RESTORATIVE DENTISTRY

Direct composite resin onlays: rationale and clinical application

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Ceramic full crowns can restore lost tooth structure, strength, and esthetics but remove about twice as much tooth as an onlay design.[1] Onlay restorations can maintain facial enamel for long-term esthetics, preserve the dentogingival junction for optimum periodontal health, and use supragingival margins for predictable adhesive dentistry. Metallic onlays can create fracture strength 3 times that of a natural tooth and can be designed to be nonvisible, but this solution may not be esthetically acceptable to all patients.[2,3] Porcelain and composite resin onlays are a solution for these patients.

Porcelain onlays are fabricated indirectly at a dental laboratory or milled in the office, whereas composite resin onlays can be fabricated with either of the aforementioned techniques, created in-office on flexible polyvinyl siloxane models, or placed directly.[4] Porcelain is a brittle material with a high modulus of elasticity, similar to that of enamel, and composite resin has a low modulus of elasticity, similar to that of dentin.[5] Composite resin deforms more during function and transfers more compressive stress to dentin than does ceramic, which absorbs more of the masticatory stress. Magne & Knezevic found that indirect composite resin onlays—whether fabricated conventionally or via computer-aided design and computer-aided manufacturing (CAD/CAM)—had higher resistance to loading than CAD/CAM porcelain onlays, despite a lower elastic modulus.[6,7] They concluded that the choice of composite resin versus porcelain may not be critical for average bite forces, as both materials withstood those, but may be relevant in the event of high forces from food trauma.

Composite resin is more easily repaired if a fracture does occur and is less abrasive to the opposing tooth; porcelain retains its gloss better, accumulates less plaque, and is more wear resistant.[8] Bottacchiari et al found that composite resin onlays were a durable restoration over 10 years.[9] Direct composite resin onlays have been recommended in preference to crowns for posterior teeth undergoing comprehensive restoration.[10,11]

Indirect composite resins are composed of materials with the same chemistry as direct composite resin but are processed extraorally with light, heat, and pressure to improve their polymerization and wear resistance.[12,13] It was anticipated that these indirect restorations would exhibit better marginal seal and less polymerization stress, since only the small cement volume is polymerized intraorally. However, multiple authors have found similar clinical results for wear resistance and marginal integrity with direct and indirect composite resins of inlay and onlay designs.[14-19] Manhart

Fig 1. Direct bonded microhybrid composite resin onlays placed on the maxillary right and left canines to treat an anterior open occlusal relationship after porcelain veneer placement. The uninterrupted lines indicate smooth canine guidance.
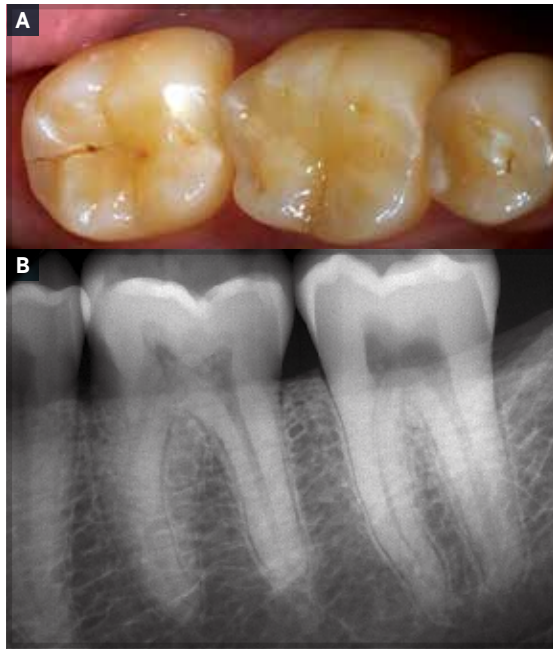
Fig 2. Case 1. A. The mandibular left second molar (tooth 18) has significant wear facets and a stained crack on the distal part of the central groove. B. A periapical radiograph of tooth 18 reveals no evidence of apical pathosis.

Fig 3. Case 1. A. Intraenamel preparation of tooth 18. The occlusal inclines have been reduced 1 mm and the crack has been cleaned and shaped for increased bonding area. B. Direct microhybrid composite resin onlay. The occlusion has been adjusted to allow normal cusp form without any excursive contact.

et al noted that the type of composite resin influences performance and that microfilled resin exhibited greater fracture rates than hybrid resin.[20] Although the indirect technique may enable better restoration of occlusal and proximal morphology, especially for patients with poorly aligned or spaced teeth, it incurs laboratory expense, additional chair time, and potential bacterial challenge from leakage of interim restorations.[21] This column will discuss the clinical application of direct microhybrid composite resin onlays for anterior guidance, incomplete fractures, endodontically treated teeth, and debilitated teeth.

Restoration to provide anterior guidance

Open contact between the maxillary and mandibular anterior teeth may occur in the natural dentition or after restoration, orthodontics, or orthognathic surgery. This can result in difficulty with sibilant sounds during speech as well as deleterious occlusal forces on posterior teeth during mandibular excursions. Closure of this space with bonded maxillary palatal metal or gold onlays is a conservative alternative

to porcelain crowns.[22,23] Direct composite onlays avoid the laboratory expense, second appointment, and esthetic limitations of metal onlays.[24,25] They remain smoother than porcelain veneers, which develop roughness after loss of the glaze layer. The microhybrid composite resin is under compressive stress during function and well supported by the enamel. Only when the cusp length is extended is the composite resin challenged by tensile stress.

Space closure with direct composite resin restorations can avoid invasive full-crown preparation, create occlusal contact to minimize occlusal adjustment on posterior teeth, and provide an optimal occlusion when porcelain veneers are placed (Fig 1).[26,27] This is a reversible procedure, since enamel is only roughened prior to etching, and is less costly than indirect techniques. If the cause of the interocclusal space is not known, little time or cost is risked. For example, if a tongue thrust is the problem and the space recurs, the time and cost associated with indirect restoration placement have not been lost.

In my experience, it is rare that a properly placed onlay is ever worn or damaged, even when the incisal edge has been

lengthened. That incisal edge must be rounded to allow for a smooth mandibular crossover excursion as the mandibular canine travels laterally past the incisal edge and onto its lingual surface. To ensure patient comfort, the onlay surface must be smoothly contoured and tapered into the enamel without ledges.

Typically, the onlay is placed solely on the maxillary palatal surface; however, the onlay thickness can be reduced if the facial surface of the opposing tooth is also bonded with composite resin. The dentist can control forces on teeth by choosing which surfaces contact in excursions. Subtractive occlusal adjustment can relieve excessive force on teeth with bone loss or resorbed or traumatized roots. Additive occlusal adjustment with direct composite resin onlays places contact on teeth with large roots and stronger periodontium to protect adjacent weaker teeth.[28]

Incomplete fracture

Tooth fracture progressing past the insensitive enamel into the vital dentin has been termed *cracked tooth syndrome* and is characterized by sharp pain of short duration to pressure, thermal, or sweet

stimuli.[29] Restorative treatment with full crowns to cover the fracture or prevent displacement of the separated tooth adjacent to the fracture has been described.[30] The interim restoration can confirm patient comfort. Pin-retained and cuspal-coverage amalgam have been presented as definitive restorations or to test comfort and stability prior to other procedures.[31,32] Partial-coverage cast gold onlay and bonded ceramic are definitive treatments for incomplete fracture.[33,34]

Bearn et al showed a more conservative technique by replacing Class I amalgam restorations with bonded amalgam to resolve cracked tooth syndrome.[35] Opdam et al had 100% success at 7 years after treating incomplete fractures with bonded composite resin and cuspal coverage.[36] They suggested that this treatment preserved tooth vitality better than full crowns and cuspal coverage placed less stress on the adhesive layer. Opdam & Roeters found that cracked teeth treated with composite resin had equivalent results with or without cuspal coverage.[37]

Case 1

A 38-year-old man presented reporting that he experienced occasional pain that was sharp and of short duration when his teeth were exposed to cold and chewing. An incipient fracture in his mandibular left second molar (tooth 18) was evident under the surgical microscope, and significant wear facets from lateral excursive contact interferences were present (Fig 2). Although some fractures can be detected with the unaided eye or 2.5× magnification surgical telescopes, small fractures and details of color and debris require a 14× to 16× magnification surgical microscope.[38] There was no history of restoration, no periodontal bone loss, and no radiographic indication of pulpal involvement.

The fracture length was delineated and cleaned with a No. 1/4 round carbide bur (Henry Schein Dental) without local anesthetic, and an intraenamel 1-mm reduction of the distal cusps was done with a straight diamond (No. 847KR, Brasseler USA) (Fig 3). The preparation was acid etched with 40% phosphoric acid (Etch Gel, Henry Schein Dental), rinsed, dried, and covered with adhesive resin (Clearfil SE Bond, Kuraray America), which was subsequently light
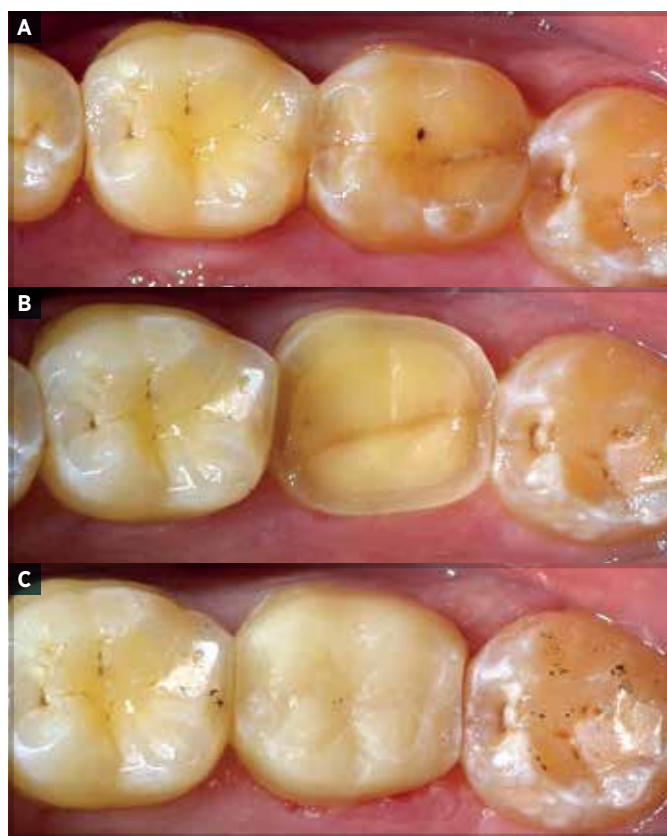
Fig 4. Case 2. A. The mandibular right second molar (tooth 31) has significant occlusal wear and a stained crack on the distal region. B. The full extent of the crack is exposed by 2-mm occlusal reduction of tooth 31. C. Direct microhybrid composite resin onlay. The occlusal anatomy allows light contact on mandibular closure without any excursive interferences.

polymerized. A microhybrid direct composite (Renamel, Cosmedent) was placed, sculpted, and light polymerized, and the occlusion was adjusted to remove any excursive interferences and wear facets. The patient reported immediate, complete comfort and there has been no wear of the onlay at 2 years.

Case 2

A 50-year-old man sought relief for constant pain in response to cold and chewing on the mandibular right second molar (tooth 31). A stained central groove crack on the distal area of the tooth was evaluated with the surgical microscope (Fig 4). There was no history of restoration or periodontal bone loss, and the findings on his periapical radiograph were normal. The pain to chewing was replicated by having him clench on a cotton swab, and the short-duration pain in response to cold was replicated by application of an air jet.

He declined restoration with a gold onlay due to the expense and understood that the fracture would progress pulpally and require endodontic therapy if left untreated. He accepted treatment with a direct composite resin onlay, which was prepared under local anesthesia. The straight diamond was used to create a multiplanar, uniform 2-mm reduction that followed the occlusal contour for proper cusp thickness and durability of the composite resin onlay in this high-force area.[39,40] The full extent of the fracture was visualized. A dentin bonding resin (SE Primer, Kuraray America) was placed in addition to use of the protocol described for case 1. The total-etch bonding technique can eliminate the need for invasive retentive features and provide a direct cuspal-coverage restoration without sensitivity.[41,42] The composite resin was sculpted and light polymerized, and the occlusion was adjusted for light
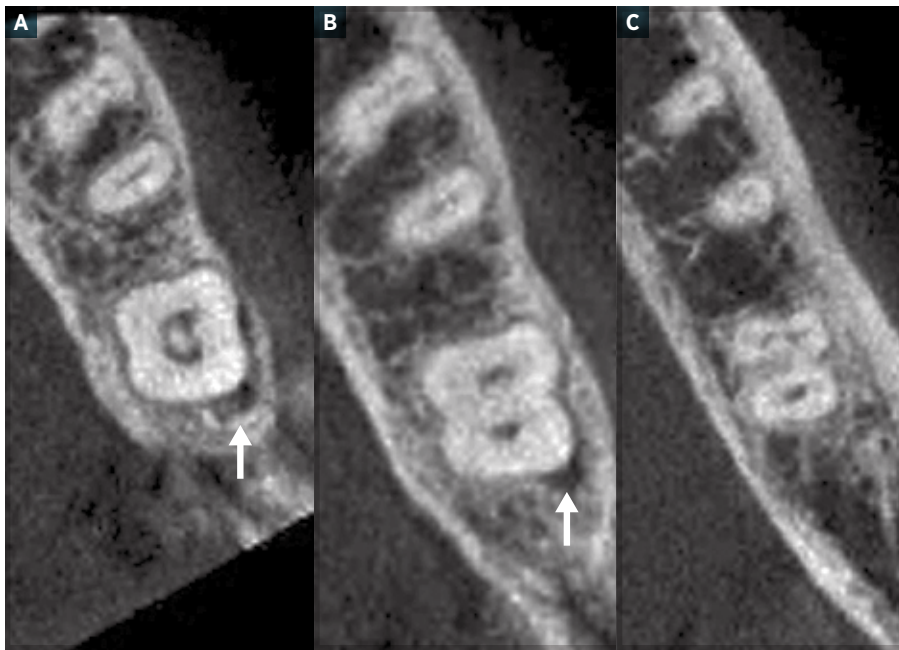
Fig 5. Case 3. Cone beam computed tomogram of tooth 18 (axial views). A. Discrete bone loss is present at the cervical third on the distofacial root (arrow), adjacent to the occlusal crack. B. Bone loss at the middle third on the distofacial root (arrow) is decreased compared to the cervical third. C. There is no evidence of bone loss at the apical third of the root.
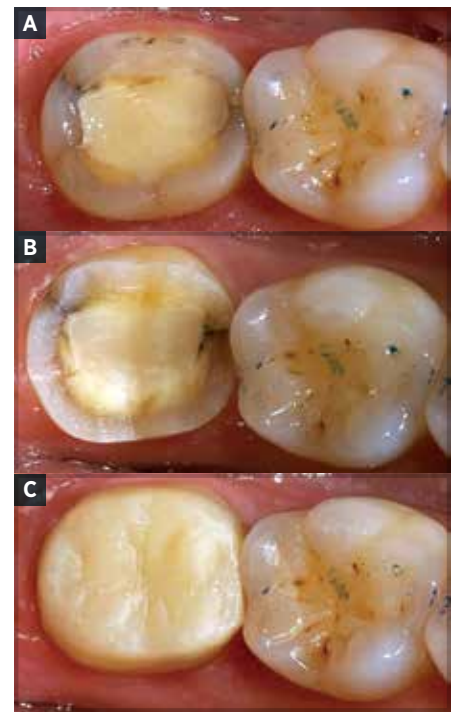

Fig 6. Case 3. A. A postendodontic occlusal view of tooth 18, with multiple cracks. B. Multiplanar occlusal reduction with enamel bevels at the fracture has been performed to ensure full enamel bonding over the cracks. C. Direct microhybrid composite resin onlay. The occlusal anatomy avoids any traumatic excursive contact interference.

contact on mandibular closure without excursive contacts. The patient reported complete comfort, and there has been no deterioration of the onlay at 4.5 years.

The etiology of occlusal fractures is multifactorial, but loss of coronal dentin from large restorations and traumatic occlusal interferences have been mentioned as common factors.[43,44] In the teeth described in both cases 1 and 2 there was no history of restoration, but there was significant destruction from traumatic occlusion. It is important that the final restoration be free of adverse occlusal stress during all mandibular movement. Conservative preparation with an inlay margin allows full cuspal coverage and preserves facial tooth structure for esthetics.

Postendodontic restoration

Adolphi et al showed that endodontically treated posterior teeth restored with a Class II composite resin restoration experienced tooth fracture 8 times more often than their vital counterparts.[45] Aquilino

& Caplan found that failure to place a crown after endodontic therapy resulted in 6 times greater loss of teeth than did crown reinforcement.[46] They suggested that onlays of composite, ceramic, gold, and amalgam may also protect teeth and resist cuspal fracture. Bonded amalgam with horizontal and vertical pin retention and the combination of composite resin and amalgam cuspal coverage have been described.[47,48] Cobankara et al, in an in vitro study, saw no difference in fracture strength among amalgam, composite resin, fiber-reinforced composite, and indirect composite resin materials.[49] Fiber reinforcement in direct composite resin acts as a stiff band over dentin cracks, resisting opening as well as inhibiting crack growth in composite resin overlays.[50,51] Direct and indirect composite resin onlays have been recommended as effective and durable postendodontic restorations.[52-54] The adhesive nature of these procedures may obviate the need for post placement, especially in teeth with remaining coronal dentin.[55,56]

Case 3

A 54-year-old woman presented with a history of increasing pain to tooth 18. Several occlusal surface cracks and a 9-mm distofacial periodontal probing depth adjacent to a crack prompted evaluation of the subcrestal root with cone beam computed tomography. Localized radicular bone loss was evident at the distofacial surface of the cervical and middle thirds of the tooth, since all fractures are populated by bacteria, but not the apical third (Fig 5).[57] There was no invasion of the fracture into radicular dentin.

Conservation of the tooth with endodontics versus removal, with or without implant restoration, and the role of periodontal grafting were discussed with the patient, endodontist, and periodontist. The patient elected endodontic treatment and a direct composite resin onlay to reinforce the tooth to avoid the cost of a gold onlay on a tooth with an uncertain prognosis.
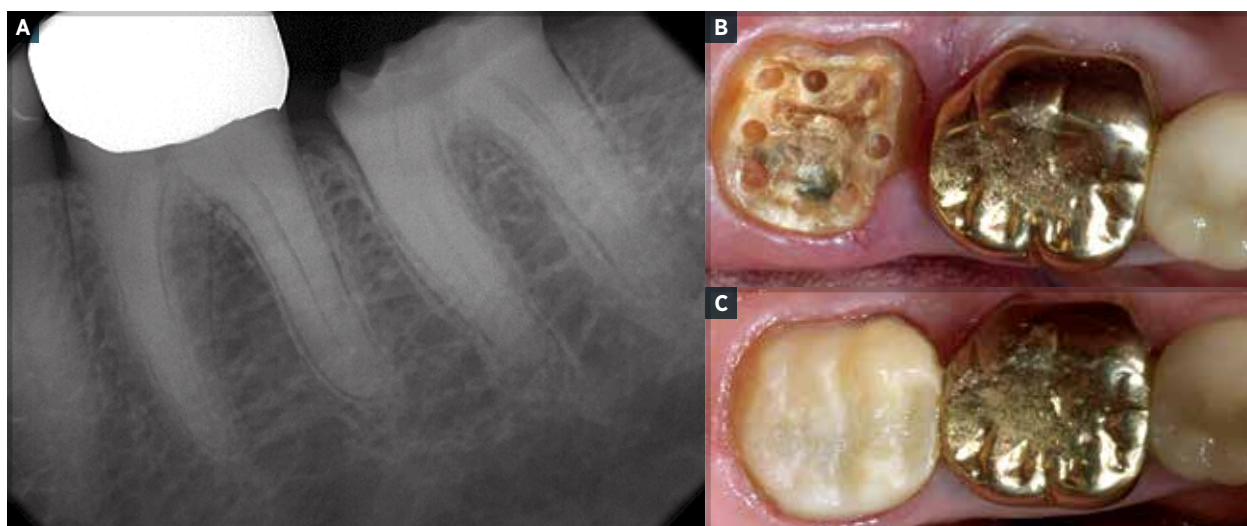
Fig 7. Case 4. A. After removal of caries, tooth 18 shows minimal coronal dentin, high furcation anatomy, and no apical pathosis. B. Circumferential 2-mm deep amalgapin channels increase the retention and resistance form as well as the surface area for bonding. C. Direct microhybrid composite resin onlay fabricated in layers. The occlusal anatomy is designed with light contact in closure and no excursive interferences.

Uniform multiplanar occlusal reduction was done, including beveling of the cavosurface at the fractures to enable bonding to the full extent of enamel (Fig 6). No attempt was made to eradicate the fracture below the enamel preparation. Future periodontal grafting would visualize the fracture directly and ablate the defect as part of root preparation. Reinforcement of the tooth allowed monitoring to confirm the tooth's prognosis prior to commitment of periodontal grafting. A direct composite resin onlay was placed to establish light contact on mandibular closure and no excursive contacts. The patient has been comfortable for 9 months and the periodontal probing depth has been maintained at 6 mm with no bleeding.

Debilitated dentition

Large amalgam and composite resins may not last as long as small ones, since the restorative material is exposed to stress that the tooth used to absorb.[58] However, some extensive amalgam and composite resin restorations can last for the long term, even though cast gold or ceramic restorations are stronger.[59-61] If a tooth has a questionable prognosis or there are limitations of time, cost, or periodontal support, a direct composite resin onlay is an appropriate alternative.

Case 4

A 78-year-old man presented with a lost crown on tooth 18. After caries removal, minimal coronal dentin remained, and root exposure via crown lengthening was limited by the furcation (Fig 7).

Tooth removal with or without implant restoration was discussed, and a direct composite resin onlay was recommended as a conservative but possibly interim solution. Due to high occlusal forces in this site, amalgapin retention channels added mechanical retention and resistance form and provided an increased surface area for bonding.[62] Layered application of adhesive and microhybrid composite resins proceeded as described for case 1, until a sectional matrix could be placed for a predictable contact area.[63] The occlusion was refined to avoid any traumatic excursive contact.

Conclusion

Restorative dentistry should prioritize preservation of healthy biological structure whenever possible. The conservative direct composite resin onlay is a versatile technique that may be considered as an alternative to full crowns.

Author information

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References

1. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for posterior teeth. *Int J Periodontics Restorative Dent.* 2002;22(3):241-249.

2. Homewood CI. Cracked tooth syndrome—incidence, clinical findings and treatment. *Aust Dent J.* 1998;43(4):217-222.

3. Crispin BJ, Watson JF. Margin placement of esthetic veneer crowns, II: posterior tooth visibility. *J Prosthet Dent.* 1981;45(4):389-391.

4. Alharbi A, Rocca GT, Dietschi D, Krejci I. Semidirect composite onlay with cavity sealing: a review of clinical procedures. *J Esthet Restor Dent.* 2014;26(2):97-106.

5. Yamanel K, Caglar A, Gülsahi K, Ozden UA. Effects of different ceramic and composite materials on stress distribution in inlay and onlay cavities: 3-D finite element analysis. *Dent Mater J.* 2009 Nov;28(6):661-670.

6. Magne P, Knezevic A. Influence of overlay restorative materials and load cusps on the fatigue resistance of endodontically treated molars. *Quintessence Int.* 2009;40(9):729-737.

7. Magne P, Knezevic A. Simulated fatigue resistance of composite resin versus porcelain CAD/CAM overlay restorations on endodontically treated molars. *Quintessence Int.* 2009;40(2):125-133.

8. Ardu S, Duc O, Krejci I, Perroud R. Amelogenesis imperfecta: a conservative and progressive adhesive treatment concept. *Oper Dent.* 2013;38(3):235-241.

9. Bottacchiari S, De Paoli S, Bottacchiari PA. Biologic restoration: the effects of composite inlays on patient treatment plans. *Int J Periodontics Restorative Dent.* 2011;31(2):115-123.

10. Dietschi D, Argente A. A comprehensive and conservative approach for the restoration of abrasion and erosion, I: concepts and clinical rationale for early intervention using adhesive techniques. *Eur J Esthet Dent.* 2011;6(1):20-33.

11. Spreafico RC. Composite resin rehabilitation of eroded dentition in a bulimic patient: a case report. *Eur J Esthet Dent.* 2010;5(1):28-48.

12. Pallesen U, Qvist V. Composite resin fillings and inlays. An 11-year evaluation. *Clin Oral Investig.* 2003;7(2):71-79.

13. Deliperi S, Bardwell DN. Direct cuspal-coverage posterior resin composite restorations: a case report. *Oper Dent.* 2006;31(1):143-150.

14. Kuijs RH, Fennis WM, Kreulen CM, Roeters FJ, Verdonschot N, Creugers NH. A comparison of fatigue resistance of three materials for cusp-replacing adhesive restorations. *J Dent.* 2006;34(1):19-25.

15. Belli R, Geinzer E, Muschweck A, Petschelt A, Lohbauer U. Mechanical fatigue degradation of ceramics versus resin composites for dental restorations. *Dent Mater.* 2014;30(4):424-432.

16. Fron Chabouis H, Smail Faugeron V, Attal JP. Clinical efficacy of composite versus ceramic inlays and onlays: a systematic review. *Dent Mater.* 2013;29(12):1209-1218.

17. Cetin AR, Unlu N, Cobanoglu N. A five-year clinical evaluation of direct nanofilled and indirect composite resin restorations in posterior teeth. *Oper Dent.* 2013;38(2):E1-E11.

18. Cetin AR, Unlu N. Clinical wear rate of direct and indirect posterior composite resin restorations. *Int J Periodontics Restorative Dent.* 2012;32(3):e87-e94.

19. de Paula AB, Duque C, Correr-Sobrinho L, Puppin-Rontani RM. Effect of restorative technique and thermal/mechanical treatment on marginal adaptation and compressive strength of esthetic restorations. *Oper Dent.* 2008;33(4):434-440.

20. Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. *Oper Dent.* 2004;29(5):481-508.

21. Jackson RD. Aesthetic inlays and onlays: the coming of age. *Br Dent J.* 2008;204(7):407-408.

22. Thayer KE, Doukoudakis A. Acid-etch canine riser occlusal treatment. *J Prosthet Dent.* 1981;46(2):149-152.

23. Eliyas S, Martin N. The management of anterior tooth wear using gold palatal veneers in canine guidance. *Br Dent J.* 2013;214(6):291-297.

24. Ford RT, Douglas W. The use of composite resin for creating anterior guidance during occlusal therapy. *Quintessence Int.* 1988;19(5):331-337.

25. Solow RA. Additive occlusal equilibration. *Gen Dent.* 2015;63(6):12-17.

26. Dietschi D, Argente A. A comprehensive and conservative approach for the restoration of abrasion and erosion, II: clinical procedures and case report. *Eur J Esthet Dent.* 2016;(2):142-159.

27. Vailati F, Belser UC. Full-mouth adhesive rehabilitation of a severely eroded dentition: the three-step technique. 2. *Eur J Esthet Dent.* 2008;3(2):128-146.

28. Shin JH, Kim RJ. Management of horizontal root fractures by fabrication of canine protected occlusion using composite resin. *Restor Dent Endod.* 2012;37(3):180-184.

29. Homewood CI. Cracked tooth syndrome—incidence, clinical findings and treatment. *Aust Dent J.* 1998;43(4):217-222.

30. Guthrie RC, DiFiore PM. Treating the cracked tooth with a full crown. *J Am Dent Assoc.* 1991;122(9):71-73.

31. Davis R, Overton JD. Efficacy of bonded and nonbonded amalgam in the treatment of teeth with incomplete fractures. *J Am Dent Assoc.* 2000;131(4):469-478.

32. Clark LL, Caughman WF. Restorative treatment for the cracked tooth. *Oper Dent.* 1984;9(4):136-142.

33. Brackett MG, Kious AR, Brackett WW. Minimally retentive gold onlays: a six-year case report. *Oper Dent.* 2009;34(3):352-355.

34. Liebenberg WH. Use of resin-bonded partial coverage ceramic restorations to treat incomplete fractures in posterior teeth: a clinical report. *Quintessence Int.* 1996;27(11):739-747.

35. Bearn DR, Saunders EM, Saunders WP. The bonded amalgam restoration—a review of the literature and report of its use in the treatment of four cases of cracked-tooth syndrome. *Quintessence Int.* 1994;25(5):321-326.

36. Opdam NJ, Roeters JJ, Loomans BA, Bronkhorst EM. Seven-year clinical evaluation of painful cracked teeth restored with a direct composite restoration. *J Endod.* 2008;34(7):808-811.

37. Opdam NJ, Roeters JM. The effectiveness of bonded composite restorations in the treatment of painful, cracked teeth: six-month clinical evaluation. *Oper Dent.* 2003;28(4):327-333.

38. Clark DJ, Sheets CG, Paquette JM. Definitive diagnosis of early enamel and dentin cracks based on microscopic evaluation. *J Esthet Restor Dent.* 2003;15(7):391-401; discussion 401.

39. Mei ML, Chen YM, Li H, Chu CH. Influence of the indirect restoration design on the fracture resistance: a finite element study. *Biomed Eng Online.* 2016;15:3.

40. Deliperi S, Bardwell DN. Multiple cuspal-coverage direct composite restorations: functional and esthetic guidelines. *J Esthet Restor Dent.* 2008;20(5):300-308; discussion 309-312.

41. Deliperi S, Bardwell DN, Alleman D. Clinical evaluation of stress-reducing direct composite restorations in structurally compromised molars: a 2-year report. *Oper Dent.* 2012;37(2):109-116.

42. Deliperi S, Bardwell DN. Clinical evaluation of direct cuspal coverage with posterior composite resin restorations. *J Esthet Restor Dent.* 2006;18(5):256-265; discussion 266-267.

43. Alassaad SS. Approaches to managing asymptomatic enamel and dentin cracks. *Gen Dent.* 2014;62(6):58-62.

44. Bader JD, Shugars DA, Martin JA. Risk indicators for posterior tooth fracture. *J Am Dent Assoc.* 2004;135(7):883-892.

45. Adolphi G, Zehnder M, Bachmann LM, Göhring TN. Direct resin composite restorations in vital versus root-filled posterior teeth: a controlled comparative long-term follow-up. *Oper Dent.* 2007;32(5):437-442.

46. Aquilino SA, Caplan DJ. Relationship between crown placement and the survival of endodontically treated teeth. *J Prosthet Dent.* 2002;87(3):256-263.

47. Uyehara MY, Davis RD, Overton JD. Cuspal reinforcement in endodontically treated molars. *Oper Dent.* 1999;24(6):364-370.

48. Shafiei F, Memarpour M, Karimi F. Fracture resistance of cuspal coverage of endodontically treated maxillary premolars with combined composite-amalgam compared to other techniques. *Oper Dent.* 2011;36(4):439-447.

49. Cobankara FK, Unlu N, Cetin AR, Ozkan HB. The effect of different restoration techniques on the fracture resistance of endodontically-treated molars. *Oper Dent.* 2008;33(5):526-533.

50. Belli S, Cobankara FK, Eraslan O, Eskitascioglu G, Karbhari V. The effect of fiber insertion on fracture resistance of endodontically treated molars with MOD cavity and reattached fractured lingual cusps. *J Biomed Mater Res B Appl Biomater.* 2006;79(1):35-41.

51. Monaco C, Bortolotto T, Arena A, Krejci I. Restoring nonvital premolars with composite resin onlays: effect of different fiber-reinforced composite layers on marginal adaptation and fracture load. *J Adhes Dent.* 2015;17(6):567-574.

52. Moezizadeh M, Mokhtari N. Fracture resistance of endodontically treated premolars with direct composite restorations. *J Conserv Dent.* 2011;14(3):277-281.

53. Chrepa V, Konstantinidis I, Kotsakis GA, Mitsias ME. The survival of indirect composite resin onlays for the restoration of root filled teeth: a retrospective medium-term study. *Int Endod J.* 2014;47(10):967-973.

54. Kölpin M, Sterzenbach G, Naumann M. Composite filling or single crown? The clinical dilemma of how to restore endodontically treated teeth. *Quintessence Int.* 2014;45(6):457-466.

55. Krejci I, Duc O, Dietschi D, de Campos E. Marginal adaptation, retention and fracture resistance of adhesive composite restorations on devital teeth with and without posts. *Oper Dent.* 2003;28(2):127-135.

56. Ferrari M, Vichi A, Fadda GM, et al. A randomized controlled trial of endodontically treated and restored premolars. *J Dent Res.* 2012;91(7 Suppl):72S-78S.

57. Ricucci D, Siqueira JF Jr, Loghin S, Berman LH. The cracked tooth: histopathologic and histobacteriologic aspects. *J Endod.* 2015;41(3):343-352.

58. Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. A retrospective clinical study on longevity of posterior composite and amalgam restorations. *Dent Mater.* 2007;23(1):2-8.

59. Scholtanus JD, Ozcan M. Clinical longevity of extensive direct composite restorations in amalgam replacement: up to 3.5 years follow-up. *J Dent.* 2014;42(11):1404-1410.

60. Chan DC, Grubbs K, Osborne JW. Case report of a 40-year, five surface complex amalgam restoration. *Oper Dent.* 2002;27(6):639-643.

61. Opdam NJ, Bronkhorst EM, Loomans BA, Huysmans MC. 12-year survival of composite vs. amalgam restorations. *J Dent Res.* 2010;89(10):1063-1067.

62. Shavell HM. Updating the amalgapin technique for complex amalgam restorations. *Int J Periodontics Restorative Dent.* 1986;6(5):22-35.

63. Loomans BA, Opdam NJ, Roeters FJ, Bronkhorst EM, Burgersdijk RC. Comparison of proximal contacts of Class II resin composite restorations in vitro. *Oper Dent.* 2006;31(6):688-693.