procedures with an auto-polishing brush and felt. The treatment was completed by informing patients about oral hygiene

measures for cleaning the new restorations with a toothbrush and dental floss. Then, intraoral photographs were taken to assist further evaluation at the baseline and at each control period.

2.5. Evaluation procedure

The restorations were evaluated between February and July 2019 by two calibrated examiners using a dental mirror and explorer in accordance with the modified United States Public Health Service (USPHS) criteria as first described by Cvar and Ryge [19], adapted by Wilson et al. [20], and expressed by Lempel et al. [21]. Patients were divided in two groups, according to the type of restoration performed: diastema closure (Group 1); shape modification (Group 2). The dentists were trained and calibrated before the start of the evaluation. Cohen's kappa statistic was used to calculate observer agreement. Excellent intra-observer (kappa values of 0.76 and 0.79) and interobserver (a kappa value of 0.81) agreement was found in this study.

2.6. Definition of clinical event

Failure (F) was registered when the restoration was lost, making repair impossible. Survival (SR) was defined when less damaging events occurred, such as minor composite fractures, chipping, marginal gaps, caries, or colour/surface deterioration (Fig. 1a–f): restorations were repaired, polished, and the type of unfavourable event was registered in the patients' record. Restorations having no failure or unfavourable event were classified as a success (S). In addition, patient with problems not related to the restorative treatment, such as diastema relapse, were classified as "not defined event" (n.d.) and, when claimed by the patient for aesthetic reason, considered for the resolution of the new clinical condition.

2.7. Statistical analysis

Restoration characteristics, including the number of unacceptable restorations, failures, and complications, were described with descriptive statistics using percentages of the overall number of samples. The primary metric of the study was the survival time of the composite restoration, defined as the time from treatment to any failure or adverse event (i.e., F, SR or n.d). To understand which factors were involved in the failure of restorations, a Cox regression analysis was performed. Considered variables were type of restoration (diastema vs shape), presence of tongue piercings (yes/no), and smoking habits (yes/no). The results are expressed as a hazard ratio (HR) with their associated 95 % confidence intervals (95 % CI) and p-values. The analysis was performed considering both single-tooth elements and patients. Moreover, Kaplan–Meier curves [24] were plotted in order to graphically show the differences of each variables in survival of the restoration. Statistical significance was set at $p < 0.05$.

3. Results

In total, 169 restorations were evaluated in 53 patients. Of these, 116 restorations (68 %) were in female patients and 53 (32 %) were in males. The mean age (±SD) was 21.5 (±8.6) years. All the restorations were in the anterior region of the upper maxilla: 67 central incisors, 81 lateral incisors, 21 canines.

Of the 169 restorations, 110 were performed to correct diastema (Group 1) and 59 to recontour tooth shape (Group 2). The follow-up time varied from 6 months to 10 years, with a mean observation period of 57.85 (±15.31) months. The mean follow-up was 59 (±15.61) months for Group 1 and 55.48 (±15.28) months for Group 2.

In Graph 1 , the qualitative evaluation at follow-up using the USPHS criteria on Group 1 for those restorations still *in situ* is shown. In this evaluation, a generally successful response was observed, with most restorations receiving satisfactory clinical function assessments. Small composite chipping was found in 13.64 % of the cases and partial fracture of the restoration in 1.82 % of the cases. Slight and acceptable wear of the restorations was found in 9.09 % of the cases. Slight wear of the

antagonist was found in 3.64 % of the cases. Only two restorations showed a carious lesion continuous with the composite-tooth margin, but only one patient agreed to retreat it. Within Group 1 five restorations were substituted as claimed by the patient, even if still present in patient's mouth for aesthetic reasons: 1 due to caries, 2 due to fracture of the restoration, 2 due to colour match and diastema relapse.
Concerning Group 2, the qualitative evaluation at follow-up using the USPHS criteria for those restorations still *in situ* is shown in Graph 2 . Even in this case, a clinical successful response was observed, with a smaller number of composite chippings (only in 1.69 % of the cases). Restoration wear was found in 5.17 % of the cases, while a small wear of the antagonist was observed in 3.45 % of the cases. Within Group 2, an absolute failure due to fracture and debonding was observed, classified as F and redone due to aesthetic reasons, as claimed by the patient. In Fig. 1 a successful case was showed, while main adverse events of the two groups are highlighted in Table 1 and Fig. 2.
The AFR of composite additive restorations was 2.59 %. An AFR of 2.07 % was found in Group 1, while an AFR of 0.47 % was found in Group 2.
A Cox regression analysis was performed considering the fracture of restoration as the event. As shown in Table 2, only the type of restoration is statistically significant (HR: 9.17 [2.1–40.044], $p = 0.0032$), while smoking, presence of piercings, and tooth element were not significant ($p > 0.05$). In addition, no differences were found considering the correction for multiple restoration per patient (type of restoration HR: 5.09 [1.118–23.21], $p = 0.0354$; piercing HR: 0.66 [0.143–3.049], $p = 0.5942$; smoking: $p = 0.9922$). In Graph 3 , all the Kaplan Meier curves are presented. As underlined by the Cox model, only the type of restoration was found to affect the fracture of restoration.

4. Discussion

Discrepancies in the dimension of upper and lower anterior teeth, known as Bolton discrepancy, clinically represent an issue that negatively affects dentition and occlusion, creating problems related to aesthetics, function, speech, crowding, or spacing [22].
Direct additive composite restorations are considered a reliable tool in these clinical scenarios compared with indirect restorations, especially for healthy teeth needing aesthetic correction in situations where a maximum tooth-saving approach is imperative, such as in young, orthodontically treated patients.
The results of the present retrospective evaluation, conducted on patients that underwent orthodontic treatment, lead to the acceptance of the tested initial hypothesis, since the use of a direct nanohybrid composite restorations showed good clinical performance after five-year follow up.
Similar results were found by Wolff et al. [7], who conducted a study analysing diastema closure with direct composite build-ups. After a mean follow-up interval of 55.1 months, the authors of the research classified more than 90 % of restorations as "clinically excellent" or "clinically good". In the present study, with a longer follow up period, more than 95 % of the restorations were found to be clinically excellent or good, thus showing data in accordance with previous authors.
Another clinical study conducted by Prabhu et al. [23] evaluated the performance of composite resin used to restore midline diastema between the maxillary and mandibular central incisors. After 60 months, the authors reported that none of the restorations were totally lost, resulting in a 91 % overall retention rate. About 62 % of the restorations had no noticeable colour difference comparing to the adjacent tooth, and gingival health indicated 73 % of the samples were without any signs of inflammation. Supporting the present study, also Lempel et al. obtained similar results with microhybrid and nanofill composites showing acceptable clinical durability in anterior restorations with 1.43 % AFR (annual failure rate) for the 7.2-year mean observation time [21].
In the present retrospective evaluation, the possibility of improving aesthetic with a combined approach including a fixed orthodontic treatment and a direct additive protocol was considered for correcting discrepancies in tooth size and form with an excellent and minimally invasive treatment.

In accordance with the present study, the four-year clinical evaluation of direct composite build-ups for space closure after orthodontic treatment by Demirci et al. [22] showed favourable survival rates. The restorations exhibited excellent scores regarding colour match, marginal adaptation, surface texture, marginal discolouration, wear/loss of anatomical form, and caries formation.
In addition to the aesthetic outcomes and the surface texture related problems, fracture of the restorations is considered one the most unfavourable event. Literature reports that class IV restorations involving the incisal edge are subjected to high masticatory loads, with composite fracture as a possible clinical outcome over time. De Moura et al. [24] stated that in class IV restorations, the involvement of the incisal angle also generates stresses not observed in other cavity configuration, challenging the tooth-restoration interface. Class IV restoration is subjected to great loads from antagonist teeth, with an extra-axial direction and stress caused by parafunctional habits, both compromising its longevity.
In the present study, the collected data showed better performances of the restoration when the composite is used for tooth recontouring than for diastema closure. Even if both clinical scenarios included the need to recreate the incisal margin with composite, the results are in conflict with the findings of De Moura et al. Indeed, even if the amount of material in the incisal portion is minimal for diastema closure, the results showed a higher tendency to fracture for this category. This scenario is probably due to the different conditions of the two groups. The closure of a diastema leads to restorations with a reduced thickness of the material, especially at the incisal level, compared to shape modification. A possible explanation of the result, hence, should be addressed to the differences in the restoration thicknesses between the two groups. Moreover, the flexural strength of a restoration is inversely dependent on the thickness of the composite (see the formula in Chang et al. [25]), and the results of the present study could be correlated with this phenomenon since tooth recontours are generally layered in higher thicknesses than diastema closures. In support to the present findings, the study of Ferracane *at al*., showed that stresses on the interface, especially on smaller thicknesses (e.g., diastema closures) are more prone to generate interfacial gaps, leakages, and fractures, therefore causing failure of the restoration [26].
In addition, not only the thickness of the material, but also the individual variability and presence of parafunctions, for e.g. bruxism, could affect the final outcome of the present study. Bruxism, defined as a multifactorial condition that consist in “a repetitive jaw-muscle activity, characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible” is one of the aspects that could be involved in the restorations outcome. Indeed, when bruxing, the occlusal load can be 2–10 times higher than that for ordinary people, changing normal physiologic wear to severe wear, leading to fatigue failure and fractures of tooth structure [27]. In the present research, the variable bruxism has not been taken into consideration as parafunctional habits can change over time and could be subjected to other external factors, that are difficult to control in a retrospective study.
More than occlusal load, when discussing direct anterior restorations, it is of fundamental importance to consider the substrate of adhesion. The systematic review by Demarco et al. [28] showed that AFR rates for anterior direct composite restorations (class III and class IV) varied from 0 to 4.1 %, with class III restorations generally reaching lower AFRs than the other restorations. The present study reported a lower AFR (2.59 %), which could be related to the different substrate of adhesion. In this particular type of patients, adhesion was totally performed on enamel. This differs from traditional class III or IV class cavities, performed due to carious or traumatic aetiology, where dentin is obviously exposed. Indeed, ss widely demonstrated in the literature, enamel is the best substrate to perform adhesion, showing long-term results and less marginal leakage [29,30].
Another possible reason for the favourable annual failure rate obtained in the present retrospective study could be determined by the definition of failure. In the present study clinical events were divided into failures (F), survivals (SR) and not defined event (n.d.) based on the possibility of repairing, redoing the restoration or waiting as the failure was not connected to a restorative reason. F was considered when an event was found that irreparably damaged the composite or the

dental substrate, such as caries, major fractures, or composite shades, forcing the operator to redo the restoration. SF was considered in all those situations in which clinically acceptable problems were found (e.g., minor chippings, surface roughness, or marginal discolouration). Given the aesthetic natures of the types of restorations considered in this study, these SF situations were easily solvable. The division between F and SF was dictated by the clinical needs of failure management: in the context of direct filing, one item is managing a problem in the same follow-up appointment, while another item is forcing the operator to take another appointment to completely restore the restoration.

The concept of repairability with no sacrifice of tooth substrate is linked to minimal intervention dentistry and goes well with the direct additive restorations of the anterior teeth. On the other hand, indirect approaches could represent the clinical alternative to manage diastema closure of teeth recontouring. However, any failure requires the remake of the whole clinical procedure, consisting of complete removal of the remaining ceramic restoration, re-preparation with inevitable removal of sound tissue, impression, and luting in a second appointment. The biological and economical cost of the failure management is thus higher than a direct approach, which gives the opportunity for immediate intervention and clinical correction. This aspect is important since it shifts the failure meaning to a different and more conservative concept, where importance is only given to tooth preservation and not only to the permanence of the restoration in the oral cavity.

5. Conclusion

After 5 years, the direct composite restoration showed a good or very good clinical performance associated with a satisfying aesthetic and complete conservative procedures. A low number of failures were collected, which were easily repaired to achieve correct shape, function, and aesthetic. Further follow-up is necessary to evaluate the mid- and long-term outcomes of the direct additive approach in diastema closure and tooth reshaping. Further studies are needed to corroborate the differences in survival of direct composite restorations when used for different purposes.

Declaration of Competing Interest

None.

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Table 1. Classification of adverse events occurred during the follow-up, expressed in months, which needed a restorative reintervention: repair, redo or follow-up.

Patient #	Group	Tooth	Follow-up (month)	Adverse Event	Definition of Clinical Event	Intervention
3	1	2.2	90	Sensitivity	n.d	Follow-up
4	1	1.2	26	Color Match/Diastema Relapse	SR/F	Repair/Redo
8	1	1.1	30	Fracture of the restoration	F	Redo
11	1	2.1	79	Fracture of the restoration	F	Redo
12	2	1.2	120	Color Match	SR	Repair
17	1	1.2	12	Diastema Relapse	n.d	Follow-up
20	1	1.1	48	Marginal Adaptation	SR	Repair
27	1	2.1	95	Caries	F	Redo
33	1	2.2	36	Diastema Relapse	n.d	Follow-up
34	1	1.1	12	Diastema Relapse	n.d	Follow-up
35	1	2.2	24	Marginal Discoloration	SR	Repair
41	2	1.1	24	Fracture of the restoration	F	Redo
43	1	2.1	12	Diastema Relapse	n.d	Follow-up
48	1	1.2	12	Marginal Discoloration	SR	Repair
52	1	2.2	56	Color Match/Diastema Relapse	SR/F	Repair/Redo
55	2	2.1	36	Surface Roughness	SR	Repair

Table 2. HR estimation from Cox regression model with 95 % CI and p values.

HR estimation					
Parameter		**HR**	**Confidence limits at 95 %**		**P value**
Type of restoration	Diastema vs Shape	9.170	2.100	40.044	0.0032
Presence of piercing	No vs Yes	0.433	0.139	1.345	0.1479
Smoking	No vs Yes	–	–	–	0.9916
Tooth element	Lateral incisors vs Canine	–	–	–	0.9907
	Lateral vs Central Incisors	0.920	0.374	2.264	0.8556

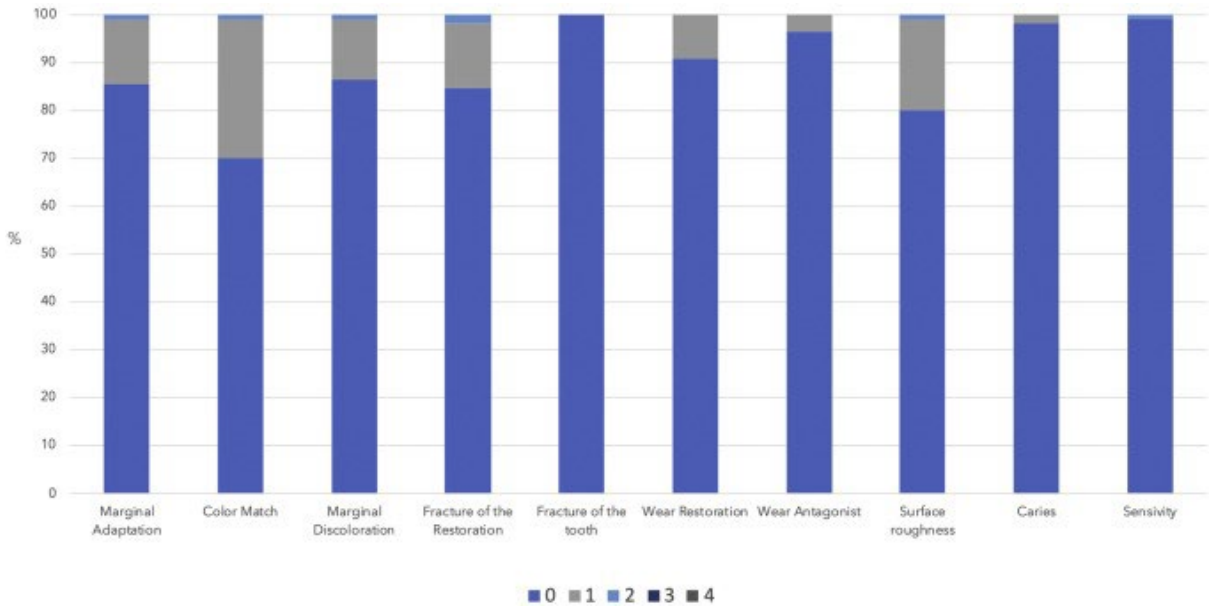
Fig. 1. Pictures showing a clinical successful clinical case: **a.** Pre-orthodontic situation; **b.** Post-orthodontic resolution of the case with diastema between anterior teeth; **c.** Restorative finalization of the case after 3 year of follow-up.



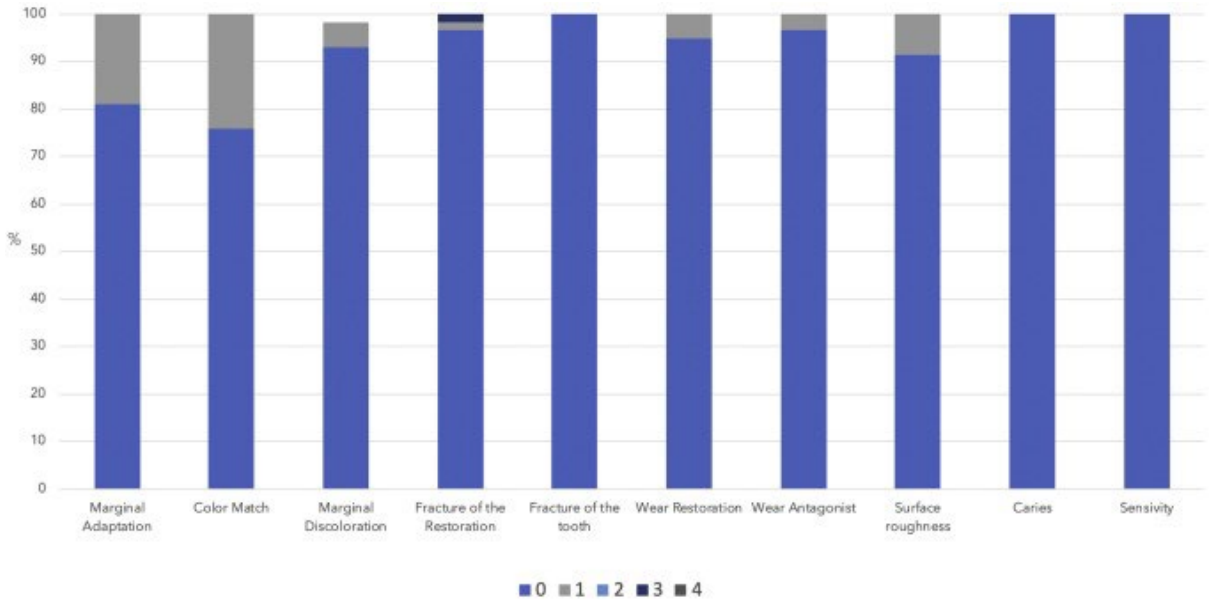
Fig. 2. Pictures showing different clinical situation showing cases of failure (F)/survival (SR): a. Marginal chipping (minor fracture of the restoration without tooth tissue involvement)(SR); b. Incisal wear of the restoration (SR); c. Chipping involving more than 50 % of the restoration (F); d. Surface roughness and texture loss (SR); e. Cervical chipping of the composite (SR); f. Marginal discoloration, chipping of the restoration, texture loss (F); g. Wrong colour match (SR); h. Diastema relapse (n.d.).



Graph 1. Graph showing percentages of USPHS criteria evaluation (score 0-4) for the group "diastema closure".



Graph 2. Graph showing percentages of USPHS criteria evaluation (score 0-4) for the group “Shape modification” group.



Graph 3. Kaplan Meier curves considering the survival of restoration by: **a.** Type of restoration (diastema closure vs shape modification); **b.** Presence of a piercing in the mouth of the patient (yes vs no); **c.** Smoking habit (yes vs no); **d.** Type of tooth element (1:incisor, 2:lateral, 3: canine).

