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Cracks in the vital dentition: a restorative conundrum

A clinical scenario using adhesively bonded indirect ceramic restorations.

By Dr. Anthony Mak and Dr Andrew Chio, Australia

Cracks affecting vital teeth is a prevalent feature encountered in everyday practice. The practitioner is often required to diagnose and to determine the ideal approach to managing such presentations, a task made difficult in the absence of clear and universally accepted consensus.

The article will review the types of cracks commonly encountered with the emphasis placed on the restorative management of asymptomatic and symptomatic cracks in the vital dentition. A series of 2 case studies will also detail the management of both types of clinical presentation utilizing an adhesive-based protocol.

Defining the crack types:

The American Association of Endodontists have classified cracks in teeth into 5 categories.[1]
The 5 categories are: **1** Craze lines **2** Fractured cusp **3** Cracked tooth **4** Split tooth and **5** Vertical root fracture.

Management

The most common, yet least concerning, "crack" found in teeth is a craze line, which only involves the enamel. Craze lines require no restorative treatment and only monitoring for any changes in the tooth and affected area.

On the other end of the spectrum of cracked or fractured teeth are vertical root fractures and split tooth fractures. Once a tooth has been diagnosed with a vertical root fracture the extraction of the tooth with such presentation is commonly indicated.

A split tooth starts in the coronal portion of the tooth and extends downward into the root surface. If the split has not progressed too far apically, then the tooth may be salvageable. But if the crack goes too far apically down the root surface, the tooth will often have to be extracted.

Management of the fractured cusp and cracked teeth remains relatively subjective and can be dependent on the crack extent, operator experience and patient symptoms. There are no definitive restorative recommendations in the literature about the treatment of cracked teeth. There are also no definitive recommendations on when a tooth exhibiting asymptomatic cracks will require restorative intervention. Limiting the amount of continued tooth flexure and associated crack propagation with cuspal protection, adhesive reinforcement protocols and bite adjustments remains the goal in the restorative management of cracked teeth.

It should also be noted that the prognosis of the cracked tooth is always questionable. There is always the possibility that the crack will progress even when the tooth is restored ideally.

Studies by Krell *et al.*[2] and Wu *et al.*[3] reported the outcomes of symptomatic cracked teeth with a diagnosis of reversible pulpitis and treated with full coverage restorations. The outcomes of the studies indicate that if a crack is identified early on a tooth with the signs and symptoms of reversible pulpitis, and a crown placed, endodontic intervention will be necessary in about 20%-30% of the cases over a 3-to-6 year period.

Symptomatic vs asymptomatic cracks

Asymptomatic cracks

While there is sufficient evidence that asymptomatic cracks or incomplete fractures can lead to more significant complications[2, 4-9], there is little consensus regarding which teeth are at risk of fracture and when restorative intervention is indicated.[10]

Asymptomatic enamel cracks

While the traditional classification of cracks has not emphasised the possibility of pathology underlying enamel cracks, several approaches are now taking asymptomatic enamel cracks into consideration.

Clark *et al.*[11] classified asymptomatic enamel cracks based on the risk of underlying pathologies including dentin cracks, decay and potential for the microleakage through the crack. The greater the risk, the more strongly it is recommended for the tooth to be restored, even if the tooth is asymptomatic.[12]

Asymptomatic dentin cracks

At present, the available literature focuses mainly on the treatment of symptomatic cracks. However, as dentin cracks should be considered as structural cracks, the principles used to treat symptomatic cracks can be applied to the management of asymptomatic dentin cracks. Any intervention would aim at preventing or limiting the progression of the crack and prevent any subsequent undesired pathological outcomes.[6]

Symptomatic cracks

The clinical signs and symptoms of a cracked tooth can vary according to the position and extent of the incomplete fracture.[13-15] Classically, pain on biting and sensitivity to thermal changes, particularly cold, are symptoms commonly relayed. Sensitivity to sweet is also occasionally reported.[18] Pain associated with the release of pressure is also a consistent presentation.[13,16-17] Cracked tooth syndrome (CTS) is a term applied to a presumptive diagnosis of incomplete tooth fracture that typically presents with consistent above-mentioned symptoms.

Associated endodontic signs and symptoms can occur when the crack extends into the pulpal complex.

Despite there being no universally accepted restorative protocol to treat CTS[19], the conventional treatment reported in literature involves some form of cuspal coverage to support the remaining tooth structure and to prevent or to limit further crack propagation. The use of core build-ups and full crowns has been reported as the restoration of choice for a significant number of practitioners as it accomplishes the above-mentioned criteria.[20]

The use of adhesive restorative protocols that provide a more conservative option has also been shown to be a viable and promising option in the restoration of cracked teeth.[21,22] Bonded restorations provide significant support to tooth function by distributing forces and reducing the risk of fracture propagation.[23] The stabilisation of the prepared tooth structure in the form of internal splinting has also been reported in several studies.[24,25] Adhesive protocols complemented by the use of fibre-reinforced composites have also shown potential to help protect the cracked tooth from further degradation by the mechanism of stress redistribution and absorption and stabilisation of the crack.[26-29]

Case presentation

The case report presents the clinical scenario where bonded lithium disilicate restorations (Initial LiSi Press, GC) were utilised to successfully rehabilitate the posterior upper right quadrant (quadrant 1) with the quadrant rehabilitation completed segmentally over a period of 2 years. The teeth were restored utilising the different configurations of adhesively bonded ceramic restorations based on the clinical situation as it pertains to the type of crack and the symptoms at the time of presentation.

Phase 1 – Initial Presentation: The restoration of the first and second upper right molars (Tooth 16 and 17)

Fig. 1: Pre-operative presentation– Quadrant 1.

A 63-year-old female patient presented to the practice for the definitive replacement of the restoration on the upper right first molar (tooth 16). The tooth had previously been provisionalised with a glass ionomer restoration due to the fracture of the disto-buccal cusp which supported a large amalgam restoration. The tooth 16 also exhibited an opening of the amalgam-tooth interface along the palatal margins of the restoration which was resulting in the entrapment of debris.

Restorative management of the upper right second molar was also indicated due to the presence of enamel cracks on the mid-buccal, mid-palatal and distal marginal ridge. The distal crack on the marginal ridge was also detectable with an explorer and housed debris, which is an indication for intervention as per the guidelines outlined in the paper by Clark *et al.*[12].

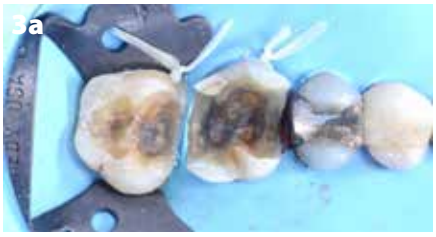
The endodontic and periodontal assessment of both molars were within normal healthy limits and unremarkable.

While the option of restoring the entire posterior quadrant simultaneously was discussed, this provisional treatment plan was not accepted by the patient then due to time and financial constraints, an issue commonly encountered in the everyday general dental practice.

Based on the available evidence from the literature, two full-cuspal-coverage indirect bonded lithium disilicate restorations were planned to restore both the tooth 16 and 17. The clinical observation of asymptomatic dentin cracks within the floor of the cavities following the removal of the old amalgam restorations were obvious. Bonded ceramic onlays would meet the goal of managing such structural cracks, which is aimed at preventing or limiting the progression of the crack and prevent any subsequent undesired pathological outcomes.

The choice of material is also supported by long-term studies, where lithium disilicate, such as Initial LiSi Press, appears to be ideally suited to provide a durable approach to restoring function, aesthetics and biomechanics of the dentition while allowing the implementation of minimally invasive preparation protocols to minimise the biological loss of the remaining tooth structure.

Fig. 2: Working field isolated with the application of the rubber dam.



Figs. 3(a) and (b): Tooth 16 and 17 following complete removal of the failed amalgam restorations, caries and unsupported tooth structure, revealing the presence of asymptomatic dentinal cracks within the floor of the cavity.

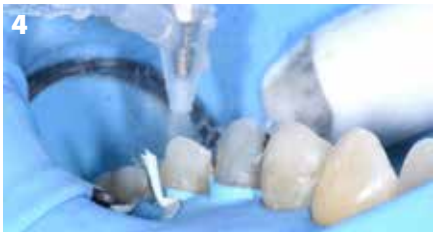


Fig. 4: Cavity air-abraded to optimize the tooth substrate for the adhesive process.

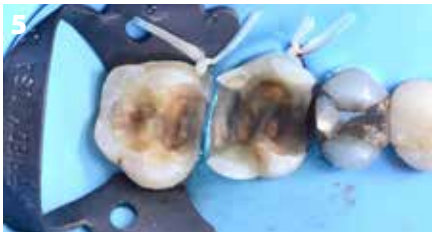


Fig. 5: Completed removal of the old restorations and existing recurrent caries.

Following adequate anaesthesia, the working field was isolated with a rubber dam (Figure 2). The rubber dam allows the creation of an unequalled clear field in which to operate. The ability to maintain a clean, dry field throughout the duration of the preparation and adhesive processes is of utmost importance.

Teeth preparation commenced with the removal of the old amalgam restorations, caries and any unsupported tooth structure. Asymptomatic dentinal fractures were clearly evident on the floor of the cavity following the completion of this preliminary process (Figures 3a and 3b). All sharp internal line angles were rounded to prevent the development of areas of stress concentration. The cavity was then air-abraded to optimise the dentin substrate for the adhesive process (Figures 4, 5). A selective-etch protocol was utilised where the enamel was etched with a 35% phosphoric acid gel, rinsed thoroughly and air-dried. A universal adhesive (G-Premio BOND, GC) was then applied to immediately

seal the dentin. Immediate dentin sealing (IDS) involves applying an adhesive system to the dentin after tooth preparation before an impression is taken and has been shown to optimise the adhesion of the indirect ceramic restoration to the tooth substrate. Following complete light-curing, the adhesive layer was reinforced by a thin layer of flowable composite (G-ænial Flo-X, GC). The purpose of the flowable layer is to fill any irregular concavities within the cavity preparation and also to reinforce the adhesive hybrid layer (Figure 6). The periphery aspects of the preparations are then finalised with the use of ultrasonic instrumentation to refine the enamel and to remove any excess adhesive or composite flashes (Figure 7).

The gingival tissues are then retracted with the retraction cords (Figure 8) and digital impressions of the preparation, the antagonists and the bite / occlusal relationship were completed (Figures 10, 11).

The provisionalisation process was accomplished with the use of a dual-cured bis-acryl composite temporary crown-and-bridge material (TEMPSMART DC, GC) in a polyvinyl-siloxane (PVS) template prefabricated from a sectional impression (Figure 12).

Fig. 6: Completed immediate dentin sealing (IDS).

Fig. 7: Finalisation of the full coverage. Onlay preparation with the refinement of the enamel margins with ultrasonic instrumentation.

Fig. 8: Final teeth preparations with gingival tissues retracted ready for the digital impression with the intraoral scanner.

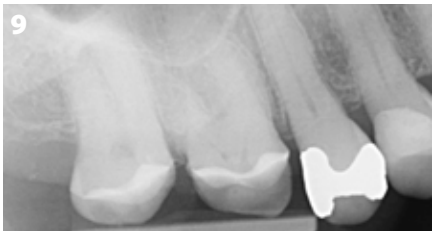


Fig. 9: Periapical radiograph of the completed IDS layer on the tooth 16 and 17.

Fig. 10: Completed intra-oral scan for the tooth preparation on tooth 16 and 17. Occlusal view.

Fig. 11: Completed intra-oral scan for the tooth preparation on tooth 16 and 17. Lateral view.

Fig. 12: Fabrication of the provisional restoration with TEMPSMART DC (shade A2) from a prefabricated PVS template.

At the second appointment, following the laboratory fabrication of the definitive lithium disilicate restorations (Figures 13-18), the provisional restorations were dislodged and all residual provisional cement was removed with an ultrasonic scaler. Before try-in of the restorations, the preparations were air-abraded to ensure that the surfaces are completely clean and free of debris. The use of 27-µm aluminum oxide is well proven to ideally clean the preparation surfaces without significant risk of removing previously placed dental bonding agents, dentin, or enamel. When utilizing immediate dentin sealing, the use of air-abrasion also serves to "reactivate" the IDS-treated surfaces.

The restorations were then tried in and the fit, margins and adequacy of the proximal contact points verified.

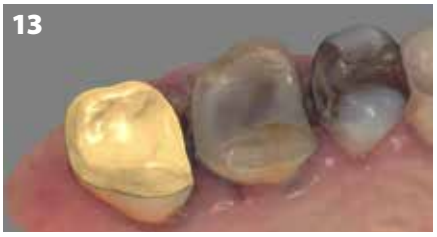


Fig. 13: The intra-oral scan is imported into the CAD/CAM software…

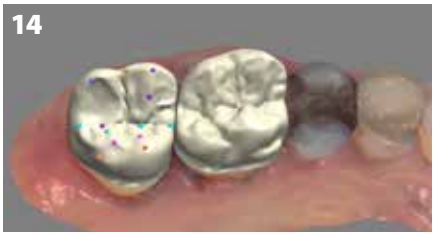


Fig. 14: …to allow the full contour LiSi Press restorations to be designed and fabricated.

Fig. 15: The designed restorations printed in the ASIGA MAX 3D-printer utilising a direct investment casting material (ASIGA SUPERCAST 3).

Fig. 16: Final Initial LiSi Press restorations for teeth 16 and 17 following completion of the laboratory phase of the manufacturing process.

Fig. 17: The Initial LiSi Press restorations seated on the model.

Fig. 18: Close-up of the Initial LiSi Press restorations for 16 and 17.

Following try-in of the restoration, the intaglio or fitting surface of the restoration was appropriately etched with hydrofluoric acid (5% HF for 20 seconds for Initial LiSi Press) and silanated with the appropriate silane/primer (G-Multi PRIMER, GC; Figure 19). Heat treatment of the silanated restoration was also carried out as research has indicated that such treatment optimised the bond strengths of resin composite to the glass-ceramic.

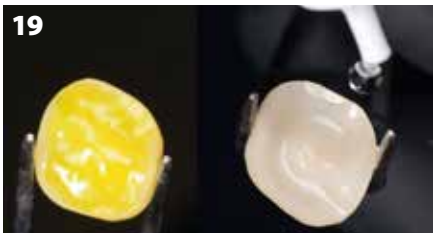


Fig. 19: Intaglio of the Initial LiSi Press restorations, hydrofluoric-acid-etched and silanated in preparation of the adhesive bonding.

Fig. 20: The Initial LiSi Press restoration adhesively bonded with G-ænial Universal Injectable, shade A2, on tooth 17.

A cementation protocol, completing the adhesive process individually and sequentially, was chosen to commence with the tooth 17.
Following the isolation of the working field with the rubber dam, a high-viscosity 35% phosphoric acid gel was used to etch the enamel and the IDS-treated surface for 15-20 seconds. The etchant was then thoroughly rinsed and carefully dried to ensure no standing moisture remains.

A layer of the universal adhesive, G-Premio BOND (GC) was applied to the preparation and light-cured. The restoration for tooth 17 was then adhesively cemented with a full-strength flowable restorative composite, G-ænial Universal Injectable (GC) in an A2 shade using a full light-cured protocol (Figure 20). Studies have indicated that with the use of a high-irradiance polymerisation lamp and extended exposure time, light-polymerizable composite resin may be adequately polymerised when used as luting materials for indirect restorations fabricated from glass-ceramic materials.

The restoration was seated onto the tooth. The gross excess of cement is removed with a combination of brushes, metal instruments and floss while maintaining a consistent seating force during the cement removal process. If the pressure is prematurely lifted, gaps or voids in the cement layer can potentially form.

Each surface of the restoration was then light-cured with air-cooling, followed by air/water cooling to prevent any inadvertent damage to the pulp during the entire light-curing process. Final light-curing of the marginal areas was completed under a layer of glycerine gel. This ensures the prevention of an inadequately cured oxygen inhibited layer in the cement at the restoration-tooth interface.

On the completion of the clean-up of all residual cement from tooth 17, tooth 16 was isolated and the adhesive cementation process repeated (Figure 21).

Marginal areas of the bonded ceramic restorations were then polished and finished using a composite finishing and polishing system. Any necessary occlusal adjustments completed after the removal of the rubber dam were made with a fine diamond polishing bur and brought back to full polish with the use of the full sequence of ceramic polishing silicones. Figures 23 and 24 demonstrates the optical and functional integration of the adhesively cemented Initial LiSi Press restorations that were delivered immediate postoperatively.

Fig. 21: Completed clean-up of residual cement from the 17. The 16 was then isolated and ready for the adhesive cementation process.

Fig. 22: Completed adhesive cementation process for the Initial LiSi Press restorations on the 16 and 17.

Fig. 23: Immediate post-operative (Initial LiSi Press full coverage onlays) on 16 and 17 (buccal view).

Fig. 24: Immediate post-operative (Initial LiSi Press full-coverage onlays) on 16 and 17 (occlusal view).

Phase 2 - 2-years post Phase 1: The restoration of the upper right first and second premolars (tooth 14 and 15)

The restoration of teeth 16 and 17 with bonded ceramic full-coverage onlays was successful in treating the upper right molars and the patient remained stable for the subsequent 2 years when she began to experience discomfort on chewing from the upper second premolar. Clinical examination revealed that both premolars were vital and no generalised or isolated deep pocketing was detected on periodontal probing (Figure 25). Periapical radiographs taken also exhibited no periapical pathology. Percussion and palpation tests did not result in remarkable reactions. However, pain to release was isolated to the buccal cusp. of the upper right second premolar (tooth 15) when tested with a bite stick. The diagnosis "cracked tooth syndrome" (CTS) was made.

As the use of an adhesively bonded protocol augmented by the internal stabilisation provided by fibre-reinforced resin composite has been shown in the literature to provide a more conservative and viable option in restoring teeth with CTS. Restoration with fibre-reinforce composite foundation for the restorations (core build-ups) and bonded lithium disilicate crowns were selected to rehabilitate the premolars tooth 14 and 15. The use of full-coverage crowns also allowed the labial surfaces of the premolars to be covered, preventing any possibility of the tooth-restoration margins to be visible when the patient would smile.

A full adhesive protocol for the restoration of the tooth 14 and 15 was again implemented and shared the similar protocols utilised for the restoration of the molars in an onlay configuration (Figures 26-40). However, the was a subtle difference in the protocols for the restoration of teeth 14 and 15 which are summarised below:

1. Bonded foundation restorations or core build-ups were completed to provide additional retention and resistance forms to the preparation due to the compromised volume of the remaining tooth substrate (Figure 26). The foundation restorations were completed using the similar adhesive protocol but a fibre-reinforced flowable material, everX Flow (GC), was used to reinforce the horizontal crack along the floor of the cavity of tooth 15 before the complete build-up of the foundation restoration with a full-strength flowable restorative

Fig. 25: Pre-operative presentation of the 14 and 15.

Fig. 26. Teeth 14 and 15 - mid operative.

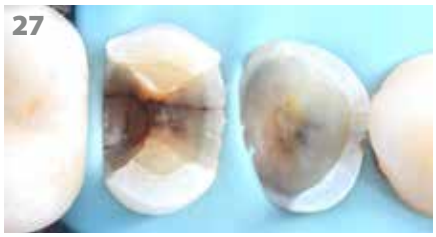


Fig. 27: Teeth 14 and 15 following complete removal of the failed amalgam restorations, caries and unsupported tooth structure. A crack extending from the mesial to distal along the floor of the cavity is clearly visible on tooth 15.

Figs. 28(a) and (b): Completed bonded foundation restorations (core build-ups) with G-Premio BOND, everX Flow and G-ænial Universal Injectable(shade AO2) and finalisation of the tooth preparations for full coverage crowns.

composite resin, G-ænial Universal Injectable (Shade A02). Research studies indicate the potential of the short fibres within everX Flow (GC) to prevent and to arrest the continued flexure and propagation of the crack when incorporated in the base of the cavity, over the crack.

2. A dual-cured resin cement (G-CEM LinkForce, GC) was utilised for the adhesive cementation of both full-coverage Initial LiSi Press crowns for tooth 14 and 15 that were inserted in a simultaneous protocol.

The immediate post-operative presentation of the case is depicted in Figures 39 and 40. Follow-up of the case one week later indicated a complete resolution of any pain on chewing from tooth 15 and seamless integration of both function and aesthetics of all the adhesively cemented Initial LiSi Press restorations (Figures 41 and 42).

Fig. 29: Periapical radiograph of the bonded foundation restorations (core build-ups) on teeth 14 and 15.

Fig. 30: Final tooth preparations with gingival tissues retracted, ready for the digital impression process.

Fig. 31: Final teeth preparations with gingival tissues retracted ready for the digital impressions.

Fig. 32: Completed intra-oral scan for the teeth preparations on teeth 14 and 15.

Fig. 33: Completed intra-oral scan for the teeth preparations on teeth 14 and 15 (monochrome).

Fig. 34: Final Initial LiSi Press restorations for 14 and 15 following completion of the laboratory phase of the fabrication process.

Fig. 35: Close-up of the Initial LiSi Press restorations for 14 and 15.

Figs. 36(a) and (b): Isolation of teeth 14 and 15 in preparation of the adhesivecementation process.

Conclusion

The article details the contemporary understanding of the management of cracks in the vital dentition and illustrates the management of the different presentations with an adhesively bonded protocol utilising lithium-disilicate-based restorations. Complemented by an extensive range of adhesive and restorative products, the provision of such modality of restorations in the management of cracks is simplified and systemised allowing the clinician to know that the interactions between the materials utilised are truly optimised.

Fig. 37: Following air-abrasion treatment, the crown preparations were selectively etched and the adhesive, G-Premio BOND, applied and cured.

Fig. 38: The HF etched and silanated Initial LiSi Press restorations were then adhesively cemented with the use of G-CEM LinkForce dual-cured composite cement (shade Opaque).

Fig. 39: Completed adhesive cementation process for the Initial LiSi Press restorations on the 14 and 15 (occlusal view).

Fig. 40: Completed adhesive cementation process for the Initial LiSi Press restorations on the 14 and 15 (buccal view).

Fig. 41: Completed Initial LiSi Press restorations for teeth 17, 16, 15 and 14.

Fig. 42: Post-operative radiograph following completed Initial LiSi Press restorations for teeth 17, 16, 15 and 14.

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