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Crown Margin Repairs in Prosthetic Dentistry

Supervisor Assist. Prof. Dr. Rita Trumpaitė-Vanagienė

Head of Institute of Dentistry Prof. Dr. Vilma Brukienė

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Student's email: lennart.kube@mf.stud.vu.lt

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Abstract

Crown margin repairs, in some extent and based on the clinical situation, are an acceptable treatment option to restore the functionality and aesthetics of the compromised crown margin in prosthetic dentistry. The process of a repair is minimally invasive and saves aesthetic, time, and expenses for the patient. It is important to be familiar with the repair materials available, to know the techniques for a successful repair and to be able to fulfil the patient's requests. Impaired crown margins not only have bad aesthetics, but also prove to be a risk of caries lesions and the loss of structural integrity of the whole crown and abutment tooth complex.

The purpose of this literature review is to inspect the longevity of crown margin repairs as well as the survival rates of different repair materials. Therefore, the composition of crown margins will be outlined, diagnostic criteria reviewed, and the direct and indirect techniques will be discussed. Additionally, clinical outcomes are compared, and the advancements and limitations of crown margin repairs will be concluded. Finally, all results are put into context and will be analysed.

Abbreviations

PFM - porcelain-fused-to-metal

FDI – World Dental Federation

GI – Glass Ionomer

CGI – Conventional glass ionomer

C-GIC – Conventional glass ionomer cements

HVGIC – High-Viscous glass ionomer cements

RMGI – Resin-modified Glass Ionomer

RBC – Resin-based composite

CR – Nano-hybrid composite

BPA – Bisphenol-A (resinous material)

CAR – Caries at the restoration

SDF – Silver diamine fluoride

CAD/CAM - computer-aided design/ computer-aided manufacturing

CEREC - Chairside economical restoration of esthetic ceramic

Summary

In this literature review, the success rate and longevity of crown margin repairs in prosthetic dentistry are evaluated. The marginal integrity of crowns provides a seamless aesthetic in the dental practice and prevent the abutment tooth from failure or microleakage which results in caries or total crown failure. Choosing the right finishing lines is a key factor to prevent this, equi-gingival and supragingival margins have therefore the greatest success rates. The initially used crown material may also prevent the patient from a crown margin repair, this will be altered by the use of all ceramic or metal ceramic crowns. When it comes to crown margin repairs, they can occur from different factors like expanding the overall estimated survival time of the crown used, bad oral hygiene or an in proper fitting of the initial crown. The use of repair materials like resin-modified glass ionomer, amalgam and nano-hybrid composites provide a wide solution of either aesthetically pleasing results or the focus of prolonged longevity of the marginal repair and reduced microleakage. The FDI criteria can help to choose the appropriate repair technique by assessing the patient's oral health and other complications to determine the best clinically and aesthetic outcome for the patient's needs. Overall provides the direct repair technique a less invasive and fast solution for the marginal comprised integrity of the crown but can be less precise and lack in build-up quality. The indirect technique takes more time but will present a more precise marginal repair due to the use of either digital or manual impression taking and a dental laboratory workflow. The indirect technique will be more expensive for the patient but can focus more on the patient's preferences and needs. In all, there are no statistically significant differences between these two techniques, while it is suggested to take the indirect technique in cases of larger crown margin cavity repairs. Lastly, the advancements in the dental practice are characterized by the digitalisation. With the CAD/CAM technology, including intraoral scanners, 3D printing and milling provide the dentist with new tools to treat crown margin repairs. While these advancements are practically to use and promise good results, they are still quite expensive to acquire and therefore are still a niche product for the common dental practice.

Keywords

Crown Margins

Repair Techniques

Crown Margin Materials

Review

Surveys

Introduction

The aim in the prosthetic dentistry is to provide the patient with a seamless aesthetic dental prosthesis in form of dental bridges, partial- or full- dentures and crowns, adapted to the patient's personal needs and demands to restore an optimal function and to prevent further decay of the tooth's integrity. Nowadays, with the many possibilities of customised dentures and crowns and their longevity and effectiveness, prosthetics has moved further into the centre of focus for the general dentist's practices. A sub-area of the field in prosthetics are the dental crowns, mostly produced out of metal-based materials, composite resins, or glass ionomer cements. These customized crowns can be a permanent and reliable part of the patient's life for many years. Due to their properties of being fixed in place, the prosthesis cannot adapt to the changes in the patient's mouth over time, which may result in the events of partial breaking or destruction. Mostly vulnerable are the crown margins for these events. Since there are many well-known products on the market for repair materials as well as constantly new arriving innovations, for the general dentist it might be hard to assess which material is the most reliable to use, according to the patient's situation. The margins build the link between the restauration and the main tooth structure and are essential for the success and persistence of the crown. In the marginal region the restoration is often at its thinnest and depending on the used material, unable to cope with certain forces. Therefore, the right diagnostic criteria's, the selection of the crown material, repair technique and margin type play a major role in this.

In the following this literature review will focus on the event of crown margin repairs, considering marginal adaptations, methods of reviewing the margins, repair materials, techniques, and clinical outcomes according to the longevity of margin repairs, used materials and microleakage comparison of certain materials. Additionally, advancements of future possibilities in crown margin repairs will be mentioned.

Literature search strategy

The material for this literature review was predominantly collected from scientific articles, reviews, surveys, and studies. The literature search strategy was conducted in the following databases: PubMed, ResearchGate, ScienceDirect and PeerJ. The studies included in this literature review are retrospective, preference based, meta-analytic, systemic review, comprehensive review and based on summary of evidence. The research was collected with the use of keywords such as crown margins, repair techniques, repair materials, crown materials, longevity of crown margins, success rates of crown margins and advancements of crown margins, in electronic data bases and by manual search. Pre-selected literature was then screened and sorted by importance, relevance, publication-date, field of specialisation and language. The last data collected for this search was in April 2024. The base search is directed on relevant studies written in English and German. The total number of managed sources for this literature review is 54.

Margins

The margin of a restoration designates the point at which the surrounding tooth tissue finishes and the restoration itself begins. This leads to a final restoration that can be both aesthetically pleasing and long-lasting, provided that the technician understands the physical requirements and limitations of the chosen restorative material.

Clinical weaknesses that result in less precise margins are on the one hand marginal differences either in its interference or smoothness. The tooth's surface and crown margin interface are susceptible to plaque buildup and microleakage development, which may cause the remaining tooth surface to decay more quickly (1). Shade discrepancies also play a role, while the tooth-coloured restoration may stain the junction because it doesn't match the patient's primary tooth colour. Another clinical weakness is the outer part of the margin, in this area the marginal junction is at its thinnest and most susceptible to material or technician failures. It may exceed its maximum capability of forces and breaks (1).

Irrelevant to the overall design is that the proper finishing is essential to ensure a smooth transition between the final restoration and the remaining tooth structure (1). Adequate tooth reduction and sufficient ceramic thickness are a key factor to success in addition to carefully smooth every margin. The position of the finishing line is relative to the gingival margin. It depends on certain factors, like the tooth's position in the mouth, the height of the lip line, the colour of the adjacent and underlying tooth and the state of the patients overall periodontal status. The restoration margins are placed typically supragingival which makes the process of preparation, impression taking, cementation and finishing most favourable for the clinical outcome and the workflow for the dentist. Also, oral hygiene procedures can be scheduled normally (1).

If there are no biomechanical restrictions, the preferred restoration for anterior crowns is all-ceramic restorations. This is because of their more translucent properties compared to PFM's. PFMs are widely used because of their strength, durability, adaptability, and aesthetics (1). Furthermore, patients with excessive occlusal loading, bruxism, tooth wear or inadequate clearance are typically candidates for anterior PFM restorations (1). In the preparation process of the tooth is nevertheless room for failure, if the tooth was reduced insufficient it may result in obstruction of the metal structure. When there is too little reduction, there is not enough room to increase the thickness of the porcelain. As a result, the porcelain and the crown become opaque or overbuilt (1). To prevent chipping, knife edge finishing lines are primarily used for PFM. Here, metal collars are used as marginal porcelain. This may result in an un-aesthetic crown that is bulky because the axial walls were not properly prepared. Over-tapering may result in an unretentive final restoration. To withstand fracture, the chamfer for PFM with metal margin and porcelain margin must be deep enough. Additionally, the bevelled shoulder provides an optimal level of rigidity, periodontal health, and marginal seal. Recession may eventually make the margin visible, and it may cause the margin to be positioned at the base of the gingival crevice (1). On the other hand, full veneer metals have knife-edge finishing lines which results in a featheredge on the crown due to the metals strength (1). Chamfers and shoulders may fail because the metal shrinks during the technicians casting process. The preparation of choice for these crowns is the deep chamfer.

A precise fit is lastly a crucial requirement for the clinical success and quality. The fit increases the marginal discrepancy and promotes cement dissolution, plaque retention, microleakage and caries. When cleaning the tooth surface, the aim is to minimize the contamination of the margin (1). The positioning of the margin is relevant for the further oral health of the patient.

Therefore, a study from 2021 analysed over 600 patients with crown and bridge margins within six months of their initial placement, the margin location, and the margin type. Additionally,

the oral health of the tooth with the restoration in place, without the restoration on the tooth and general oral hygiene were observed. The chosen margin by the initial dentists was in anterior crowns an equi-gingival margin with 75.92 per-cent and for posterior crowns supragingival margins, 89.87 per-cent. It was stated that 91.87 per-cent choose the margin for hygiene purposes, while 83.89 per-cent chose the type of margin according to its aesthetics (2). The final examination concluded that equi-gingival and supragingival margins have better gingival health signs than subgingival margins (2). It was also noted that 92 per-cent of the patients were not involved in the process of choosing a margin according to their preferences (2).

Another way to verify the adequate marginal fit is by radiographic evaluation (3,4). Especially in the proximal regions it is often hard to ensure a proper fit by visual inspection only. While sharp explorers are a viable option for checking the margin after final placement in the buccal and lingual areas, interproximal and subgingival margins with horizontal and vertical discrepancies cannot be checked that easily (4). To validate the radiographic evaluation, in 2018 a study examined 230 interproximal margins in 115 crowns, mostly out of metal-ceramic. The crowns were assessed by fit before their cementation, then probed using a sharp explorer and finally a bite-wing radiograph was performed (4). The keyword "Discrepancy" was used to mark any vertical and horizontal inaccuracies in proximal areas, greater than 0.5 mm of the initial margins. The results show that 113 distinct spots have marginal "Discrepancies" out of the 230 interproximal margins in the 115 crowns. The "discrepancies" were summed up into 19.1 per-cent of horizontal, 25.2 per-cent vertical and 4.8 per-cent for both horizontal and vertical (4). It was also concluded, that in maxillary crowns, the margins on the mesial surface were allied to horizontal crown margin inconsistencies, while distal surfaces of all crowns, independently to the arch, are prone to vertical inconsistencies (4). Finally, when analysed on the radiograph, nearly half of the clinically acceptable crowns had some degree of marginal inconsistencies. While the mesial margins of the maxillary crowns showed the most horizontal incompatibilities, the distal surfaces of the crowns in all arches showed the most vertical inconsistencies.

Crown margins are particularly important in determining a successful survival of the surrounding supporting tissues as well as the restoration itself. Careful consideration must be given to designing and creating finishing lines that are appropriate for the restorative material being used. The likelihood of a successful outcome is significantly increased when appropriate planning and execution are paired with thoughtful preparations as well as accurate checking of the fit and a final review using a radiograph. Healthcare providers should also involve the patient in treatment decisions, as far as possible, to achieve optimal periodontal health and patient satisfaction.

Crown Margin Repair Materials

Common crown margin repair materials in use now-a-days are composite resins, glass ionomer cements or amalgam. Also, SDF is a first solution for arresting decay of crown margins, by sealing them (5). All these materials are relevant to repair or stop the decay of the margin of each individual patient, on the other hand they are limited by the requirements and may have technical problems (6). Composite resin materials are produced out of organic polymer and a combination of inorganic particles. These materials are based on BPA. It provides the material strength, rigidity, and a low biodegradation (7). Composite resins provide suitable aesthetics compared to amalgam (8). Besides that, it is suggested that also composite resin materials have toxicity traits to the patient's health and environment (9). Composite resin is used to restore

cavities in the posterior region, depending on the size of the cavity near the margin (9). Small to medium sized cavities are repaired by using the direct restoration technique, while larger cavities suggest the use of indirect restoration techniques (10). Glass ionomer cements are referred to as C-GIC. They are defined as “chemically curing materials without a resin component” (8). Conventional glass ionomer cements can also be categorized as HVGIC and “low-viscous” C-GIC’s (8). Glass ionomer can also be modified using resins, resulting in RMGI. Surprisingly, amalgam is still a relevant repair material to this day, being used in several countries to repair crown margins (11), (12) due to its low cost and effectiveness (9). Since amalgam consists partly of mercury, there always have been concerns regarding not only the environmental impact, but also its use in the dental practice as a dangerous material for the patient and dentist (9). Lastly, SDF’s provide a less invasive approach in dealing with crown margins (5). The dental use of it is easy, in the view of applying it to the margins to protect them from decay. Additionally, it is cost efficient, eradicates pathogens and has a positive impact on the softened dentine by making it abrasion resistant (5). It is applied to minor marginal irritations and margins with caries development. For sufficient aesthetics, it is not useful (5).

Crown Margin Repair Techniques

Crown margin repair techniques are essential for addressing problems like fractured margins in dental crowns, recurring decay, and marginal discrepancies. These methods are crucial for keeping patients' oral health at its best while guaranteeing the durability and functionality of dental restorations. There are two main methods used: direct and indirect techniques. Each has its own benefits and key-points to consider. Using direct techniques, restorative materials are directly applied to the existing crown margin. This technique is usually used for small repairs because it is chairside convenient and can correct minor defects right away without requiring further laboratory work (13). On the other hand, the indirect technique involves creating a new crown margin or restoration outside of the mouth, usually in a laboratory. If the marginal defect is insufficient to restore the margin integrity by direct restoration, the indirect method is crucial for these repairs. The restoration is fabricated using the indirect technique, guaranteeing durability, fit, and aesthetics (13). To achieve the best results, both direct and indirect crown margin repair techniques need to carefully consider variables like material selection, margin preparation, bonding procedures, and occlusal adjustments. Furthermore, the effectiveness and durability of these repair techniques are being improved by technological and dental material advancements, giving clinicians more and more dependable answers to problems with the crown margin (13).

To briefly outline and categorize crucial criteria on which technique to use, there is the list of “FDI” for evaluating direct and indirect restorations. The "FDI" diagnostic system uses 16 distinct categories, each with five grades, to classify biological, functional, and aesthetic aspects and covers a range of failure types. Only a few of those categories will be emphasized more in this case, because of their relevance to crown margin repairs (3).

A portion of the restoration margin is clinically exposed due to defective interfaces between the dental hard tissue and the restoration material, known as marginal gaps. Both width and depth can vary greatly. The transition between the restorative material and the dental hard tissue should be seamless in ideal circumstances (3). CAR is a condition where there is no healthy

tooth structure between the restoration margin and the cavity. Large cavities can be reached by caries, even in non-cavitated carious lesions. At the restoration margin, it represents a carious process. Importantly to mention is that stained restoration margins with no demineralized hard tissue should not be considered as caries. As part of a minimally invasive intervention strategy, demineralisations can be left at the margins of the cavity during restoration placement (3). A minimally invasive, additive technique involves directly applying restorative material after a small cavity has been prepared, the remaining surfaces (artificial or biological surfaces) have been roughened or conditioned, and enough of the existing restoration has been preserved. Localized flaws, such as chipping, small bulk and cusp fractures, or caries at the restoration, can usually be fixed with direct clinical access (3). However, if the restoration defects are so severe that a repair is not practical, then replacement is necessary. The present material must be removed, the cavity and tooth must be prepared, and a new direct or indirect restoration must be applied (3).

Different interfaces exist in the marginal adaptation between the restorative material, adhesive and the dental hard tissue. Every interface has the potential to deteriorate and change marginal adaptation (3). Only marginal adaptation can be checked in a clinical setting by probing, while using a final radiograph for evaluation will bring clarity about the marginal gap (4). The properties of the adhesive, resin/cement, and restorative material, as well as the operator's skill and knowledge in creating a good restoration with proper cavity preparation, moisture control, and material application in accordance with usage instructions, all contribute to the quality of marginal adaptation (3). A smooth transition from the restoration material to the surrounding tooth structure characterizes ideal marginal adaptation, and a gentle probe should reveal no marginal irregularities. Small marginal deficiencies, such as discoloured ditches or margins, are considered "sufficient" (3). Broad marginal gaps with a gap depth of less than or equal to two millimetres signify a clinical insufficiency and most likely call for dental intervention, depending on the patient's caries risk in addition to the gap's location (3). Another factor is hard tissue defects in the teeth near the restoration margin. This measurement includes cusp fractures at the restoration margin, tooth cracks, and enamel chipping. Furthermore, taken into consideration is cracked tooth syndrome, which can also result in pain or hypersensitivity (3). Caries at the margin or lost restoration material need to be considered as well. The anatomical form, surface gloss, surface texture, marginal staining, and colour match all contribute to the aesthetic performance of dental restorations. Due to its subjective nature, the evaluation is more vulnerable to preference and variability. The degree to which a restoration blends in with the surrounding tooth structure determines how aesthetic it looks and is largely determined by the overall oral hygiene of the patient (3). The assessment of aesthetic qualities has clinical significance solely for visible, tooth-coloured restorations located within the smile line, typically involving canine to canine. The mesio-buccal aspect of upper premolars is crucial for aesthetic appearance because it is visible when patients smile in many cases. For most people, however, the assessment of posterior teeth aesthetics is not as significant (3). Dentists have the option to evaluate the aesthetic qualities from a speaking distance or from a standard examination distance under operating light. Choosing these two options could produce different results. Intraoral photos or scans, colour scales, colorimeters, spectrophotometers, and 3D imaging are further tools for measuring aesthetics (3).
For additional clarification, marginal staining is the discoloration of a gap between the restoration and the cavity wall that affects the restoration's margin. The effectiveness of the adhesive/cementation system to adhere the restoration to the dental hard tissue, as well as the specific patient characteristics, determine marginal staining. The list of patient characteristics includes smoking and dental hygiene practices in addition to dietary choices like drinking coffee, black tea, or red wine (3). The intraoral microbiome of the patient may be involved as

well. The chosen technique or the restorative material are less significant. However, some data indicates that the occurrence of marginal discoloration is associated with a compromised marginal seal, which is often linked to the composite's polymerization shrinkage (3). When there are very few, if any, visible differences between the dental hard tissues and the restorative material, the colour match is convenient. It is possible for the restorative material's shade, translucency, or opacity to differ from the surrounding dental hard tissues if the restorative material's colour is chosen differently. The natural teeth darken or become more yellow with the patients age, or if the restorative material itself has intrinsic colour instability (3). The preferred method for evaluating colour matching is visual examination. Furthermore, intraoral photos can be helpful, but they can also be challenging to standardize for follow-up examinations. On the other hand, commercially available colour measuring devices, such as colorimeters, have become more widely used because of their acceptable level of accuracy, dependability, and ease of use (3). In practice-based or health service research, patient satisfaction with a dental restoration is a subjective measure that is receiving more attention. It is typically measured using visual analogue scales. Asking the patient for their subjective impression may be sufficient as well. A thorough report regarding pain, hypersensitivity, chewing comfort, occlusion, proximal contacts, cleanability, contours, or aesthetics may be helpful in situations where there is dissatisfaction (3). The patient's opinion matters, particularly if the restorations' aesthetics seem off to them and a replacement needs to be discussed. The clinical judgment and dental assessment may be hindered by the patient's own perspective.

Direct repair technique

Techniques to use to repair crown margins are direct and indirect approaches. Making the decision to use an indirect technique or a direct technique is in restorative dentistry is harder to decide than in prosthetic dentistry, since most crown margin repairs require mostly an indirect approach (5). Direct posterior composite restorations for example, that require only one visit, allow for the preservation of tooth structure and crown function (13). This method builds up the composite restoration incrementally, curing each layer as it is added, enabling the practitioner to sculpt the restoration after etching and applying the bonding agent to the prepared cavity (13). Therefore, mesiodistal layers that are angled toward the facial and lingual, have a maximum thickness of 2 mm and are gradually inserted into cavities. As the bond strength grows, the layering technique effectively reduces polymerization stress (13). The potential for repair and the enhanced strength of the remaining tooth structure beneath the crown is one benefits of the direct technique but on the other hand, these restorations lack the mechanical strength of indirect restorations (13). Additional drawbacks include technique sensitivity, inferior bonding to dentin, proximal wear, surface roughness, marginal discoloration, loss of marginal integrity, postoperative sensitivity, secondary caries, and low fracture toughness (13). In the case of crown margin repairs, the direct technique is rarely used. Minor margins can be treated using silver diamine fluoride to seal them and prevent further caries decay (5).

Indirect repair technique

The term "indirect technique" describes the process of creating a restoration in a lab after the prepared tooth margin has been placed with resin cement, but before entering the oral cavity (13). There are differences in the fabrication process between direct and indirect cavity restorations. An impression must be created, or an intraoral scan conducted and taken in a laboratory for the indirect repair technique (13). In the case of using composite as the restoration material, more heat (140°C), advanced pressure (0.6 MPa for 10 min), and nitrogen atmosphere may be used in the laboratory processing of the composite to enhance its physical properties, wear resistance, and degree of polymerization (13). Since the prepared tooth does not experience polymerization shrinkage, induced stresses are lessened, lowering the possibility of leakage as well as a better occlusal contacts, enhanced wear resistance, decreased

polymerization shrinkage, enhanced fracture resistance, and improved proximal surface contouring are all provided by the composite used in the laboratory (13). It is also biocompatible and makes the final outcomes more precise in some points (13). The disadvantages of composites include higher time and cost requirements, the need for two appointments, the creation of a temporary restoration, and a low likelihood of future repairs (13). Because of this, choosing between particularly direct and indirect composite restorations can be difficult since the success or survival rate of individual direct and indirect composite restorations has been the subject of numerous clinical investigations (13). Additionally, the comparing of direct and indirect composite restorations has been the subject of very few articles (13). Therefore, also other materials are used in the indirect technique such as amalgam and glass ionomer (11).

Technique Conclusion

While the direct approach is a valuable option to a fast repair of a crown margin, the indirect technique provides more accuracy and stability. In a conducted review, including thirteen studies of comparing the two techniques using composite margin restorations in posterior teeth, the results concluded that there was no significant difference between direct and indirect technique (13). However, the available evidence revealed inconclusive results, which sums up into the relevance of further research (13). This research should focus on randomized controlled trials with long term follow-up to give concrete evidence on the clinical performance of direct and indirect composite restorations for margin repairs (13).

In a different study about the longevity of direct versus indirect resin composite restorations in permanent posterior teeth, the results were the same (14). Based on the systematic review and meta-analysis, there is evidence of no difference in terms of clinical longevity between direct and indirect resin composite restorations, even when the type of restored tooth is considered (14). The conclusion of the study suggest that direct restorations should be given preference to indirect restorations in many situations, since the former require less effort and cost (14).

Clinical outcomes

When it comes to prosthetic dentistry, the durability and long-term success of restorative treatments are directly impacted by the integrity of crown margins. Crown margin repairs are an essential part of dentistry that require to restore compromised or defective margins. The clinical results of crown margin repairs provide a foundation for assessing the viability and efficacy of different repair methods and materials that dentists use now a days. To know which repair material performs best over time and is also satisfactory for the patient is key, which makes the outcomes of the following studies even more important for the workflow as a dentist. Achieving optimal crown margin integrity is important because it has a direct impact on several clinical factors, such as patient satisfaction and restoration longevity. A compromised crown margin can lead to microbial infiltration and secondary caries formation, in addition to impairing the aesthetic and functional aspects of the dental restorations (3). Because of this, the search for reliable repair techniques that guarantee long-lasting and aesthetic results continues to be a priority in modern prosthetic dentistry. To be able to classify today's progress in crown margin repairs, statistics on longevity and survival analysis were considered and categorised. In addition, the various repair materials and repair techniques are evaluated and placed in context with other outcomes to be able to present a conclusive evaluation. Taken into consideration is also a survey, conducted in the United States of America, about the used materials for crown margin repairments.

The study from the year 2020 on the longevity of crown margin repairs included patients with glass ionomer and resin-modified glass ionomer cement restorations who were diagnosed with crown margin repairs on permanent teeth. The data set consisted of 2324 records with resin restorations. The patients were randomly selected from a list of "trigger words" and then assessed manually. After the final assessment, 115 individual patients and 214 treated teeth, which were divided into anterior and posterior, build the base for this review (15). The "Kaplan-Meier" survival diagram was used to calculate the survival time of the crown margin repairs. In addition, a Cox proportional hazard model was used to evaluate factors which affect crown margin repair survival times. Correlation between multiple teeth within a patient were also set. The average age of the patients treated was 69.4 years, while 48.7 per cent were male and 51.3 per cent female. The treated teeth were divided into anterior and posterior, as lower anterior teeth showed a significantly lower percentage than all others, they were combined with the upper anterior teeth and together form 21.5 per cent of the treated crown margin repairs (15). The posterior teeth were divided into maxilla and mandible. In the maxilla, 40.65 per cent posterior teeth were treated, while in the mandible 37.85 per cent posterior teeth were processed. Of all crown margin repairs with glass ionomer or resin from this study, 62.9 per cent had a five-year survival rate with an accuracy of 95 per cent. The annual failure rate evaluated during this study was 8.86 per cent of all restoration repairs carried out. 29.4 per cent of all repairs failed due to a series of complications, with the average time until a fault was detected being 2.7 years (15). Failed or new crown margin repairs were censored in the following follow-up appointments and were not included in the study, whereby an average of 3.06 years passed before censorship occurred at a follow-up appointment (15). In the final evaluation, lower posterior teeth had the greatest time of failure with a follow-up time of 3.44 years and a censoring time of 3.34 years. Censored anterior teeth had a follow-up time of 3.01 years, while anterior teeth assessed as failure had a follow-up time of 2.48 years (15). The Cox hazard model was used to determine whether age, gender or tooth type influenced the time to crown margin repair failure. In addition, the model evaluates the interaction of several teeth to be treated in a single patient. The result shows that neither age, gender, tooth type or multiple teeth in a single patient influence the time to a failed crown margin repair. Crown margin repairs using glass ionomer and resin had a five-year survival rate of 62.9 per-cent with 95 per-cent accuracy and an annual failure rate of 8.86 per-cent. Remarkably, a failure rate of 29.4 per-cent was recorded for restorations, with an average failure time of 2.7 years (15).

Fig. 1: Isolated defective carious PFM margin (15)

The remaining crown margin repairs were censored during follow-up appointments. The Cox hazard methodology analysis showed that there was no significant effect of age, gender, tooth

type, or correlation between multiple teeth on the failure time. This suggests that the results are vigorous across a range of clinical and demographic variables (15).

Taken the results of the longevity of crown margin repairs with glass ionomer and resin-modified glass ionomer cement restorations in consideration, a different study from 2021 looked at the crown margin repairs' survival trajectory over an 11-year period and identified the factors that contributed to the survival (11). Among them were repair materials like amalgam, GI, RBC, and RMGI. Resin and flowable sealants were also considered (11) The main goal of this study is to state that restoration repairs are primarily minimally invasive, save money, lengthens the life of the original tooth structures, and conserves time. Most dental schools worldwide accept restoration repair as a treatment option instead of complete replacement. In light of this, data from 2018 indicate that 33% of crowns and 59% of direct restorations were replacements as opposed to repairs (11). These restorations were most frequently replaced due to secondary caries, and the likelihood increased when patients changed dental departments more frequently. This points to a possible lack of technical knowledge or expertise in the clinician's field, as well as some inconsistency in secondary Carie’s diagnostic and treatment planning when deciding whether to replace or repair the restoration. Additionally, it is mentioned that there is insufficient scientific data, based on randomized clinical trials, to carry out a sufficient repair. Finally, the patient has the option to refuse restoration repair if they do not want a flawed restoration to be monitored (11). Since a gap on a restoration margin does not increase the risk of bacterial impact or the development of caries, when the defect will not exceed 400um, the practice of replacing restorations because of secondary caries is most often based on weak evidence (11). Since secondary Carie's is thought to form alongside the restoration interface, it should be treated with minimal invasiveness. Most minor flaws and stains can be controlled with polishing or observation. Over a period of five to ten years, monitoring these marginal defects and discolorations is just as effective as resealing them. Additionally, the survival rate of the restoration will rise with each additional repair made to it (11). In this survival analysis study, the comprehensive data set includes several variables relating to dental procedures and patient attributes. It contains details about the patient's age, gender, Carie's risk level, and kind of provider (student, faculty, or resident). The tooth's arch, type, surface repairs, prior root canal treatment, and crown type are also included in the details. Documentation is also provided for the repair material used, which includes amalgam, glass ionomer, resin-based composite, and glass ionomer modified by resin (11). Every crown margin repair, associated with a specific patient, is tracked from the start date until a so called “Event” happens. Any restoration of the tooth surface that underwent the initial crown margin repair, as well as any endodontic treatment, crown replacement, or tooth extraction associated with the initial repair, are all considered “Events” (11). The first repair acts as the starting point, and the event's occurrence indicates the end date, which corresponds to the reintervention date. The patient's final recorded visit is the endpoint for repairs made without experiencing an event. Patients are considered “baseline cases” if there are no follow-up records (11). The differences between the repair materials are summarized using Kaplan-Meier survival analysis. Furthermore, a Cox-proportional hazards model is used to investigate the relationship between the time until an event and different covariates. The covariates undergo significance testing, and the final model is refined by backwards elimination to make sure all relevant factors pertaining to crown margin repairs are included. 1009 patient records in all were reviewed. Patients ranged in age from 32 to 104 years old, with a mean age of 74.5 years. Most of the patients were female and showed little chance of getting Carie's lesions. Remarkably, students

completed 64 per-cent of the repairs, with most of them focusing on a single posterior tooth surface (72 per-cent) out of 81 per-cent (11). Clinical intervention was required when patients at the crown margin repair site presented with defects, gaps, or secondary Carie's lesions. GI and RBC were used less frequently than RMGI and Amalgam, which were the two most often used repair materials (1). “Baseline cases” were those 109 patients who were not scheduled for follow-up visits. Five years was determined to be the median survival time for a crown margin repair (11). For Carie's risk assessment, sex and age were not included in the final model processing due to missing data. 990 patients with complete data were subjected to the backwards elimination methodology. Repair material was the only statistically significant covariate or “P value” in the final model (11). Exactly 32.8 per-cent of patients had an “Event” over the course of an 11-year follow-up period while 141 needed further repairs, 4 had endodontic treatment, 44 had crown replacements, and 138 had extractions (11). Repair material was found to be the only significant covariate, with reintervention being necessary in about 32 per-cent of repairs. Remarkably, there was no substantial distinction found between the materials amalgam and glass ionomer modified with resin (11). In contrast to amalgam, resin-based composites and traditional glass ionomers were found to have higher reintervention rates, with hazard ratios ranging from 1.02 to 2.10 times and 1.40 to 2.73 times, respectively (11). Overall, it was found that crown margin repairs had a median survival time of 5.1 years. In terms of repair materials, the median survival times were 3.0 years for glass ionomer, 3.2 years for resin-based composite, 5.3 years for resin-modified glass ionomer, and 5.7 years for amalgam (11).

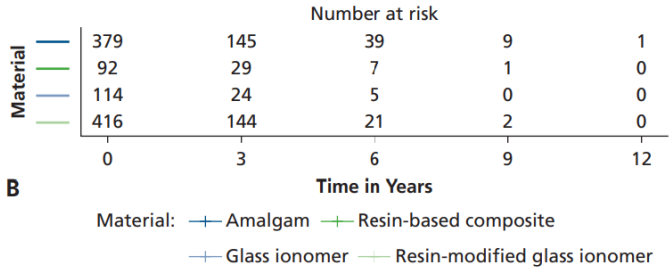

Fig. 2: Risk assessment for the repair materials over the time in years. (11)

The Result of the study supports the practice of crown margin repairs while amalgam and resin-modified glass ionomer are more considerable for crown margin repairs than glass ionomer or resin-based composites (11).

Additionally, to the already described outcomes, in 2021 a survey by the “American Dental Association” in the United States of America among dental participants was conducted (12). The “American Dental Association” performed a clinical evaluators panel survey with responses of four hundred panel member dentists from the United States (12). The purpose of the panel is to gather clinical insights as well as experiences and share them with the dental community to focus more on dental materials and clinical-based research. The goal of the survey was to determine, how many dentists perform either a repair or a replacement of defective restorations (12). The overall result shows that 83 per-cent of the respondents stated they repair defective restorations. In more detail, 87 per-cent repair non-carious marginal defects, 79 per-cent repair partial loss or fractures of restorations and 73 per-cent perform crown margin repairs due to carious lesions (12). While 98 per-cent of the respondents vote to repair direct resin composite restorations, one third of them do not repair amalgam, glass ionomer or fractured indirect all-ceramic crown restorations (12). While resin composite is used to repair

direct resin composite restorations, glass ionomer is most often used to repair glass ionomer restorations, respectively. Out of the 400 participants, 54 per-cent state to use amalgam to repair amalgam restorations, while 31 per-cent of them do not use surface treatment when repairing amalgam restorations (12).

Also crucial for determine the success rate of the conducted repair and the used materials, the following study reviewed the microleakage between CGI, RMGI and CR, in restored marginal gaps of crown margin repairs (16). The study was conducted for better understanding of the prevention of secondary caries around indirect restoration margins to prevent failed repair approaches in the future (16). Extracted molars of ninety patients were used by splitting the teeth into three groups, each group was prepared with margins (16). While group one margins were prepared in the cervical area of the crown, with a depth of 1.5mm in the margin and a width and length of 1 to 2mm, group 2 margins were prepared onto the cervical area and extending subgingival to the roots of the teeth with margin depth between 2 to 5mm (16). Lastly, group 3 was prepared to have a depth of 2mm, and greater width and length compared to the other two groups in 3mm (16). All the prepared margins were then restored using CGI, CR and RMGI and a demineralizing solution was added at the cervical finishing lines to simulate a formation of caries (16).

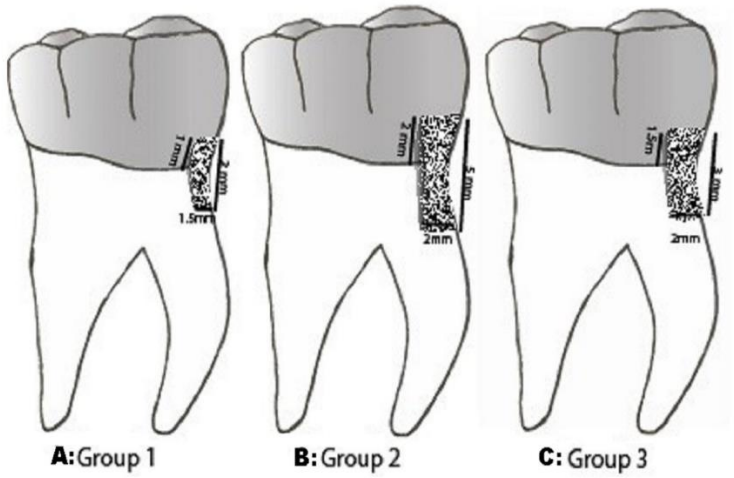

Fig. 3: Comparison of microleakage between different restorative materials to restore marginal gap at crown margin; Group of secondary caries. (16)

Evaluation was conducted by thermocycling the teeth samples to simulate aging while being isolated with nail varnish and then submerged into a methylene blue solution to access the rate of microleakage. After 24 hours the teeth were washed with water and the process of analysis was performed (16). A stereomicroscope is used to measure the dye penetration in depth and categorize the results into “no penetration of dye” as 0, “penetration of dye along the gingival wall” as 1 and “penetration including gingival margin and an axial wall” as 2 (16).
The material with the highest mean microleakage in the margin repairs is conventional glass ionomer with a score of 1.450, while nano-hybrid composite material has the least microleakage with a score of 0.350 (16). In view on the cementum restoration interface has nano-hybrid composite again the lowest rate of microleakage with a score of 0.850, while resin modified glass ionomer has the greatest value with a score of 1.700 (16).
In understanding of the possibility of microleakage in crown margin repairs, this study suggests using nano-hybrid composites to effectively restore marginal gaps at crown margins.

To also summarize the survival rates of the crown production materials by themself, before a crown margin repair occurs, a systemic review of the survival time and complication rates in single crowns is mentioned as well, starting with common complications.

The most frequently mentioned biological issues for single crowns were secondary caries, abutment tooth fracture, and loss of abutment tooth vitality (6). Technical issues with single crowns included framework fracture, ceramic chipping, fractured ceramic, marginal discoloration, loss of retention, and poor aesthetics (6). Ceramic chipping was a prevalent issue that generally happened at all-ceramic crowns and with metal-ceramics as well (6).

Metal ceramics have long been regarded as the golden standard for the repair of damaged restorations (6). With a five-year complication rate of 1.8 per-cent, loss of abutment tooth vitality was the most common biologic complication for metal-ceramic crowns while for lithium-disilicate reinforced glass ceramic and glass-infiltrated alumina crowns, this issue happened less frequently (6). Furthermore, abutment tooth fracture was primarily observed in patients with metal-ceramic crowns, with a 1.2 per-cent five-year complication rate (6). This problem happened much less frequently with zirconia-ceramics, glass infiltrated alumina, and all-ceramics, while after five years of use, 1 per-cent of metal-ceramic crowns were found to have secondary caries (6). Most of the time, the five-year caries rates for metal-ceramic crowns and all-ceramic crowns were comparable. On the other hand, ceramic crowns with glass infiltration had higher caries rates, whereas zirconia-based crowns had much lower secondary caries rates (6).

With a cumulative five-year event rate of 2.6 per-cent, ceramic chipping was the most common technical complication for metal-ceramic crowns and a tendency to greater veneering ceramic chipping was noted for crowns based on zirconia and alumina than for all other ceramic crowns (6). Metal-ceramic crowns had a cumulative rate of 0.03 per-cent for framework fractures, which happened infrequently over a five-year period (6). Regardless of the kind of ceramic used, this issue was much more common in ceramic crowns, here the mechanical stability of the ceramic material was linked to the incidence of framework fracture (6). Weaker ceramics, such as early ceramics based on feldspathic or silica, have a high framework fracture rate of 6.7 per-cent after five years. Fractures in the framework occurred in 2.3 per-cent of crowns made of lithium-disilicate reinforced glass ceramics, but only in 0.4 per-cent of single crowns made of zirconia (6). Except for crowns made of zirconia, loss of retention was not a common technical issue and with a five-year estimated complication rate of 4.7 per-cent, zirconia-based crowns showed significantly more loss of retention than metal-ceramic crowns (6). All-ceramic crowns had an annual failure rate ranging between 0.69 and 1.96 per-cent translating into an overall estimated five-year survival rate percentage of 90.7 to 96.6. The survival rates of all ceramic crowns differ due to the various types of ceramics (6). The overall survival times estimated in this study reveal for metal ceramic crowns a mean follow up of 7.3 years with an estimated annual failure of 0.88 per-cent, while a five-year survival rate is estimated to be at 95.7 per-cent (6). On the other hand, zirconia has a significantly lower estimated five-year survival rate compared to metal-ceramic crowns with 91.2 per-cent (6). Glass ceramics have an estimated survival rate over the 5 years of 96.6 per-cent, which is a similar survival rate compared to metal-ceramic crowns (6). Crowns made of glass-infiltrated alumina have a five-year survival rate of 94.6 per-cent while densely sintered alumina crowns have a five-year survival rate of 96.0 per-cent (6). Lastly, all-ceramic crowns had an annual failure rate ranging between 0.69 and 1.96 per-cent translating into an overall estimated five-year survival rate percentage of 90.7 to 96.6 while, feldspathic and silica-based ceramic have an estimated five-year survival rate of 90.7 per-cent, significantly lower than the rate for metal ceramic crowns (6). The survival rates of all ceramic crowns differ due to the various types of ceramics in this study (6). Linking the anterior to posterior regions of metal-ceramic crowns, lithium-disilicate reinforced glass ceramic crowns, and zirconia- and alumina-based crowns did not yield any statistically significant results (6). However, the posterior region's survival rates were

significantly lower than the anterior region's for crowns made of feldspathic or silica-based ceramic (6).

Finally, for the outcomes mentionable, are porcelain-fused-to-metal crowns, which are compared in a review with all-ceramic crowns in a long-term survival analysis. PFM crowns have the acceptable biological quality required for periodontal health, good mechanical qualities, and satisfactory aesthetic results (17). PFM crowns, however, have certain drawbacks that might restrict their application. For instance, the metal framework and opaque porcelain layer required to cover the underlying metal greyish shade which limits the aesthetic appeal of PFM crowns (17). Over the past forty years, all-ceramic crowns have been used to overcome the aesthetic limitations of PFM crowns while different types of ceramic can be used to create all-ceramic crowns, and not all ceramic types have the same physical and aesthetic qualities (17). The first metal-free crowns to be used historically were resin-based crowns, but due to their poor fracture resistance, they were abandoned (17). There were twenty-nine studies and systematic reviews in all in the text, most of which were predicated on observational, uncontrolled studies (17). The long-term survival of approximately 8 years of porcelain-fused-to-metal crowns ranged from 92 to 96 per-cent and that of all-ceramic crowns ranged from 84 to 100 per-cent (17). Studies that compared all-ceramic crowns to porcelain fused to metal crowns in a controlled context revealed a lower survival rate of 48 per-cent for PFM's and 62 per-cent for all-ceramic crowns (17). After ten years of use, porcelain-fused-to-metal crowns prove to be more cost-effective than all-ceramic crowns, according to the cost-effectiveness analysis, which was conducted too (17). The contextual factors that could affect clinical and cost-effectiveness were not adequately supported by any of the identified literature. One non-randomized study, authors examined variables that affected crown longevity, but they did not provide distinct analyses for various crown materials.

Outcomes conclusion

In aspect of the five mentioned studies and the survey included in the clinical outcomes, it is firstly quite surprising that amalgam is still a valid material for crown margin repairs. Since the median survival time for all crown margin repairs is 5.1 years, amalgam has compared to the other materials like glass ionomer, resin-based composites and resin-modified glass ionomers with 5.7 years the best result (11). It is also stated that glass ionomer and resin-based composites are less frequently used than resin-modified glass ionomers and amalgam, while in this study no significant differences between amalgam and resin-modified glass ionomer, which has the second-best survival time with 5.3 years, was found (11). Additionally, the survey from the American Dental Association also states, that 54 per-cent of the 400 participating dentists still use amalgam as a repair material today, while one third of the participants say to not repair both amalgam and glass ionomer (12). Also do 31 per-cent of them not use surface treatment when repairing amalgam restorations (12). In view of resin-modified glass ionomer with second best survival rate in the study from 2022, the collected data about microleakage in marginal gaps in crown margin repairs suggests the use of nano-hybrid composite materials, since resin-modified glass ionomer has the greatest microleakage in cementum restoration interfaces with a score of 1.700 (16). While conventional glass ionomer has the mean highest microleakage with a score of 1.450, nano-hybrid composite material has the least mean microleakage with a score of 0.350 and in the interface of cementum restorations a microleakage score of 0.850 (16). The microleakage scores are valuable for assessing the risk of secondary caries lesions at the crown margin gap, while resin-modified glass ionomer repairs have a good longevity rate but lack in the field of microleakage, the study suggests the prone use of nano-hybrid composite materials

(11,16). For nano-hybrid composite materials were no longevity rates found, but in a different study, the score of microleakage for amalgam was compared with composites and nano-hybrid composite materials (18). Here, both amalgam and nano-hybrid composite had less microleakage than conventional composites (18). Based on the studies also mentionable are the prevalent areas where crown margin repairs are needed. The most repairs were completed in posterior teeth with 40.65 per-cent in the maxilla and 37.85 per-cent in the mandible (15). The conducted repairs in the anterior regions were so small that the mandible and maxilla were added together with 21.5 per-cent of all crown margins (15). Failure rates are also listed, with 3.44 years have lower posterior repairs the greatest time of failure, while in anterior teeth the rate is at only 2.84 years (15). For glass ionomer and resin-modified glass ionomer the survival time is 62.9 per-cent with an accuracy of 95 per-cent and an annual failure rate of 8.86 per-cent (15). In the study about longevity, it is also stated that glass ionomers and resin-based composites have higher reintervention rates compared to amalgam (11). In comparison to the survival times of the crown margin repairs, there are also the overall survival times and complication rates of single crowns listed. These crowns are produced out of metal ceramic, lithium-disilicate glass ceramic, glass-infiltrated alumina, and all ceramic (6). The greatest five-year survival rate is achieved with glass ceramic crowns (96.6 per-cent) and densely sintered alumina crowns, which have a survival rate 96 per-cent (6). Due to the various types of ceramics, the percentages for all ceramic crowns are in this range of 90.7 to 96.6 per-cent, metal ceramic crowns reach 95.7 per-cent, glass infiltrated alumina crowns reach 94.6 per-cent, zirconia crowns reach 91.2 per-cent, and silica-based crowns reach only 90.7 per cent (6). In the category of complication rates, metal ceramic crowns have abutment loss of tooth vitality as the most common biological complication with 1.8 per-cent in five years, as well as abutment tooth fractures of 1.2 per-cent in five years and secondary caries of 1 per-cent in five years (6). Additionally, are the five-year caries risk rates in the phase of the five-year survival time equal in metal ceramic and all ceramic crowns (6). At the highest risk of caries lesions are ceramic crowns with glass infiltration, while zirconia-based crowns are at lowest risk compared to all other crown materials (6). Lastly, there are no statistically significant results found in the anterior and posterior regions for metal ceramic, lithium-disilicate reinforced glass ceramic and zirconia- and alumina-based crowns (6). However, the survival rates for silica-based ceramic crowns are in the posterior region lower compared to the anterior region (6). Finally, the long-term survival rates for porcelain-fused-to-metal crowns are compared to all ceramic crowns in the final study (17). Here all ceramic crowns have an eight-year survival rate of 62 per-cent and PFM crowns have a rate of 48 per-cent in the controlled study (17). In the uncontrolled eight-year survival study, the rates for all ceramics are up to 100 per-cent, while PFM crowns reach up to 96 per-cent (17). Since these numbers are from uncontrolled studies, they will not be in consideration from further on. The controlled long-term survival of all ceramic crowns seem fitting to the five-year survival rates from the other study.

Advancements

Progress in crown margin repairs includes a range of new materials, methods, and tools, all adapted to clinical situations and patient requirements. Modern methods place a strong importance on achieving the best marginal fit, biomechanical integrity, and aesthetic integration. Examples of these methods include the use of advanced resins and metal-free crown systems. Moreover, digital dentistry has transformed the workflow by helping an accurate restoration design and fabrication with low margin discrepancies. Clinical challenges persist due to difficulties like attaining smooth marginal adaptation, controlling subgingival margins, and guaranteeing long-term stability. An individual strategy for every case is crucial, as evidenced by the need to consider variables like microleakage, extended damages, material

compatibility, achievable aesthetics, patient's oral hygiene and the clinician's skill level when choosing the right materials and methods. The major advancement in crown margin repairs is the" CAD/CAM" technology, or "computer-aided design/computer-aided manufacturing, which was invented and first used in the year 1985 (19). The main components for this technology to work is a digital scanner which is used in the dental office to scan full arches of the patients maxilla and mandible, or partial segments, then a computer with the fitting software is needed to store and manage the scanned data, finally the dental laboratory needs either a milling- or 3D printing device to produce the final restoration (19). There are also companies specialised in having milling machines to produce in large quantities. CAD/CAM can be used to also produce crown margins, by scanning the marginal gap and sending the details to a dental laboratory. In a study from 2021, the CAD/CAM system was tested on the marginal integrity of crowns with two different finishing lines, shoulder finishing line and chamfer finishing line (19). The marginal crown repairs were produced using the "CEREC" system, which is a chairside economical restoration of esthetic ceramic system (19). Out of 180 tested teeth, two crowns were clinically not acceptable, while the system overall produced clinically acceptable crowns with no significant differences in the choice of finishing lines (19). Furthermore, the impact of different CAD software systems was tested in a different in vitro study, to analyse the marginal and internal fit of provisional crowns (20). Software programs used included "Dentbird", "Exocad" and "Inlab 20" (20). Temporary single crowns were prepared with the same cement gaps and later analysed by a software, which concluded that Dentbird provides the most accurate internal fit in buccal surfaces and the best marginal fit in buccal and mesial areas, Exocad has the best solution for distal surfaces in marginal fit as well as in internal fit (20). Lastly, the most advanced fit for mesial internal fit surfaces and palatal marginal fit surfaces, is provided by Inlab (20). These results show that the software to choose from the dentist will also have an impact on the final restoration, which makes an easy solution harder again. An addition to milling machines is 3D printing, which is now-a-days used to produce also crowns and bridges (21). 3D laser-sintered crowns already provide clinically acceptable crown margins (21). All this a side, the process of taking the digital impression can be challenging. While the taking of digital impressions reduces the discomfort of conventional impression taking for the patient and a lesser risk of cross infections, the learning process for the dentist to use a scanner properly takes some time (22). Taking impressions the conventional way is a well-known technique which is practiced in most dental universities, due to the simple equipment, which is needed, the low cost for the dental practice and the known accuracy (22). For digital impressions is complex equipment needed which also comes with a high cost to purchase and it is prone to being damaged when not used and stored properly (22).

Discussion

Crown margin repairs are used in several altercations to prolong the functionality and aesthetic of the initial crown for the patients' needs and, in a cost-effective way. To understand the best solution to treat these marginal defects, which repair material is the most reliable to use and which technique promises the greatest marginal fit is the main question this literature review will answer. While porcelain-fused-to-metal crowns are most used crowns for posterior teeth in prosthetic dentistry due to their robustness and good aesthetic qualities, they also provide the patient with a satisfactory survival time for the next years of wear. For these crowns a proper preparation is in need to not reveal their metal properties underneath the porcelain. The knife

edge finishing lines can be used to prevent chipping in PFM crowns as well. In the anterior region, most provided by the dentists are all-ceramic restorations. These restorations are not based on zirconium and provide in the more visible smile-line of the patient even better aesthetic results. This is because their more translucent properties compared to PFM crowns. They are usually prepared with a deep chamfer margin for a perfect fit. Additionally do all-ceramic crowns also prove to have a long survival rate but are at higher risk of secondary caries in the future when modified with glass infiltration or zirconia. The bevelled shoulder is prepared for zirconium-based crowns, which have a slightly less induced survival rate but are easier to conceal due to their opaque substructure and a lighter main colour. The bevelled shoulder presents in this case an advanced marginal seal, an optimal level of rigidity and balances the periodontal health. While most of the finishing lines are at the same level as the crown margin, the care considered to prepare these finishing lines with great caution, will prolong the survival success of the initial crown and prevents the event of a crown margin repair. The margins with the greatest success rates are therefore supragingival and equi-gingival margins, because of their better gingival health properties than subgingival margins. Also to be deemed is the proper checking of the final fit by using a radiograph to eliminate discrepancies, while the patient is still in the dental care. Now the patient has his new crown in place, and it might occur while the estimated survival time of his crown, or after the survival time is expired, that the gingival margin withdraws. This either happens because the dentist and patient agreed on prioritising aesthetics over functionality and longevity, bad oral hygiene or just the ravage of time. Now there is a marginal gap which makes room for plaque to penetrate the marginal gap. Also, microleakage can appear, the need for a crown margin repair is inevitable. While minor marginal caps can be sealed using silver diamine fluoride to prevent further microleakage and secondary caries, major cavities must be repaired using one of the many repair materials on the dental market. These materials are either used with a direct or indirect approach. Composite resins are used in the posterior regions, in small and medium cavities the direct technique is used, for larger cavities the indirect technique is appropriate. The resins provide suitable aesthetics compared to the other repair materials like amalgam, but lack in their survival time to that of amalgam. In the face of reintervention time, both materials are equal. While the aesthetic properties of amalgam are not as satisfying as resin composites, glass ionomers or resin-modified glass ionomer, it still has the greatest survival potential of them and is still used in several countries to repair crown margins due to its relatively low costs and effectiveness. Besides that, amalgam is still produced partly out of mercury which proves to have an environmental impact and can be a dangerous working substance for the dentist and patient. On the other hand, do composite resin materials also have a toxic trait to the patient's health and the environment, but there were no controlled studies that could clearly prove this and compare it with the toxicity of amalgam. Another suitable material for crown margin repairs is chemically curing materials without a resin component, such as glass ionomers and nano-hybrid composites. While glass ionomers have compared to amalgam a less successful survival time and prove to have bad microleakage capabilities, they don't face a particular danger to the patient and dentist in terms of toxicity. Nano-hybrids on the other hand have the best prevention of microleakage compared to conventional glass ionomers and resin-modified glass ionomers. The material resin-modified glass ionomer lacks in terms of microleakage but has with amalgam together the greatest survival time in crown margin repairs so far. The crown margin repair material of choice is now resin-modified glass ionomer and amalgam due to their survival rate and microleakage compatibility. Also, when nano-hybrid composites have the best results

in term of microleakage, there are no longevity and survival rates mentioned. Now, that the dentist has chosen his repair material, he must determine the appropriate repair technique, considering the size of the marginal defect and factors like secondary caries and the oral health status of his patient. Therefore, the diagnostic system of the FDI criteria can help to determine the suitable repair technique. In this diagnostic system crucial criteria are categorized to classify functional, biological, and aesthetic attributes. It also covers a range of possible failure types which could stand against the preferred repair technique. Assessment will be supported for caries at the margin, marginal adaptation and aesthetic performance like anatomical form, surface texture, marginal staining and colour matching as well as characteristics of the patient like oral hygiene or smoking and nutrition habits. While the direct repair technique is suitable for minor crown margin repairs and the application of SDF for sealing and further decay prevention, the indirect repair technique suggests better clinically outcomes in the view of marginal integrity and fit, aesthetic properties and microleakage. The direct repair is less invasive and safes the patient time and money by having only one appointment to attend, but the survival time of the repaired crown margin is uncertain and might result in even greater costs soon for a possible compromised crown or a destructed tooth structure beneath. While the advancements in the face of digitalization in the dental practice progress in great speeds, with the use of CAD/CAM systems, the indirect technique will also gain in rapidity of completing a crown margin repair. Based on the studies in this review, there were no significant differences between the direct and indirect repair technique found due to the lack of randomized controlled studies in this field. Same results for the comparison of longevity for both techniques. Even when given credit to the points of lesser effort and costs, using the indirect technique in greater crown margin repairs with the new possibilities of intraoral scanning and manufacturing a repair solution in more than one steps, seems the safer way to guarantee the survival time of the existing crown and the marginal repair. The digitalisation makes it also easier for the dentist to store the scanned data for the patients, than having physical impression trays stored in great bulks in his office. But digitalisation also comes with a price, the investments for a working scanner system and the costs of producing the marginal repair can be hefty. The purchase of such a system must be carefully considered and calculated. The patient base and the dentist’s specialisation also play a role in this. While the digital impression taking provides a faster workflow and good accuracy, the conventional impression taking is a well-known technique and is being practiced in most dental offices and in the university environment. This is because only simple equipment is needed, and the impression material is at a relatively low cost. The accuracy of these impressions is also known and predictable. Therefore, the purchase of a scanner only makes sense if impressions are taken daily, and the scanner would pay for itself over a predetermined period.

Conclusion

To be able to classify today's progress in crown margin repairs, statistics on longevity and survival analysis were considered in this literature review. In addition, the various repair materials and repair techniques are evaluated and placed in context with the other statistics to be able to present a conclusive evaluation. The use of crown margin repairs results as a valid solution over the practice of removing and re-manufacturing the existing crown. The repair

provides new stability and a satisfactory aesthetic for the existing crown, while showing promising results in longevity and survival times in these repairs. The best materials to use for these repairs are resin-modified glass ionomer, nano-hybrid composite, and amalgam. While amalgam will not provide the most aesthetic solution in the most cases, it has together with resin-modified glass ionomer the best median survival time and longevity in crown margin repairs. Amalgam is also quite cost efficient, beside its toxicity factor. Resin-modified glass ionomer also has good properties against microleakage, nano-hybrid composite has the least microleakage out of these three but lacks in results about longevity. Materials like glass ionomer and resin-based composites need higher reintervention and have generally lower survival rates in posterior and anterior teeth. The proper use of either a direct or indirect repair approach is measured by the marginal crown defect and is at the preference of the practicing dentist. The indirect technique promises more accuracy and an overall better fit, while the direct technique is less invasive and spares the patient and dentist time in several appointments. It is recommended to always perform a radiograph after crown margin repairs, to analyse the integrity and marginal fit with no overhangs of the result. The recent advancements in prosthetic dentistry by the digitalisation process of intraoral scanning, 3D printing and milling crowns and margin repairs also supports the practice of crown margin repairs. Also important to mention is the material of the initial crown, which may have an impact in preventing the event of a crown margin repair. Metal ceramic crowns have good survival times and are cost efficient but are prone to several complications such as abutment loss of tooth vitality, abutment tooth fracture, ceramic chipping, and secondary caries. Glass ceramic and all-ceramic crowns are less affected by these complications and have high survival times compared to other crown materials on the dental market.

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