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Selected and simplified FDI criteria for assessment of restorations

(Short title: *Select FDI criteria for dental restoration failure*)

Christina Maillet^{a,b,c}; Franck Decup^{d,e,f}; Emmanuelle Dantony^{g,h,i,j}; Jean Iwaz^{g,h,i,j}; Charlène Chevalier^{g,h,k}; François Gueyffier^{g,h,i,j,l}; Delphine Maucort-Boulch^{g,h,i,j}; Brigitte Grosgeat^{f,g,h,k,m}; Justine Le Clerc^{n,o,p}

^a Université de Reims Champagne-Ardenne, Reims, France;

^b Laboratoire « Biomatériaux et Inflammation en Site Osseux » EA 4691, Structure Fédérative de Recherche CAP Santé, FED 4231, Université de Reims Champagne-Ardenne, Reims, France.

^c Pôle de Médecine Bucco-Dentaire de Reims, Centre Hospitalier Universitaire de Reims, Reims, France

^d Université de Paris, Paris, France.

^e Service de Médecine Bucco-Dentaire, Hôpital Charles Foix, Assistance Publique des Hôpitaux de Paris, Ivry-sur-Seine, France.

^f Laboratoire UR 2496 Pathologies, Imagerie et Biothérapie Orofaciales, Université de Paris, UR 2496, Montrouge, France.

^g Université de Lyon, Lyon, France.

^h Université Lyon 1, Villeurbanne, France.

ⁱ Service de Biostatistique-Bioinformatique, Pôle Santé Publique, Hospices Civils de Lyon, Lyon, France.

^j CNRS UMR 5558, Laboratoire de Biométrie et Biologie Évolutive, Équipe Biostatistique-Santé, Villeurbanne, France.

^k Service d'Odontologie, Hospices Civils de Lyon, Lyon, France.

^l Service des bases cliniques et épidémiologiques, Hôpital pneumologique et cardiovasculaire Louis Pradel, Hospices Civils de Lyon, Bron, France.

^m Laboratoire des Multimatériaux et Interfaces (LMI), UMR CNRS, 5615, Villeurbanne, France.

ⁿ Université de Rennes, Rennes, France.

^o Pôle odontologie, Centre Hospitalier Universitaire de Rennes, Rennes, France.

^p CNRS UMR 6226, Institut des Sciences Chimiques de Rennes (ISCR), Rennes, France.

Corresponding author

Faculté d'odontologie

11 rue Guillaume Paradin

69008 Lyon, France

E-mail: brigitte.grosgogeat@univ-lyon1.fr

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

CM, FD, ED, DMB, BG, JLC - Conceptualization.

CM, FD, ED, JI, CC, DMB, BG, JLC - Data curation.

CM, FD, ED, DMB, BG, JLC - Formal analysis.

FD, BG - Funding acquisition.

CM, FD, JLC - Investigation.

CM, FD, ED, FG, DMB, BG, JLC - Methodology.

FD, BG - Supervision.

CM, FD, ED, JI, FG, DMB, BG, JLC - Validation.

CM, FD, ED, JI, CC, BG, JLC - Visualization.

CM, FD, ED, JI, DMB, BG, JLC - Writing - original draft.

All authors - Writing - review & editing.

DATA AVAILABILITY

The data underlying this study are not available because of high probabilities of breach of patient confidentiality.

Selected and simplified FDI criteria for assessment of restorations

INTRODUCTION

Over the last decades, dental care has undoubtedly evolved with the development of a wide diversity of filling materials and the provision of more conservative care procedures [1,2]. Furthermore, in performing dental restoration, most dentists aim to achieve a successful, aesthetic, and long-lasting restoration. Unfortunately, the potential causes of failure are too numerous and may add up during the procedure to end up with an insufficient or unsatisfactory restoration quality [3,4].

Improving dental repair or replacement decisions and practices requires regular assessments of previous restorations, which was the objective of various assessment tools such as the one developed in 1971 by Cvar & Ryge [5] for the US Public Health Service. More than 10 years ago, a new assessment tool of dental restorations was proposed by Hickel et al. [6,7]; however, still little is known about the ways practitioners have understood and integrated that tool into their everyday practice. In 2017, Marquillier et al. [8] showed that, since their introduction, FDI criteria were used in 16.3% of published studies and that this percentage increased from 4.5% in 2010 to 50% in 2016. Furthermore, though Hickel et al. [6,7] have advised that their recommendations should be adapted to the purpose of each particular study, Marquillier and al. [8] noticed that the most used criteria were: ‘marginal adaptation’, ‘staining’, ‘fracture of material and retention’, ‘recurrence of caries/erosion/abfraction’, ‘post-operative sensitivity/tooth vitality’, and ‘surface luster’. In addition, FDI criteria are still the most frequently used in hospital-based studies but their use or ways of use in private practice-based studies are still under investigation.

To our knowledge and to date, only eight studies of dental restorations have been conducted in private dental practices [9-16]. To the latter may be added a recent observational study in a practice-based research network that identified the need for reintervention on previous dental restorations in French adults [17].

The present work extended the above-cited study to analyses of quality of restorations (as assessed by selected and simplified FDI criteria) and examination of the relationships between quality and other general characteristics of restored teeth.

MATERIALS AND METHODS

Study design, setting, investigators, and participants

This observational multicenter cross-sectional study (RESTO DATA) [17] was conducted within RECOL (a dental practice-based research network) and 13 hospital dental clinics. The data were collected between March 2019 and June 2020 by 76 investigators: 40 dentists from private practices and 36 from hospital clinics. The mean age of those dentists was 40 years (SD: 10) and the male/female ratio 0.69.

Patient inclusion criteria were: being 18 years or over and not under legal guardianship or curatorship, having at least one tooth with coronal restoration, having had no history of dental examination within the past six months, being affiliated to a social security scheme, and having approved the study protocol. To minimize patient selection bias, proposals of participation were made either to consecutive or to randomly selected patients from each participant dental practice diary.

The study included finally 822 patients: 422 from hospital dental clinics and 400 from private practices; i.e., nearly ten participants per investigator. **Before starting patient recruitment, all investigators had to attend at least one of three training and calibration sessions. These sessions aimed to explain the use of assessment criteria as required for the study, ensure investigator ratings' consistency to a large degree, and limit bias. All training sessions took place off work time and place. Two trainers (or supervisors), always the same (authors BG and FD), conducted together all sessions. They explained first the aim of the session, the objectives and methods of the study, the way of including patients, and the scope and advantages of the collaboration. Afterwards, the investigators were shown typical dental images to comment on and rate using the selected and simplified criteria of Table 1. Comments and ratings on each image were compared and potentially corrected by the trainers with arguments and**

recommendations (obviously, not all criteria could be examined on each image). Generally, nearly 30 images were examined over two hours per session; no additional images were needed because of a feeling of ‘data saturation’.

Assessment scale and general tooth characteristics examined

Each restoration was assessed on nine criteria selected from the FDI World Dental Federation; precisely, criteria 3 to 8, 11, 12, and 14 (i.e., color match, anatomic form, fracture of material and retention, marginal adaptation, occlusal wear, proximal contact, tooth vitality, recurrence of caries, and periodontal response, respectively) [6,7] (Table 1). Each criterion could be rated: A for ‘ideal’ (equivalent to FDI score 1), B for ‘clinically satisfactory’ (equivalent to FDI scores 2 and 3), or C for ‘clinically unsatisfactory/poor’ (equivalent to FDI scores 4 and 5). An additional grade D was used whenever a criterion could not be assessed. A restoration was considered as a failure whenever at least one of the above-mentioned nine criteria was rated C.

The general characteristics of a restored tooth used for relationship determination were: the location (anterior or posterior), the number of restored surfaces (1, 2, 3, or cervical), the type of restoration (direct or indirect), the filling material used (composite, amalgam, glass ionomer cement –GIC, ceramic, metal, or other).

Data management

Each restoration was assessed by clinical examination (visual and tactile) and all data were collected in an eCRF (Clininfo, Lyon, France). Interactive controls were used to check data ranges and between-form coherence. In compliance with the directives of the French ‘Commission Nationale de l’Informatique et des Libertés’ (CNIL) and the European ‘General Data Protection Regulation’ (EU 2016/679), all data were kept anonymous with high-level security storage and encryption of all transfers.

Statistical analysis

The qualitative variables of the study population were summarized by numbers and percentages and its quantitative variables by medians and first - third quartiles.

Among the restorations, selected criteria rated C were graphed with UpSet plots using UpSetR package [18]. This graph allows showing the failure frequency relative to each of the nine selected criteria (Fig. 1, horizontal bars) as well as the most frequent single or combined criteria rated C (Fig. 1, vertical bars; only the first 40 single or combined criteria are shown).

Moreover, according to each modality of the general characteristics, the frequencies of the four grades (A to D) were plotted using barplots. The part of each criterion rated C (indicating failure) was highlighted and the percentage written in full.

All statistical analyses were performed with R software [19] (R Core Team).

Ethical considerations

The protocol of the study was approved by the local committee for ethics in research (Comité de Protection des Personnes Île-de-France III (3660-NI 01/29/2019) and registered on ClinicalTrials.gov (no. NCT03854526). Full written information on the study was given to all potential participants and all actual participants provided signed consents to participate.

According to the EU General Data Protection Regulation, subjects' data were anonymized before analysis and all data are kept confidential and securely stored.

RESULTS

Characteristics of the study population

As shown in Table 2, women outnumbered men (57 vs. 43%). The participants' mean age was 44 years (SD: 17) and age group 30-59 was the most represented (53%). Nearly two-thirds of the participants (63%) were new patients into the practices. The main reasons for the dental visits were routine check-up (58%) and pain (17%). High percentages of participants were abiding by the recommendations of at least two daily brushings (85%) and regular visits (69%). About two-thirds (65%) of the participants were exposed to one or more environment-related caries risk factor that led to reintervention on a previous restoration: poor dental hygiene, saliva-reducing factors (pathological or therapeutic), frequent snacking, or unbalanced diet [17]. Overall, the characteristics of private and hospital practices were fairly close; however, there were differences regarding the age ranges, the socioeconomic statuses, and the reason for the visit; otherwise said, generally, private practice patients were older, had intellectual occupations, and visited less for emergency care.

Distribution of criteria rated C

According to the selected criteria, 2,048 of 4,612 restorations (44%) were classified as 'failures'. Fig. 1 shows the distribution of restoration criteria rated C. In nearly half of the fillings (n = 1,044), failure was due to a single criterion rated C, and, in the other half (n=1,004), to a combination of criteria rated C, of which 445 combinations of two criteria. 'Color match' was the most frequent failure criterion (n = 912), either alone or with any number of other criteria. For example, 'color match' and 'anatomic form' was the most frequent association of criteria for failure (n = 63). Regarding the functional properties, the most frequent criteria rated C were 'marginal adaptation' (n = 572) and 'proximal contact' (n =

496) (Fig. 1, second vertical bar). Regarding the biological properties, the most frequent criterion rated C was ‘tooth vitality’ (Fig. 1, third vertical bar) which corresponds to a non-viable tooth or to a tooth with irreversible pulpitis and very intense sensitivity.

Involvement of selected FDI criteria according to the location of the restored tooth

Failures of restorations were seen in 45% anterior fillings and 44% posterior fillings (524 / 1,169 and 1,524 / 3,443, respectively). The nine criteria were similarly involved in both locations (Fig. 2). ‘Color match’, ‘proximal contact’, and ‘marginal adaptation’ were the three top criteria rated C. ‘Proximal contact’ concerned 15% of anterior fillings, whereas ‘anatomic form’ concerned 18% of posterior fillings.

Involvement of selected FDI criteria according to the size of dental restoration

The 4,612 restorations under study were distributed as follows: 148 cervical fillings, 1,973 one-surface, 1,520 two-surface, and 971 three-surface or more fillings; and the percentages of failure were 32%, 36%, 46%, and 61%, respectively. Whatever the surface restored, ‘color match’ was the most frequent criterion rated C (Fig. 3). ‘Anatomic form’ was the most frequent failure in one-surface restorations (11%) and ‘marginal adaptation’ in cervical fillings (14%). The latter three criteria and ‘proximal contact’ were among the most frequent in two-surface fillings (17%, 16%, 13%, and 15%, respectively) as in three-surface fillings (25%, 28%, 22%, and 22%, respectively). ‘Tooth vitality’ was rated C in 24% of three-surface fillings. In addition, ‘fracture of material and retention’ and ‘occlusal wear’ were more frequent in three-surface fillings than in other restorations.

Involvement of selected FDI criteria according to the material in direct and indirect restorations

Among the 4,612 restorations, 4,449 were evaluable for the materials and 163 (4%) fillings could not be identified or evaluated. Hence, 4,185 direct restorations were assessed; they included 61% composite, 37% amalgam, and 2% GIC fillings. The 264 other fillings were indirect restorations made of ceramic (33%), composite (51%), or metal (16%). The failure rates according to the materials are shown in Table 3.

Among the 4,185 direct restorations, 1,827 were considered as failures. The latter included 978 composite, 782 amalgam, and 67 GIC fillings. In those failures, ‘Color match’ was the first criterion rated C (24% for amalgams, 17% for composites, and 56% for GIC) (Fig. 4) and ‘Anatomic form’ was the second (19% for amalgams, 13% for composites, and 48% for GIC). **The failure rates were 50.7% for amalgam fillings and 38.3% for composite resins. GIC fillings showed a lot of defaults (‘marginal adaptation’ in 32%, ‘occlusal wear’ in 28%, ‘proximal contact’ in 28% and ‘tooth vitality’ in 38% of fillings).**

Among the 264 indirect restorations, 105 were considered as failures. The latter included 47 composite, 34 ceramic, and 24 metal restorations. In those failures, ‘tooth vitality’ was the most frequent in ceramic and metal restorations (17% and 31%, respectively) (Fig. 5). In ceramic indirect restorations, ‘proximal contact’ was another criterion frequently rated C (14%). In metal indirect restorations, excluding ‘color match’, ‘marginal adaptation’ and ‘proximal contact’ were also frequently rated C (12% and 10%, respectively). In indirect composite restorations, ‘color match’ was the main reason for failure (15%).

DISCUSSION

The present study revealed that, according to the herein selected and simplified FDI criteria, 44% of 4,612 dental restorations assessed proved clinically unsatisfactory. Nearly one third of those restoration failures had one or two criteria rated C. Typically, the esthetic criterion ‘color match’ was the most frequent, whereas the less frequent ones were ‘recurrence of caries’, ‘fracture of material and retention’, and ‘periodontal response’. Interestingly, ‘Contact proximal’ was the second main reason for failure, whereas it is rarely mentioned as clinically unsatisfactory criterion in the specialized literature.

The assessments of anterior and posterior dental restorations showed that these two sites had failure criteria that followed the same order of frequency; i.e., ‘color match’, ‘anatomic form’, ‘marginal adaptation’, and ‘proximal contact’. Nevertheless, obviously, this fact would not have the same influence on the decision to reintervene because corrections of ‘color match’ and/or ‘anatomic form’ are much more valued by the patient than ‘marginal adaptation’ and/or ‘proximal contact’, especially in anterior restorations. In other words, the patient might prefer esthetics, whereas the practitioner would seek improving biological integration and patient comfort [3,20,21]. Currently, most restorations involve a compromise between esthetics and durability. In fact, esthetic materials may have long-term color stability but time-limited resistance, whereas more resistant materials (amalgams or metal) are much less esthetic. Within the context of the present study, one may consider that criterion ‘color match’ should not have been scored for amalgam or metal fillings or, at least, scored ‘NA’ instead of ‘C’ by all investigators. The use of ‘C’ in nearly 400 restorations and by a part of the investigators has introduced a bias and resulted in i) higher unsatisfactory restorations than previously reported in similar studies; ii) a higher failure rate in amalgam than in composite fillings; and, iii) inadequate comparisons between filling materials. Though the esthetic criterion was deemed

important for various reasons (essentially patient satisfaction), its simplification should be reconsidered and standardized in any further analyses of the same data. For example, a refined analysis would distinguish between visible and other teeth, single- and multi-surface fillings, and possibly, involve patients' initial preferences at previous restorations as originally mentioned in the FDI criteria.

In accordance with other studies [4,12,22-28], an increase in the size of dental restoration (one vs. more surfaces) was found associated with increases in C-rated 'anatomic form', 'fracture of material and retention', 'marginal adaptation', 'occlusal wear', and 'proximal contact'.

The risk of failure depends also, obviously, on the procedures and materials used. Direct restorations represented 91% of dental restorations of which nearly two thirds used composite fillings. Some retrospective studies have shown acceptable survival rates of resin composites [23,29,30], which would be similar to those of amalgams [24,25,27]. The present study would confirm those results because the deterioration of restorations made with the latter materials were overall comparable and confirm also other results regarding the survival of GIC fillings [14,24,31,32].

In this study, indirect restorations represented nearly 6% of all restorations assessed and were made mainly with resin composite. Composite inlays met the functional/biological criteria –though their colors have been often questioned– and ceramic inlays met all criteria described by Hickel et al. [6]. According to previous studies [33-36], whenever an indirect method was required, esthetic treatment options showed the lowest restoration failure rate.

As already recommended by Hickel et al. [6,7], authors that use FDI criteria might select them according to their specific objectives. For example, studies on performance of adhesives would preferably select FDI criteria related to 'marginal staining', 'fracture of material and retention', 'marginal adaptation', 'post-operative (hyper)sensitivity', and

‘recurrence of caries’ [37-39]; whereas studies on materials or validation of long-term procedures would select criteria related to tooth and periodontium prognosis and to patients’ opinions [40-42]. For a general assessment of the quality of dental restoration, the present study selected nine of the sixteen FDI criteria: two esthetic criteria (‘color match’ and ‘anatomic form’); four functional criteria (‘fracture of material and retention’, ‘marginal adaptation’, ‘occlusal wear’, and ‘proximal contact’); and three biological criteria (‘tooth vitality’, ‘recurrence of caries’, and ‘periodontal response’). Of those nine criteria, four are among the six most commonly chosen by other studies [8], and, most interestingly, that selection shows various similarities with other selections used in previous investigations [12,16,43,44] devoted to general assessments of the quality of dental restorations [7].

Assessing a previous restoration with selected, modified or simplified FDI criteria informs on the degree of deterioration and indicates the need for and the type of reintervention. Nevertheless, this indication has to meet both the practitioner’s and the patient’s decisions [7,45,46]. In document-based studies, restoration longevity was examined on repairs or replacements made necessary by imperative conditions such as caries, fractures, pain, and/or endodontic treatment [22,27,33]. However, though carried out with FDI criteria, most of those studies did not specify scores that motivated the selection of their failure criteria. Thus, the types or extents of reports on reinterventions may have fallen short of the actual needs [21,47]. In agreement with Laske et al. [21], we believe that accurate definitions of failure and failure criteria allow better comparisons between studies and are likely to improve restorative intervention protocols.

A number of results from the present study do not agree with those already reported by the literature. The discrepancies might be due to the study design as to some degree of individual interpretations of the criteria despite the specialized training [29,34,48,49]. One limitation of the design was that this cross-sectional observational study did not collect

retrospective details such as the dates of completion of the previous restorations. Another limitation was the investigators' heterogeneous and insufficient degrees of experience with observational studies, the use of FDI criteria, or the use of the criteria as modified for the present study. It seems the training sessions destined to standardize dentists' scores –to some extent– were not sufficient. The lack of sufficient calibration as well as the lack of accurate statistical analysis of investigator calibration (i.e., analysis of inter- and intra-investigator scoring reproducibility) are flaws that should be corrected to increase the validity of further analyses. Furthermore, one important imperfection was merging scores 4 and 5 for simplicity purposes and to keep with the objective of the examination (intervene or wait-and-see). This did not prove to be a good idea because, in many instances, it concealed the indication for restoration or replacement. In future analyses, this idea should be carefully reconsidered, fully justified, or avoided. Finally, the results reported here cannot be compared with others obtained with the original FDI criteria. They reflect an evolution of dental practice and take into account the current requirements in esthetic restoration.

Despite those limitations, the present study has important assets. We mention first the high number of participant dentists (76) and the very large numbers of patients (822) and fillings (4,612). We mention also the study's large patient sampling frame (adults aged 18 to 84, new and established patients) and its mix of: i) reasons for seeking care (regular or emergency visits); ii) filling characteristics (number, location, materials, or techniques); iii) private and hospital patients, which, to our knowledge, is quite uncommon [9-16]. That rich mix has been seldom the object of accurate and standardized observations.

CONCLUSION

Monitoring dental restorations and their performance throughout life is very important but uneasy to undertake. Today, the main difficulty is defining accurate and reliable indicators that help making right decisions. Since their publication, the FDI recommendations improved previous decision-making processes and practices but more progress is still needed. The assessment approach described here should raise the interest of practitioners faced with daily dilemmas regarding replacement or repair of previous dental restorations. It should also help more private practitioners become involved in large on-the-field research projects whose results should support more focused projects.

REFERENCES

- [1] S.C. Bayne, J.L. Ferracane, G.W. Marshall, S.J. Marshall, R. van Noort, The Evolution of Dental Materials over the Past Century: Silver and Gold to Tooth Color and Beyond, *J. Dent. Res.* 98 (2019) 257–265. <https://doi.org/10.1177/0022034518822808>.
- [2] M.B. Blatz, G. Chiche, O. Bahat, R. Roblee, C. Coachman, H.O. Heymann, Evolution of Aesthetic Dentistry, *J. Dent. Res.* 98 (2019) 1294–1304. <https://doi.org/10.1177/0022034519875450>.
- [3] F.F. Demarco, K. Collares, M.B. Correa, M.S. Cenci, R.R. de Moraes, N.J. Opdam, Should my composite restorations last forever? Why are they failing?, *Braz. Oral. Res.* 31 (2017) e56. <https://doi.org/10.1590/1807-3107bor-2017.vol31.0056>.
- [4] R.J. Wierichs, E.J. Kramer, H. Meyer-Lueckel, Risk Factors for Failure of Direct Restorations in General Dental Practices, *J. Dent. Res.* 99 (2020) 1039–1046. <https://doi.org/10.1177/0022034520924390>.
- [5] J. Cvar, G. Ryge, Reprint of criteria for the clinical evaluation of dental restorative materials. 1971, *Clin. Oral Investig.* 9 (2005) 215:32. <https://doi.org/10.1007/s00784-005-0018-z>.
- [6] R. Hickel, J.-F. Roulet, S. Bayne, S.D. Heintze, I.A. Mjör, M. Peters, V. Rousson, R. Randall, G. Schmalz, M. Tyas, G. Vanherle, Recommendations for conducting controlled clinical studies of dental restorative materials, *Clin. Oral Investig.* 11 (2007) 5–33. <https://doi.org/10.1007/s00784-006-0095-7>.
- [7] R. Hickel, A. Peschke, M. Tyas, I. Mjör, S. Bayne, M. Peters, K.-A. Hiller, R. Randall, G. Vanherle, S.D. Heintze, FDI World Dental Federation: clinical criteria for the evaluation of direct and indirect restorations-update and clinical examples, *Clin. Oral Investig.* 14 (2010) 349–366. <https://doi.org/10.1007/s00784-010-0432-8>.
- [8] T. Marquillier, S. Doméjean, J. Le Clerc, F. Chemla, K. Gritsch, J.-C. Maurin, P. Millet,

- M. Pérard, B. Grosgeat, E. Dursun, The use of FDI criteria in clinical trials on direct dental restorations: A scoping review, *J. Dent.* 68 (2018) 1–9.
<https://doi.org/10.1016/j.jdent.2017.10.007>.
- [9] P.A. Da Rosa Rodolpho, T.A. Donassollo, M.S. Cenci, A.D. Loguercio, R.R. Moraes, E.M. Bronkhorst, N.J.M. Opdam, F.F. Demarco, 22-Year clinical evaluation of the performance of two posterior composites with different filler characteristics, *Dent. Mater.* 27 (2011) 955–963. <https://doi.org/10.1016/j.dental.2011.06.001>.
- [10] H. Fron, J.-N. Vergnes, C. Moussally, S. Cazier, A.-L. Simon, J.-B. Chieze, G. Savard, G. Tirlet, J.-P. Attal, Effectiveness of a new one-step self-etch adhesive in the restoration of non-carious cervical lesions: 2-Year results of a randomized controlled practice-based study, *Dent. Mater.* 27 (2011) 304–312. <https://doi.org/10.1016/j.dental.2010.11.006>.
- [11] H. Fron Chabouis, C. Prot, C. Fonteneau, K. Nasr, O. Chabreton, S. Cazier, C. Moussally, A. Gaucher, I. Khabthani Ben Jaballah, R. Boyer, J.-F. Leforestier, A. Caumont-Prim, F. Chemla, L. Maman, C. Nabet, J.-P. Attal, Efficacy of composite versus ceramic inlays and onlays: study protocol for the CECOIA randomized controlled trial, *Trials.* 14 (2013) 278. <https://doi.org/10.1186/1745-6215-14-278>.
- [12] R.A. Baldissera, M.B. Corrêa, H.S. Schuch, K. Collares, G.G. Nascimento, P.S. Jardim, R.R. Moraes, N.J.M. Opdam, F.F. Demarco, Are there universal restorative composites for anterior and posterior teeth?, *J. Dent.* 41 (2013) 1027–1035.
<https://doi.org/10.1016/j.jdent.2013.08.016>.
- [13] V.V. Gordan, J.L. Riley, D.B. Rindal, V. Qvist, J.L. Fellows, D.A. Dilbone, S.G. Brotman, G.H. Gilbert, Repair or replacement of restorations: A prospective cohort study by dentists in The National Dental Practice-Based Research Network, *J. Am. Dent. Assoc.* 146 (2015) 895–903. <https://doi.org/10.1016/j.adaj.2015.05.017>.
- [14] T. Klinker, A. Daboul, A. Turek, R. Frankenberger, R. Hickel, R. Biffar, Clinical

- performance during 48 months of two current glass ionomer restorative systems with coatings: a randomized clinical trial in the field, *Trials*. 17 (2016) 239.
<https://doi.org/10.1186/s13063-016-1339-8>.
- [15] F. Cieplik, K.J. Scholz, I. Tabenski, S. May, K.-A. Hiller, G. Schmalz, W. Buchalla, M. Federlin, Flowable composites for restoration of non-cariou cervical lesions: Results after five years, *Dent. Mater.* 33 (2017) e428–e437.
<https://doi.org/10.1016/j.dental.2017.09.012>.
- [16] S. May, F. Cieplik, K.-A. Hiller, W. Buchalla, M. Federlin, G. Schmalz, Flowable composites for restoration of non-cariou cervical lesions: Three-year results, *Dent. Mater.* 33 (2017) e136–e145. <https://doi.org/10.1016/j.dental.2016.12.009>.
- [17] F. Decup, E. Dantony, C. Chevalier, A. David, V. Garyga, M. Tohmé, F. Gueyffier, P. Nony, D. Maucort-Boulch, B. Grosogeat, Needs for re-intervention on restored teeth in adults: a practice-based study, *Clin. Oral Investig.* (2021). <https://doi.org/10.1007/s00784-021-04058-5>.
- [18] N. Gehlenborg, UpSetR: A More Scalable Alternative to Venn and Euler Diagrams for Visualizing Intersecting Sets. R package version 1.4.0., (2019). <https://CRAN.R-project.org/package=UpSetR>.
- [19] R Core Team, R: A language and environment for statistical computing. (2018). <https://www.R-project.org/>.
- [20] C. Signori, K. Collares, C.B.F. Cumerlato, M.B. Correa, N.J.M. Opdam, M.S. Cenci, Validation of assessment of intraoral digital photography for evaluation of dental restorations in clinical research, *J. Dent.* 71 (2018) 54–60.
<https://doi.org/10.1016/j.jdent.2018.02.001>.
- [21] M. Laske, N.J.M. Opdam, E.M. Bronkhorst, J.C.C. Braspenning, M.C.D.N.J.M. Huysmans, The differences between three performance measures on dental restorations,

- clinical success, survival and failure: A matter of perspective, *Dent. Mater.* 35 (2019) 1506–1513. <https://doi.org/10.1016/j.dental.2019.07.010>.
- [22] N.J.M. Opdam, F.H. van de Sande, E. Bronkhorst, M.S. Cenci, P. Bottenberg, U. Pallesen, P. Gaengler, A. Lindberg, M.C.D.N.J.M. Huysmans, J.W. van Dijken, Longevity of Posterior Composite Restorations: A Systematic Review and Meta-analysis, *J. Dent. Res.* 93 (2014) 943–949. <https://doi.org/10.1177/0022034514544217>.
- [23] E. Lempel, Á. Tóth, T. Fábrián, K. Krajczár, J. Szalma, Retrospective evaluation of posterior direct composite restorations: 10-Year findings, *Dent. Mater.* 31 (2015) 115–122. <https://doi.org/10.1016/j.dental.2014.11.001>.
- [24] M. Laske, N.J.M. Opdam, E.M. Bronkhorst, J.C.C. Braspenning, M.C.D.N.J.M. Huysmans, Ten-Year Survival of Class II Restorations Placed by General Practitioners, *JDR Clin. Trans. Res.* 1 (2016) 292–299. <https://doi.org/10.1177/2380084416663192>.
- [25] U. Palotie, A.K. Eronen, K. Vehkalahti, M.M. Vehkalahti, Longevity of 2- and 3-surface restorations in posterior teeth of 25- to 30-year-olds attending Public Dental Service—A 13-year observation, *J. Dent.* 62 (2017) 13–17. <https://doi.org/10.1016/j.jdent.2017.05.012>.
- [26] A. Borouzinia, H. Khaki, S. Majidinia, Retrospective evaluation of the clinical performance of direct composite restorations using the snow-plow technique: Up to 4 years follow-up, *J. Clin. Exp. Dent.* 11 (2019) e964–e968. <https://doi.org/10.4317/jced.55639>.
- [27] R.A. da Silva Pereira, G.R. da Silva, L.M. Barcelos, K.G.B.A. Cavalcanti, Á.M. Herval, T.M. Ardenghi, C.J. Soares, Practice-based analysis of direct posterior dental restorations performed in a public health service: Retrospective long-term survival in Brazil, *PLoS One.* 15 (2020) e0243288. <https://doi.org/10.1371/journal.pone.0243288>.
- [28] C. Wong, I.R. Blum, C. Louca, M. Sparrius, K. Wanyonyi, A retrospective clinical study on the survival of posterior composite restorations in a primary care dental outreach setting over 11 years, *J. Dent.* 106 (2021) 103586. <https://doi.org/10.1016/j.jdent.2021.103586>.

- [29] F.H. van de Sande, N.J. Opdam, P.A. Da Rosa Rodolpho, M.B. Correa, F.F. Demarco, M.S. Cenci, Patient Risk Factors' Influence on Survival of Posterior Composites, *J. Dent. Res.* 92 (2013) S78–S83. <https://doi.org/10.1177/0022034513484337>.
- [30] E. Borgia, R. Baron, J.L. Borgia, Quality and Survival of Direct Light-Activated Composite Resin Restorations in Posterior Teeth: A 5- to 20-Year Retrospective Longitudinal Study: Retrospective Study of Direct Posterior Resin Restorations, *J. Prosthodont.* 28 (2019) e195–e203. <https://doi.org/10.1111/jopr.12630>.
- [31] S.D. Heintze, V. Rousson, R. Hickel, Clinical effectiveness of direct anterior restorations—A meta-analysis, *Dent. Mater.* 31 (2015) 481–495. <https://doi.org/10.1016/j.dental.2015.01.015>.
- [32] B.M. Vetromilla, N.J. Opdam, F.L. Leida, R. Sarkis-Onofre, F.F. Demarco, M.P.J. van der Loo, M.S. Cenci, T. Pereira-Cenci, Treatment options for large posterior restorations: a systematic review and network meta-analysis, *J. Am. Dent. Assoc.* 151 (2020) 614–624.e18. <https://doi.org/10.1016/j.adaj.2020.05.006>.
- [33] K. Collares, M.B. Corrêa, M. Laske, E. Kramer, B. Reiss, R.R. Moraes, M.-C.D.N.J.M. Huysmans, N.J.M. Opdam, A practice-based research network on the survival of ceramic inlay/onlay restorations, *Dent. Mater.* 32 (2016) 687–694. <https://doi.org/10.1016/j.dental.2016.02.006>.
- [34] J. Abduo, R.J. Sambrook, Longevity of ceramic onlays: A systematic review, *J. Esthet. Restor. Dent.* 30 (2018) 193–215. <https://doi.org/10.1111/jerd.12384>.
- [35] J. Souza, M.V. Fuentes, E. Baena, L. Ceballos, One-year clinical performance of lithium disilicate versus resin composite CAD/CAM onlays, *Odontology.* 109 (2021) 259–270. <https://doi.org/10.1007/s10266-020-00539-3>.
- [36] C. Fotiadou, J. Manhart, C. Diegritz, M. Folwaczny, R. Hickel, I. Frasher, Longevity of lithium disilicate indirect restorations in posterior teeth prepared by undergraduate

students: A retrospective study up to 8.5 years, *J. Dent.* 105 (2021) 103569.

<https://doi.org/10.1016/j.jdent.2020.103569>.

[37] A.D. Loguercio, I.V. Luque-Martinez, S. Fuentes, A. Reis, M.A. Muñoz, Effect of dentin roughness on the adhesive performance in non-carious cervical lesions: A double-blind randomized clinical trial, *J. Dent.* 69 (2018) 60–69.

<https://doi.org/10.1016/j.jdent.2017.09.011>.

[38] P. Manarte-Monteiro, J. Domingues, L. Teixeira, S. Gavinha, M.C. Manso, Multi-Mode adhesives performance and success/retention rates in NCCLs restorations: randomised clinical trial one-year report, *Biomater. Investig. Dent.* 6 (2019) 43–53.

<https://doi.org/10.1080/26415275.2019.1684199>.

[39] T. de Paris Matos, J. Perdigão, E. de Paula, F. Coppla, V. Hass, R.F. Scheffer, A. Reis, A.D. Loguercio, Five-year clinical evaluation of a universal adhesive: A randomized double-blind trial, *Dent. Mater.* 36 (2020) 1474–1485.

<https://doi.org/10.1016/j.dental.2020.08.007>.

[40] J.C. Pontons-Melo, I.M. Garcia, M. Vargas, F.M. Collares, Bio-additive and enameloplasty technique for restoring anterior esthetics: 54-month clinical follow-up, *Quintessence Int.* 51 (2020) 622–629. <https://doi.org/10.3290/j.qi.a44814>.

[41] M. Bhatnagar, L. Tomer, P. Saxena, A. Singh, V. Sharma, S. Singh, Evaluation of Clinical Performance of Cast Metal vs. Glass Fiber Posts in the Restoration of Endodontically Treated Teeth, *J. Evol. Med. Dent. Sci.* 10 (2021) 1496–1500.

<https://doi.org/10.14260/jemds/2021/313>.

[42] W. Bömicke, F. Rathmann, M. Pilz, J.L. Bermejo, M. Waldecker, B. Ohlmann, P. Rammelsberg, A. Zenthöfer, Clinical Performance of Posterior Inlay- Retained and Wing- Retained Monolithic Zirconia Resin- Bonded Fixed Partial Dentures: Stage One Results of a Randomized Controlled Trial, *J. Prosthodont.* 30 (2021) 384–393.

<https://doi.org/10.1111/jopr.13258>.

- [43] B. Korkut, C. Türkmen, Longevity of direct diastema closure and recontouring restorations with resin composites in maxillary anterior teeth: A 4- year clinical evaluation, *J. Esthet. Restor. Dent.* 33 (2021) 590–604. <https://doi.org/10.1111/jerd.12697>.
- [44] F. Cieplik, K.J. Scholz, J.C. Anthony, I. Tabenski, S. Ettenberger, K.-A. Hiller, W. Buchalla, M. Federlin, One-year results of a novel self-adhesive bulk-fill restorative and a conventional bulk-fill composite in class II cavities—a randomized clinical split-mouth study, *Clin. Oral. Investig.* (2021). <https://doi.org/10.1007/s00784-021-04019-y>.
- [45] R. Hickel, K. Brühaver, N. Ilie, Repair of restorations – Criteria for decision making and clinical recommendations, *Dent. Mater.* 29 (2013) 28–50.
<https://doi.org/10.1016/j.dental.2012.07.006>.
- [46] I.R. Blum, C.D. Lynch, N.H. Wilson, Factors influencing repair of dental restorations with resin composite, *Clin. Cosmet. Investig. Dent.* 6 (2014) 81–87.
<https://doi.org/10.2147/CCIDE.S53461>.
- [47] B.L.P. Moro, R.D. Freitas, L.R.A. Pontes, A.L. Pássaro, T.L. Lenzi, T.K. Tedesco, K.R. Ekstrand, M.M. Braga, D.P. Raggio, M.S. Cenci, F.M. Mendes, Influence of different clinical criteria on the decision to replace restorations in primary teeth, *J. Dent.* 101 (2020) 103421. <https://doi.org/10.1016/j.jdent.2020.103421>.
- [48] F. Beck, S. Lettner, A. Graf, B. Bitriol, N. Dumitrescu, P. Bauer, A. Moritz, A. Schedle, Survival of direct resin restorations in posterior teeth within a 19-year period (1996–2015): A meta-analysis of prospective studies, *Dent. Mater.* 31 (2015) 958–985.
<https://doi.org/10.1016/j.dental.2015.05.004>.
- [49] F. Angeletaki, A. Gkogkos, E. Papazoglou, D. Kloukos, Direct versus indirect inlay/onlay composite restorations in posterior teeth. A systematic review and meta-analysis, *J. Dent.* 53 (2016) 12–21. <https://doi.org/10.1016/j.jdent.2016.07.011>.

FIGURE CAPTIONS

Fig. 1: *Distributions of single or combined criteria rated C in dental restorations (n = 2,048).*

Horizontal bars show the frequencies of single criteria. Solid vertical bars show the 40 most frequent single or combined criteria in decreasing order. Solid bottom right lines show the single or combined criteria involved in the upper corresponding solid lines.

Fig. 2: *Involvement of the selected FDI criteria according to the location of the restored tooth.* Panel 2a: anterior fillings. Panel 2b: posterior fillings. Only the percentages of restoration failure criteria (scored C) are written in full.

Fig. 3: *Involvement of the selected FDI criteria according to the size of the dental restoration.* Panel 3a: one-surface fillings. Panel 3b: two-surface fillings. Panel 3c: three-surface or more fillings. Panel 3d: cervical restorations. Only the percentages of restoration failure criteria (scored C) are written in full.

Fig. 4: *Involvement of the selected FDI criteria according to the material used for direct dental restorations.* Panel 4a: Amalgam fillings. Panel 4b: Composite fillings. Panel 4c: Glass-ionomer cement fillings. Only the percentages of restoration failure criteria (scored C) are written in full.

Fig. 5: *Involvement of the selected FDI criteria according to the material used for indirect dental restorations.* Panel 5a: Ceramic indirect restorations. Panel 5b: Composite indirect restorations. Panel 5c: Metal indirect restorations. Only the percentages of restoration failure criteria (scored C) are written in full.

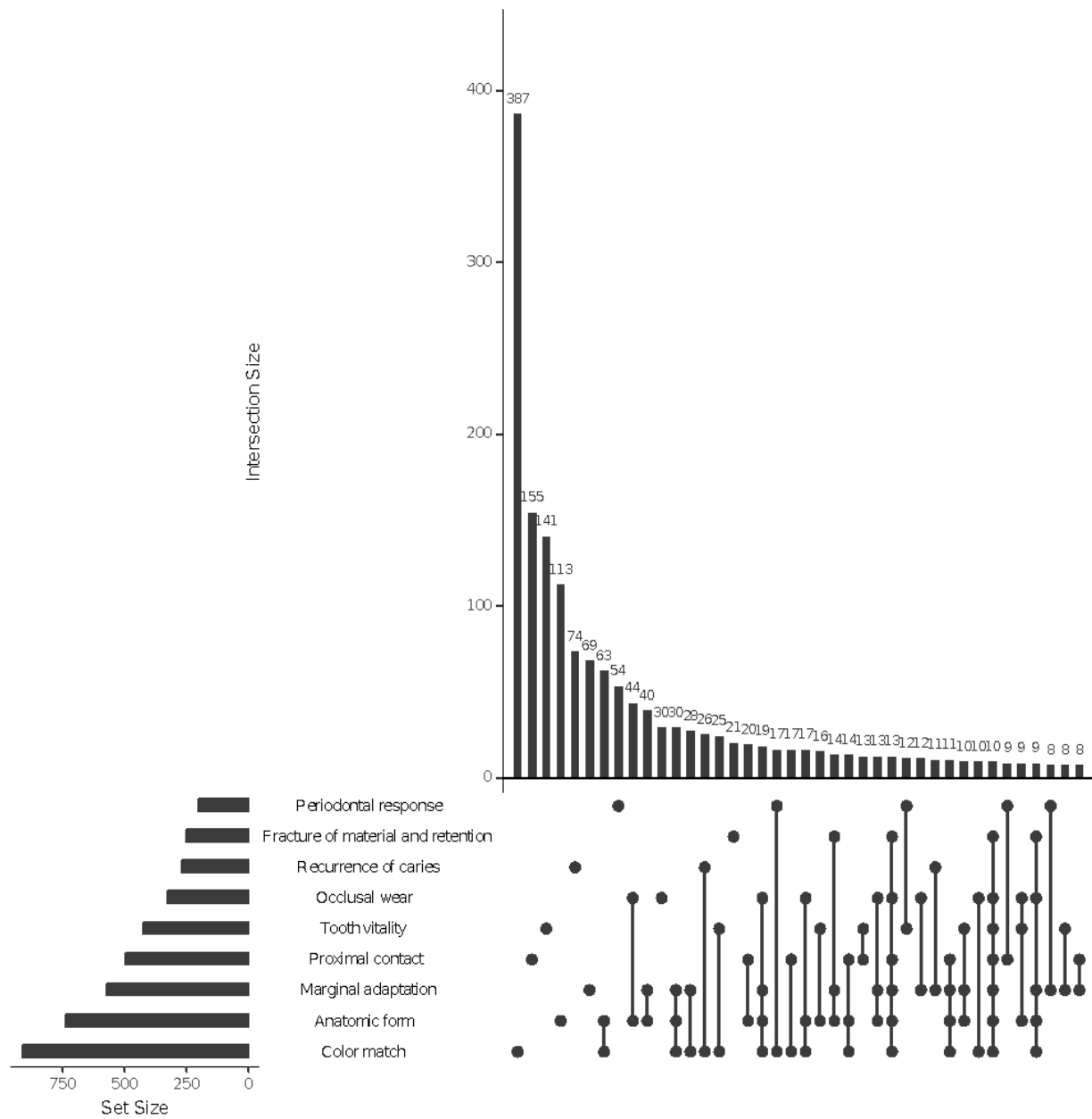
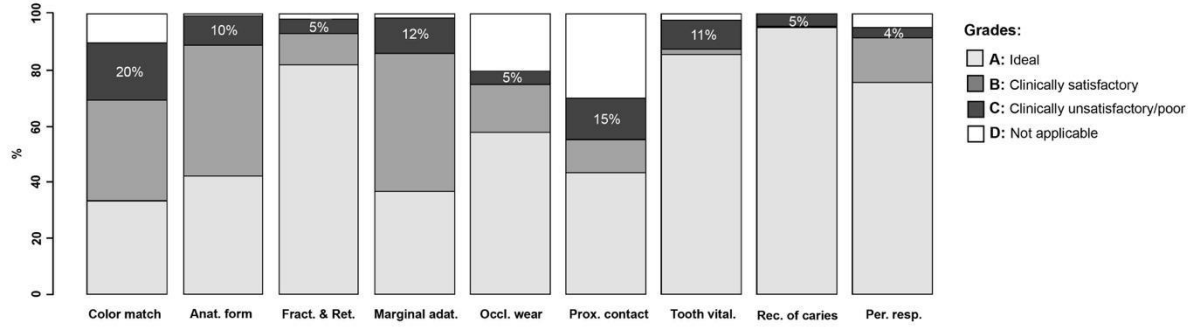


Figure 1

2a: Partial dental restorations of anterior teeth (n=1169)



2b: Partial dental restorations of posterior teeth (n=3443)

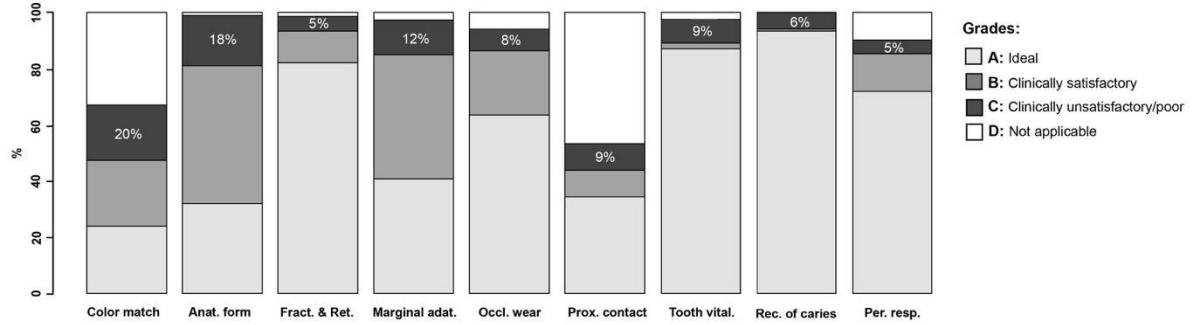
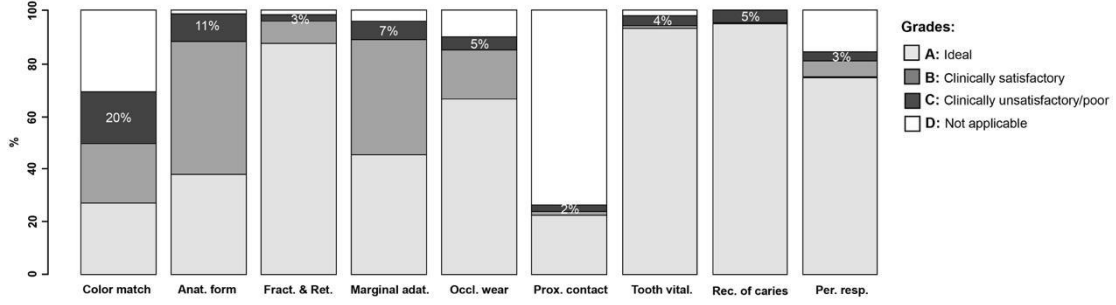
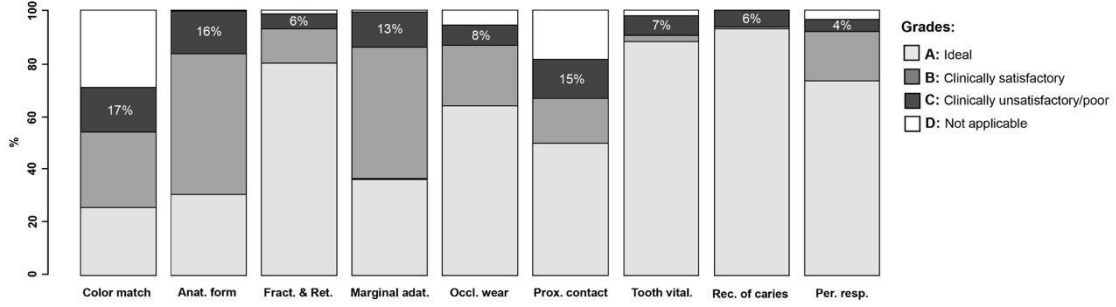


Figure 2

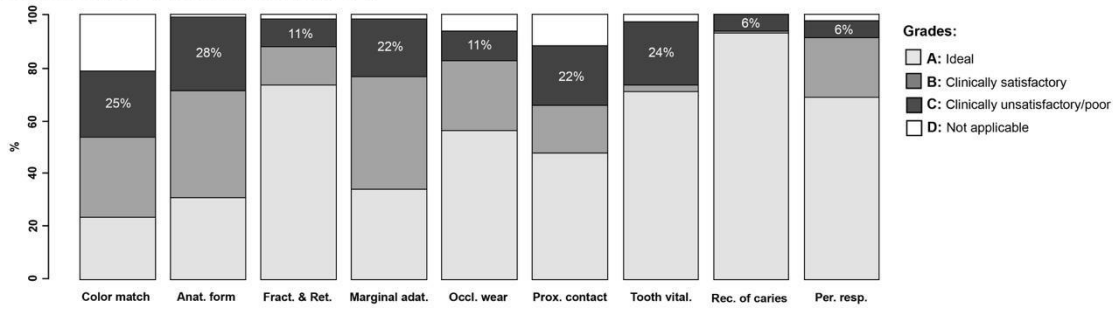
3a: One-surface restorations (n=1973)



3b: Two-surface restorations (n=1520)



3c: Three-surface or more restorations (n=971)



3d: Cervical restorations (n=148)

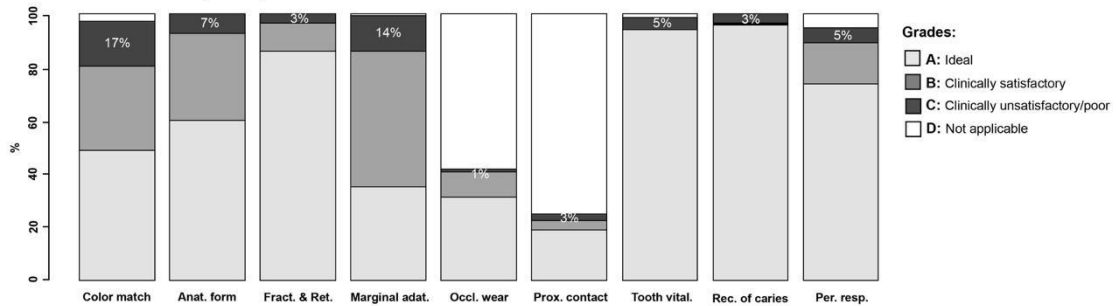
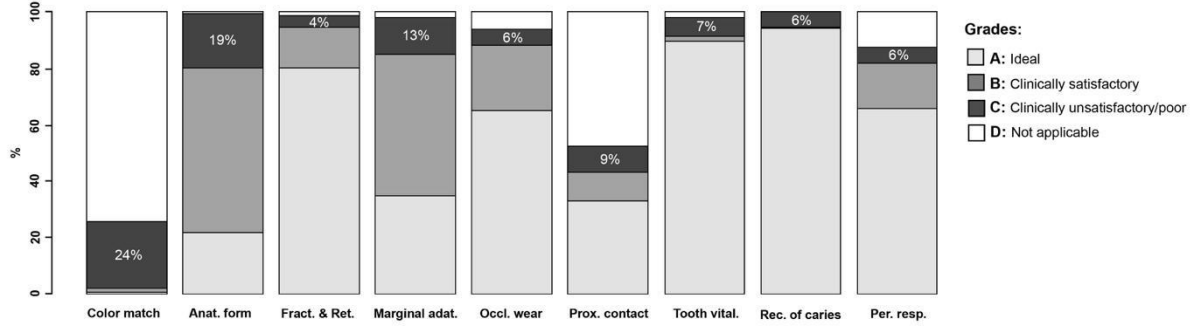
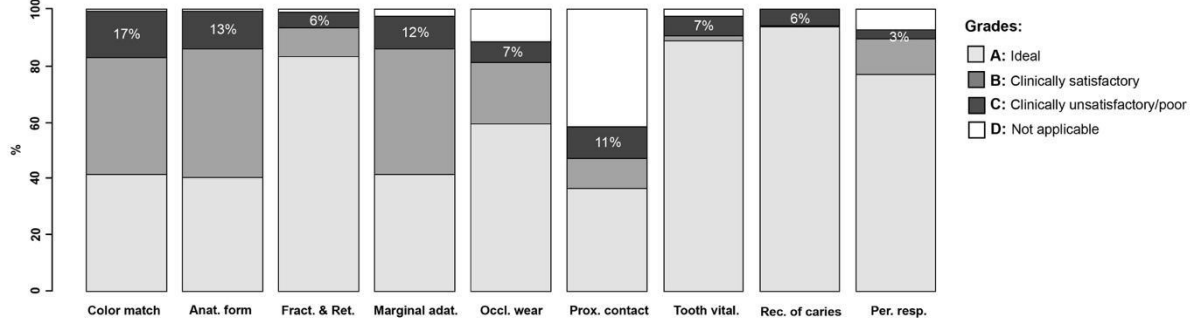


Figure 3

4a: Amalgam fillings (n=1542)



4b: Composite fillings (n=2555)



4c: Glass-ionomer cement fillings (n=88)

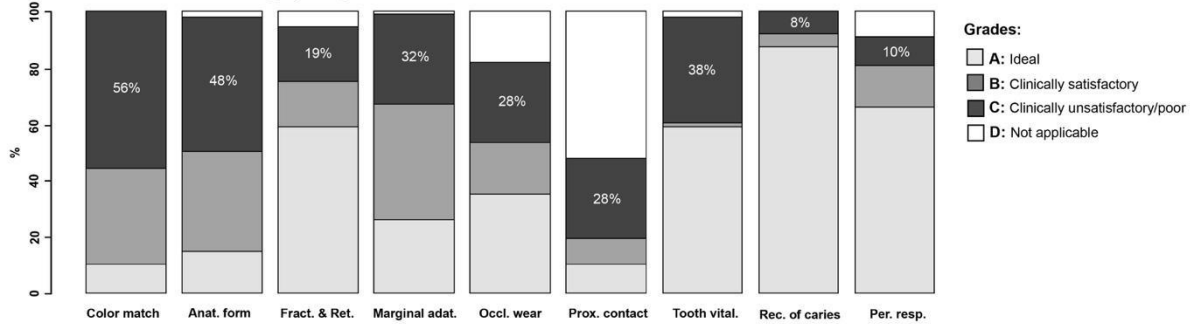
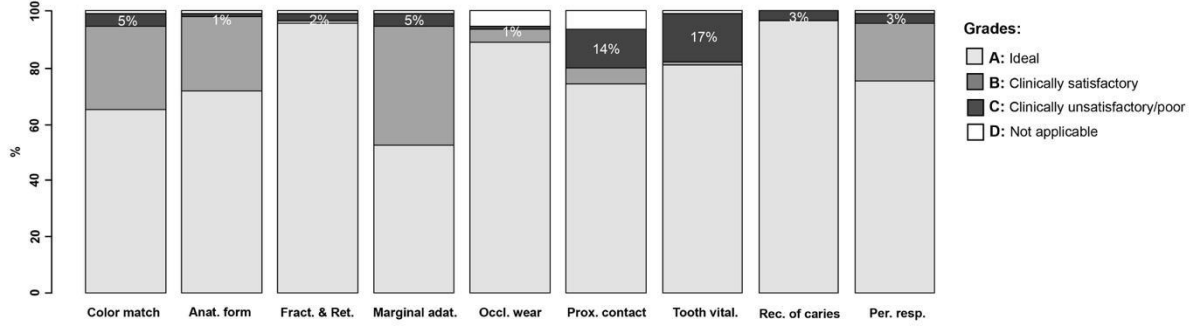
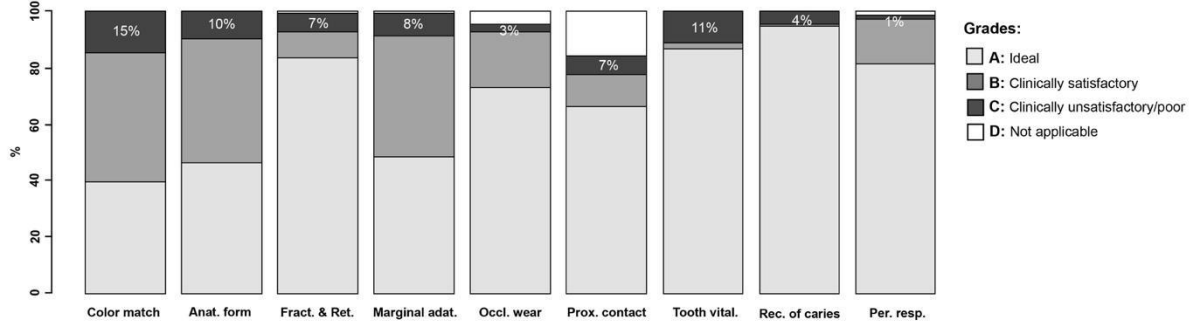


Figure 4

5a: Ceramic indirect partial restorations (n=88)



5b: Composite indirect partial restorations (n=134)



5c: Metal indirect partial restorations (n=42)

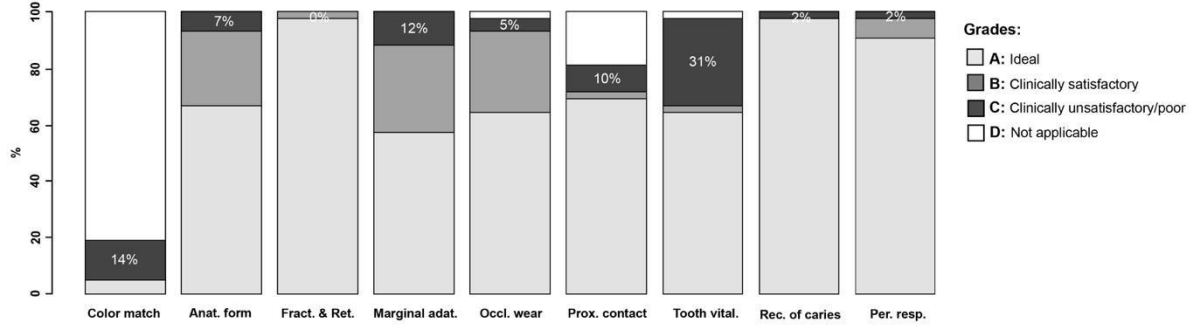


Figure 5

Table 1 - Selected FDI criteria and simplified rating

Selected criteria *	Criteria assessment grades			
	A = Ideal	B = Clinically satisfactory	C = Clinically unsatisfactory or poor	D= Not assessed
<i>Esthetic properties</i>				
3. Color match	1†	2 or 3†	4 or 5†	NA
4. Anatomic form	1	2 or 3	4 or 5	NA
<i>Functional properties</i>				
5. Fracture of material & retention	1	2 or 3	4 or 5	NA
6. Marginal adaptation	1	2 or 3	4 or 5	NA
7. Occlusal wear	1	2 or 3	4 or 5	NA
8. Proximal contact	1	2 or 3	4 or 5	NA
<i>Biological properties</i>				
11. Tooth vitality	1	2 or 3	4 or 5	NA‡
12. Recurrence of caries	1	2 or 3	4 or 5	NA
14. Periodontal response	1	2 or 3	4 or 5	NA

* From Hickel et al. 2010. † Hickel score(s). ‡ An endodontic-treated tooth was considered as non-vital.

Table 2 - Characteristics of the study population

Characteristics	Population	Private practice	Hospital
	N (%)	N (%)	N (%)
<i>Participants</i>	822 (100)	400	422
<i>Sex</i>			
Women	467 (57)	230 (57)	237 (56)
Men	355 (43)	170 (43)	185 (44)
<i>Age (years)</i>			
18-29	208 (25)	76 (19)	132 (31)
30-59	434 (53)	241 (60)	193 (46)
≥ 60	180 (22)	83 (21)	97 (23)
<i>Occupation / Socioeconomic class</i>			
Craftsmen, traders, business leaders	50 (6)	34 (9)	16 (4)
Managers, higher intellectual activity	174 (21)	131 (33)	43 (10)
Intermediate professions	37 (4)	25 (6)	12 (3)
Employees	217 (26)	77 (19)	140 (33)
Workers	22 (3)	11 (3)	11 (3)
Retirees	145 (18)	64 (16)	81 (19)
Not in active employment	63 (8)	13 (3)	50 (12)
Other	114 (14)	45 (11)	69 (16)
<i>Patient status</i>			
New patients in the dental office	514 (63)	184 (46)	330 (78)
Patients of the dental office	308 (37)	216 (54)	92 (22)
<i>Tooth brushing habit</i>			
0 brushing/day	11 (1)	5 (1)	6 (1)
1 brushing/day	112 (14)	45 (11)	67 (16)
≥2 brushings/day	699 (85)	350 (88)	349 (83)
<i>Consultation frequency</i>			
Regular (biannual, annual or biennial)	570 (69)	296 (74)	274 (65)
Irregular	252 (31)	104 (26)	148 (35)
<i>Reason for dental visit</i>			
Routine check-up	476 (58)	273 (68)	203 (48)
Pain	141 (17)	40 (10)	101 (24)
Tooth injury	44 (6)	19 (5)	25 (6)
Troublesome dental filling	20 (2)	10 (2.5)	10 (2)
Troublesome prosthesis	39 (5)	10 (2.5)	29 (7)
Gingivitis	35 (4)	19 (5)	16 (4)
Other	67 (8)	29 (7)	38 (9)
<i>Risk factor</i>			
Yes	533 (65)	240 (60)	293 (69)
No	289 (35)	160 (40)	129 (31)

Table 3 – Need for reintervention according to the tooth location, the filling position, and the type of material previously used.

Procedure & material	Anterior fillings				Posterior fillings				Totals	Failure rate
	One surface	Two surfaces	>Two surfaces	Cervical fillings	One-surface	Two-surfaces	>Two surfaces	Cervical fillings		
<i>Direct restorations</i>	109 / 167	201 / 278	140 / 97	35 / 72	560 / 1,078	459 / 500	315 / 140	8 / 26	1,827 / 2,358	43.7
Resin composite	82 / 148	143 / 244	119 / 91	33 / 66	246 / 617	201 / 295	148 / 95	6 / 21	978 / 1,577	38.3
Amalgam	21 / 19	55 / 33	14 / 6	0 / 1	295 / 451	244 / 203	152 / 44	1 / 3	782 / 760	50.7
Glass-ionomer cement	6 / 0	3 / 1	7 / 0	2 / 5	19 / 10	14 / 2	15 / 1	1 / 2	67 / 21	76.1
<i>Indirect restorations</i>	1 / 4	4 / 6	6 / 11	2 / 1	6 / 7	14 / 24	71 / 106	1 / 0	105 / 159	39.8
Composite	1 / 3	2 / 3	2 / 7	2 / 1	6 / 6	6 / 17	28 / 50	0 / 0	47 / 87	35.1
Ceramic	0 / 0	1 / 2	4 / 3	0 / 0	0 / 1	5 / 6	23 / 42	1 / 0	34 / 54	38.6
Metal	0 / 1	1 / 1	0 / 1	0 / 0	0 / 0	3 / 1	20 / 14	0 / 0	24 / 18	57.1
<i>Other or not assessable</i>	3 / 0	5 / 3	18 / 6	0 / 0	25 / 13	18 / 8	45 / 16	2 / 1	116 / 47	71.2

Bold and light numbers indicate respectively the numbers of teeth deemed needing reintervention and not needing reintervention. Adding the two numbers gives the total number in each cell. As example, the failure rate for Direct restorations is calculated as follows: $1,827 / (1,827 + 2,358) = 43.7\%$.