The compression dome concept: the restorative implications

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Evidence now supports the concept that the enamel on a tooth acts like a compression dome, much like the dome of a cathedral. With an overlying enamel compression dome, the underlying dentin is protected from damaging tensile forces. Disruption of a compression system leads to significant shifts in load pathways. The clinical restorative implications are significant and far-reaching. Cutting the wrong areas of a tooth exposes the underlying dentin to tensile forces that exceed natural design parameters. These forces lead to crack propagation, causing flexural pain and eventual fracture and loss of tooth structure. Improved understanding of the microanatomy of tooth structure and where it is safe to cut teeth has led to a revolution in dentistry that is known by several names, including microdentistry, minimally invasive dentistry, biomimetic dentistry, and bioemulation dentistry. These treatment concepts have developed due to a coalescence of principles of tooth microanatomy, material science, adhesive dentistry, and reinforcing techniques that, when applied together, will allow dentists to repair a compromised compression dome so that it more closely replicates the structure of the healthy tooth.

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Anyone who has practiced dentistry for long enough recognizes that the conventional model of diagnosis and restoration proposed by G.V. Black does not serve well in the long term. When G.V. Black's restorative model was formulated, amalgam and gold were the primary restorative options, and the associated preparation techniques were based on the then available technologies and the requirements of the available restorative materials. The diagnostic model was the naked eye and a probe. Applying the current understanding of the ultrastructure of teeth in conjunction with modern diagnostic technologies, materials, adhesive techniques, and restorative approaches, dentists can now use minimally invasive biomimetic techniques to provide restorations that come close to functionally and biomechanically mimicking the original, healthy state of a tooth.

These advances started more than 25 years ago with a concept known as microdentistry, and one of the pioneers in this field was J.T. Rainey. His articles on dental microanatomy and micro-air abrasion were primary stepping stones and are now core to the biomimetic and bioemulation concepts currently taught in advanced restorative programs.\(^1\)\(^2\)

Concept of the compression dome

An early article describing the compression dome concept in association with biomechanical function addressed a previously unreported enamel fracture mechanism now described as occlusal effect caries.\(^3\) The problem is that teeth have been designed by nature primarily to withstand compressive loads. Teeth have not evolved to tolerate the damage that dentistry and high-speed

Fig 1. Stress patterns generated by a vertical load.\(^4\) The direction of the lines indicates the direction of the stresses, obliquely vertical in the enamel compression dome and horizontal in the dentin core. Increased width of the fringes indicates increased stress. Stress concentration can be seen at the dentinoenamel complex. Stress concentration occurs where the fringes are closer together, a contributory factor to cervical abfraction.
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**Fig 2.** Mesiodistal vertical fracture. A. Symptomless fracture in a mandibular second molar. B. A plunger cusp on the opposing maxillary second molar is creating a wedging effect, placing the distal half of the mandibular tooth into tension and generating the fracture.

**Fig 3.** Restoration of the vertical fracture shown in Fig 2. A. Initial adhesive onlay preparation and discrete dissection of the vertical fracture have been completed. B. The fracture outline was smoothed and an adhesive lithium disilicate onlay was bonded. The opposing plunger cusp has been modified to allow a shallow, smooth occlusal contour in the onlay, and the occlusion has been shifted to place a primarily compressive load on the existing mesial working cusp.

cutting equipment can cause. Once the occlusal surface is cut, the tooth can flex under compressive loads.

The enamel is designed to act as a compression dome, much like the dome of a cathedral, transforming and transferring loads, via the dentinoenamel complex (DEC), into a primarily compressive load in the dentin. The *dentinoenamel complex* is a new descriptive term for the dentinoenamel junction. The DEC is a complex interface between the enamel and dentin where the enamel develops a trabeculated structure and the underlying dentin does not develop a “normal” dentin structure for 2-300 μm below the enamel. This interface allows for stress transfer, thus protecting the dentin from damaging tensile stresses while maintaining compression in the dentin (Fig 1).

Once the enamel compression dome is violated, the underlying dentin is exposed to tensile forces it was not designed to handle. Disruption of the enamel compression dome leads to energy concentration in the dentin rather than energy dissipation.

Within the enamel compression dome, there are several microanatomical structures designed to absorb and distribute compressive loads, such as the peripheral rim of enamel, the subocclusal oblique transverse ridge, and the maxillary web of enamel. It has recently been reported that intracollogenous hydroxyapatite nanocrystals in the dentin collagen fibrils keep the fibrils in tension, essentially acting like prestressed reinforcing steel in concrete, keeping the surrounding hydroxyapatite hard structure in compression. The combination of this factor with the functioning of the DEC and the overlying intact enamel compression dome creates a dental structure that can last a lifetime.

**Disruption of the compression dome**

Once the integrity of the enamel compression dome is disrupted, the tooth can begin to flex and distort. Enamel is a complex structure in that it can behave like brittle glass and at the same time like a viscoelastic material. When intact and loaded, enamel has been shown to tip and rotate semi-independently of the underlying dentin due to the flexible nature of the DEC.

The underlying dentin is compressible by nature, yet it is overlaid by a strong but brittle material. These function in harmony to absorb and distribute applied forces. A commonly used material that incorporates both brittle and flexible materials to create something stronger than the individual components is the laminated glass in automobile windshields. Laminated glass is so strong that when it is bonded to the frame of the car, it becomes a critical component in the designed torsional rigidity of the chassis. If a stone strike causes a starburst chip and a small crack, this crack can be easily spread simply by pushing outward from the inside of the windshield. Such pressure puts the outside layer of glass into tension. Glass is only strong in compression, just like enamel.

It is this tensile phenomenon that creates the vertical fractures in the peripheral rim of enamel that leads to occlusal effect caries. Once the occlusal enamel has been disrupted by removal of essential cross-bracing structures, such as the subocclusal oblique transverse ridge, the underlying dentin distorts under lateral compressive loads on the enamel compression dome, causing the enamel at the marginal ridges to be placed into tension and creating an unstable vertical fracture.

Once the enamel compression dome has been violated, the most common failure observed is the oblique fracture that leads to the loss of the cusp. When the occlusal incline planes are loaded, the underlying dentin is placed into tension. The presence of a sharp internal line angle in a tooth acts as a stress concentrator, and over a period of time a crack begins to propagate, eventually leading to loss of the cusp. This failure is most commonly observed in teeth restored with amalgam but is equally prevalent in teeth restored with gold when the cusps have not been overlaid.
A less common but more dangerous tooth fracture is the mesiodistal vertical fracture most often associated with an opposing plunger cusp. These fractures can occur even in unrestored teeth and are further evidence that teeth do not cope well with tensile forces (Fig 2). Left alone, a fracture will eventually propagate to the pulp. Simple modification of the occlusion will not predictably stabilize the fracture and prevent further propagation. In the author’s opinion, the least invasive technique available to reestablish a stable compression dome is an adhesive lithium disilicate onlay (Fig 3).

**Restorative Implications**

To prevent the ongoing biomechanical degradation of a tooth, the primary goal is to avoid the need to mechanically interfere with the core integrity of the enamel compression dome. The need to interfere is essentially the result of the modern diet, which leads to a diseased biofilm that eventually causes caries. The primary goal in dentistry should be to help patients retain or regain a healthy biofilm.15,16

For decades dentists have been telling patients to brush, floss, and use fluoride, but within certain population demographics the incidence of caries and untreated carious lesions is still growing.15,16 In many areas of biology, it is readily apparent that changes cannot be forced, but, over time, human intervention can create a population or evolution shift. This applies to the health of the dental biofilm. Dentists have to help their patients “train” their oral biofilm back to health through pH management and dietary modification that will allow healthy commensals to repopulate the oral biofilm and replace disease-causing aciduric and acidogenic bacteria in the biofilm.17

Once the biofilm has been compromised, intervention eventually becomes necessary. The primary cavitation sites are the occlusal fissures. This area is also the critical zone required to maintain stability of the enamel compression dome. An early, accurate diagnosis made using one of the new diagnostic technologies allows for early intervention. The goal is to maintain the occlusal cross-bracing structures. For the past 20 years, the author has found that the most effective early intervention technique has been to completely debride the fissures, dissect out any damaged fissure enamel with fine-tipped micro-air abrasion (guided with a caries detection dye), and then restore the microcavities with an autocuring glass ionomer cement.19,20 To revisit the cathedral dome analogy, this approach would be similar to placing discrete windows within the dome that do not interfere with the energy compression pathways. If the window (cavity preparation) is too large, the associated instability could lead to collapse.

When intervention is delayed and the critical biomechanical tooth components are lost, a downward restorative spiral begins. Bonded restorations provide significant support to tooth function in that they help distribute forces, reducing the risk of fracture propagation.21 Amalgam-restored teeth fracture at a rate 7.5 times that of teeth restored with bonded composites.22

Teeth are often restored with a monophase technique, when the tooth in reality is a multiphase system combining enamel, which is a brittle material, bonded to dentin, which is a more yielding elastic material. To begin restoring function and stability to the compression dome, dentists need to consider replicating the natural, layered, laminated system. Materials and bonding systems are now evolving that offer options to more closely replicate the natural structure and energy distribution systems of teeth. With smaller restorations, simple monophase adhesive restorations are probably adequate. However, when there is greater damage, long-term success is more dependent on restabilizing the tooth and redirecting the forces as they occur in the natural compression dome system. Techniques that utilize fiber-reinforced composites to create laminated direct restorations and more complex stress-absorbing designs that use woven high–molecular weight polyethylene fibers have been recently developed and refined; these offer the potential to help protect the tooth from further stress-related degradation.23,24 Once the significance of the enamel compression dome and its protective function is understood and the concept is consistently applied in conjunction with modern adhesive restorative options, the phrase “you need a crown” may almost disappear from the professional lexicon.

The stability of compressive structures has been well understood over the millennia, and ancient engineers utilized these principles. Figure 4 shows an example of Incan engineering.
that demonstrates how these principles were applied. The stone block was a part of a 2000-year-old wall engineered to withstand earthquakes. When disturbed by an earthquake, these types of blocks are naturally self-centering and can reassemble themselves as they move. A marble placed on the surface of one of these blocks will roll to the center.

Figure 5 illustrates how these same principles are used in a basic adhesive ceramic onlay design. Even when not bonded, the restoration is self-centering, both mesiodistally and buccolingually. The marginal chamfer is kept above the height of contour and, when placed under load, transmits a compressive stress to the underlying dentin. This concept works only if a material with a high modulus of elasticity is used. Hybrid materials with a lower modulus will allow too much flexibility.

There are now materials and bonding systems that allow dentists to restore biomechanical function to the tooth without cutting away the sides of the tooth. This involves another new term in biomimetic dentistry, the bio-rim. The bio-rim is a layer of a posterior tooth that lies below the maximum point of convexity. If the occlusal enamel of a tooth is considered to be the cathedral compression dome, then the bio-rim is the walls supporting the dome. When the bio-rim is retained and an adhesive lithium disilicate onlay is placed on the tooth, the risk of fracture and the severity of any failure are reduced compared to the risk for a full crown that requires the removal of the bio-rim.

Compression dome adhesive ceramic onlay

There comes a point in the restorative continuum where internally bonded direct restorations reach their limitations. The biomechanical integrity of a tooth can now be restored without destroying the bio-rim, thanks to advances in materials and adhesives. Anecdotally, many operators using the compression dome adhesive ceramic onlay technique have noted a reduction in posttreatment endodontic indications when compared to teeth prepared for full ferrule crowns. This is most likely associated with the retention of the bio-rim, which maintains a greater distance between the preparation and the underlying pulp as well as significantly reduces the number of cut odontoblastic processes closer to the pulp. The severity of endodontic reactions depends more on remaining dentin thickness than on the type of preparation.

To recreate the enamel compression dome, simple cementation techniques have to be abandoned, and a commitment must be made to adhesively bond a ceramic, such as lithium disilicate, to the tooth. Over the past 9 years, the author has placed more than 3000 adhesive ceramic lithium disilicate onlays (Multilink Automix, Ivoclar Vivadent) based on the design concepts presented in this article and can report 2 fractured restorations and zero incidents of dentin debonding. The high-end bonding systems now available are coming close to replicating the strength of the natural enamel-dentin bond at the dentinoenamel complex. As a restorative material, lithium disilicate performs clinically as an equal to both metal-ceramic and veneered zirconia crowns. The primary advantage of lithium disilicate is that it can be adhesively bonded. In a recent clinically based study, the authors reported that:

The presence of a liner or base of glass-ionomer cement resulted in a risk for failure twice as large as that of restorations without liner or base material. Restorations performed with simplified adhesive systems (2-step etch-and-rinse and 1-step self-etch) presented a risk of failure 142% higher than restorations performed with adhesives with bonding resin as a separate step (3-step etch-and-rinse and 2-step self-etch).

Simple cementation or the use of a self-etching resin cement does not provide this laminated integrity, so the overlying restoration cannot behave as a compression dome. If adhesive
technology is combined with a high-strength ceramic onlay, such as lithium disilicate, to create a fully integrated, multiphase, laminated structure, the tooth can be restored to a biomechanical state close to its original state before it began to fail.

To successfully embrace the restorative concepts associated with the compression dome, there has to be a commitment to adhesive dentistry. Amalgam is not a good restorative material choice for trying to retain, restore, or recreate the integrity of the enamel compression dome. Similarly, the cementation of restorations, whether inlays or crowns, does not provide the adhesive support between the restoration and the tooth that is required for the reestablished restorative compression dome to function correctly. The natural enamel compression dome is “bonded” to the dentin and peripheral enamel. To replicate the natural design, ceramic onlay restorations should create the same type of bonded interface. By retaining the bio-rim and staying above the maximum point of convexity as much as possible, the preparation design for a compression dome adhesive ceramic onlay allows most, if not all, of the restorative margin to be placed on enamel, greatly increasing clinical performance.32

Success with adhesive ceramic onlay restorations is well documented in the literature.33,34 Arnetzl & Arnetzl reported a 93-month survival rate of 99.3% in 286 occlusal onlays made of Vita Mark II ceramic (VITA North America).35 Considering Vita Mark II has a compressive strength approximately one-third that of lithium disilicate, equal or better performances could reasonably be expected.35 Schulte et al reported 95% survival rates over a range of 9.5 years with IPS Empress ceramics (Ivoclar Vivadent), a material that is similar in strength to Vita Mark II.33,35 The success of these weaker materials, even in challenging adhesive onlay designs, can probably be attributed to the previously described adhesive lamination effect, whereby a brittle material such as ceramic or enamel can work in strain harmony with the underlying dentin and enamel when they are adhesively bonded together. A recent article eloquently describes the concepts of lithium disilicate adhesive onlays.37

**Conclusion**

The engineering world is focusing more and more on working out how nature has solved engineering problems. As a consequence, materials and design solutions are being developed to integrate what are often simple but elegant solutions. Clinicians can look at restorative dentistry from a similar perspective due to the new, more biomimetic materials and effective adhesives, creating the opportunity to revolutionize restorative approaches. The simple concept of visualizing a tooth as a complex compression dome system has created a different perspective, and new materials and improved adhesive technologies provide the opportunity to apply the concept in less invasive restorative options with the potential for increased performance and longevity.

**Author information**

Dr Millich is a recently retired private practitioner in Hamilton, New Zealand.

**Disclaimer**

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**References**