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THE "ABFRACTION – PARADOX" – A LITERATURE REVIEW ON BIOMECHANICS, DIAGNOSIS AND MANAGEMENT

Dental Science

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ABSTRACT

Non-carious cervical lesions (NCCLs) are pathological processes characterized by the hard tissue dental loss at the cemento–enamel junction (CEJ) independent of bacterial process. These non-carious processes may include abrasion, corrosion and possibly abfraction, acting alone or in combination. Abfraction lesions occurs due to repeated non-axial tooth loading that can cause cuspal flexure and stress concentration at the cervical region of teeth leading to break away of tooth structure. There is theoretical evidence existing in support of abfraction but very little experimental evidence is available today. Understanding the biomechanics involved in development of abfraction lesions is important for the diagnosis and management. The objective of this article is to critically review the literature about concept of abfraction and their management.

KEYWORDS

Abfraction, Non-carious cervical lesion, Cervical restoration

Introduction

Non-carious cervical lesions (NCCLs) are pathological processes characterized by the hard tissue dental loss at the cement–enamel junction (CEJ) independent of bacterial process.[1, 2] This tooth structure loss is routinely seen and increasing commonly in dental clinical practice.[1, 3] These lesions vary from shallow grooves to broad dished-out lesions or large wedge-shaped defects with sharp internal and external line angles. Earlier, etiology of NCCLs have been ascribed to toothbrush and dentifrice abrasion alone or mainly due to acids and was termed "erosion". In 1991, Dr. Grippo[4] introduced the term "abfraction" based on work completed by McCoy[5] and Lee and Eakle.[6] Excessive non-axial forces results from masticatory system, malpositioned teeth and bruxism causes flexure of teeth that leads to disruption of the prismatic structure at the site of least resistance, namely, the tooth cervix.[4] The word "abfraction" was derived from the Latin word which means " to break away" It was postulated that abfraction lesions were caused by flexure of the tooth during loading, leading to fatigue of the enamel and dentin at a location away from the point of loading occurring most commonly in the cervical region of the teeth. Presently it is considered that, NCCLs can be either due to abrasion, corrosion and abfraction occurring independently or together. Non-axial forces on occlusal and palatal guiding surfaces of teeth in an acid environment may increase the damage at the cervical margin. In an *in vitro* study, 8% of the test teeth developed abfraction-like lesions under stress when exposed to 10% sulphuric acid. None of the control teeth that were placed in 10% sulphuric acid without occlusal loading developed such lesions.[7, 8] NCCLs with reported prevalence ranging from 5–85%[9], increased with age suggesting a fatigue component in their formation associated with occlusal interferences or any event that changes the dental occlusion, such as tooth occlusal surface wear, restorative procedures, altered tooth position and tooth brushing behavior.

History

Miller (1907) reported that erosion was caused by weak acids or gritty tooth powders, or by both.[10] G.V. Black- described about wedge shaped areas of erosion named keilformige defect in his first volume, titled "Pathology of the Hard Tissues of the Teeth". McCoy (1983) proposed that bruxism produced most of the destructive lateral forces on tooth structure and discussed occlusal equilibration as a way to reduce lateral forces. Lee and Eakle (1984) described lateral forces as the cause of the breakdown of tooth structure. Grippo in 1991 stated that either static or cyclic forces can cause abfraction. Lambert and Lindenmuth (1994) proposed occlusal stress as a primary factor in the creation and progression of cervical notch lesions which is also termed as idiopathic erosion.. McCoy (1995) stated that vertical forces (compressive) were less harmful because they provide axial stimulation to the teeth and bone. Horizontal forces (tensile), however, were extremely damaging, because they subjected teeth and bone to torquing and offloading.

Etiology

Mc Coy postulated that alternating tensile and compressive stresses cause weakening of enamel, dentin and when this cyclic tension and compression reaches a fatigue limit, there occurs cracking and breakdown of tooth structure. The tensile stresses created at CEJ pull apart enamel prisms and increases susceptibility to chemical erosion. Occlusal interferences, premature contacts, parafunctional habits of bruxism and clenching all tend to contribute as stresses transmitted by occlusal loading forces.

Damaging lateral forces caused by occlusion: Occlusal interferences, premature contacts, bruxism, clenching and malocclusions may act as stressors. Gibbs et al. found that occlusal forces during swallowing and mastication account for only approximately 40 percent of the maximal bite force. As the duration and magnitude of forces during bruxism are much greater than those during functional activity, it is more likely that parafunctional habits would result in micro-fracture rather than function[11] (Fig 1).

Damaging lateral force caused by abnormal tongue activity: Suit et al. reported that tooth contact occurs on average for only 194 milliseconds during mastication and for 683 milliseconds during swallowing[12]. According to Straub and Kydd, tooth contact during swallowing occurs 2,400 times daily. Excessive pressure from tongue movements also contribute to development of abfraction lesions though this theory requires more experimental evidence.

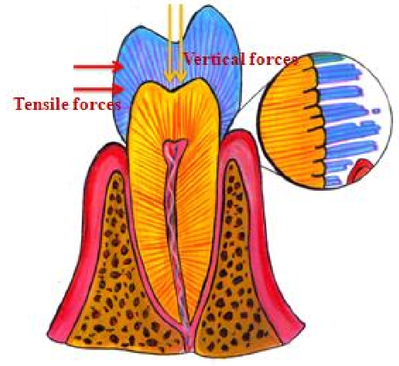

Fig.1. Microfracture of enamel due to repeated flexural loading.

Combined mechanisms of tooth wear

Though abrasion, erosion and abfraction act independently, combined mechanisms occur frequently during the dynamics of interocclusal activity[13] (Fig. 2).

- **Attrition-** Abfraction is the joint action of stress and friction when teeth are in tooth-to-tooth contact, as in bruxism or repetitive clenching.
- **Abrasion-** Abfraction is the loss of tooth substance caused by friction from an external material on an area in which stress concentration due to loading forces may cause tooth substance to break away.
- **Corrosion –** Abfraction is the loss of tooth substance due to the synergistic action of a chemical corrodent on areas of stress concentration[10,14].

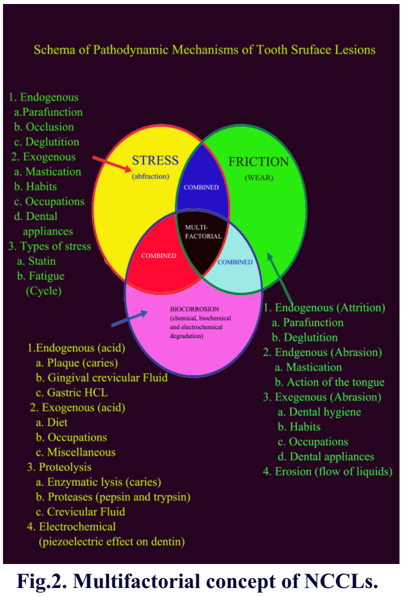

Fig.2. Multifactorial concept of NCCLs.

Etiopathogensis

Lee and Eakle hypothesized that the primary etiological factor in cervical lesions was the impact of tensile stress from mastication and malocclusion.[6] Normally, during mastication, while mandible moves from working side to centric occlusion, lingual slopes of the maxillary cusps contact buccal slopes of the mandibular cusps. This contact serves as an inclined plane and forces are generated perpendicular to the tangents drawn from the respective cusps (Fig. 2). These lateral forces are resolved into vertical components of forces which are directed along the long axis of the tooth and they are well tolerated due to their compressive nature, whereas transverse component forces (non-axial) produce compressive stress on the side towards which the tooth bends and the tensile stress is on the other side. Stresses are four times higher under lateral loading compared with axial loading.[14] Maximum stresses are caused by non-axial loading, which are concentrated at the buccal cervical region exceeding the maximum tensile strength of enamel (<17 Mpa).[15] These tensile forces cause disruption of chemical bonds between hydroxyapatite crystals of enamel and dentin (Fig. 3).

In addition, the CEJ is usually subjected to erosion and abrasion, caused by acidic exposure and tooth brushing, respectively, which further weaken and undermine the structure of cervical enamel and dentine[3,16]. McCoy[5] proposed that bruxism could be the primary cause for abfraction and tooth flexure from tensile stresses leading to cervical tooth breakdown[5]. Considering that the duration and magnitude of forces during bruxism are much greater than those during functional activity and it is more likely that parafunction would result in such a process rather than function[17].

Other mechanisms of abfraction

When a tooth is subjected to tension or compression, electric potential gradient is generated in different regions of the tooth. The so called piezoelectric effect may accelerate loss of tooth substance[18].

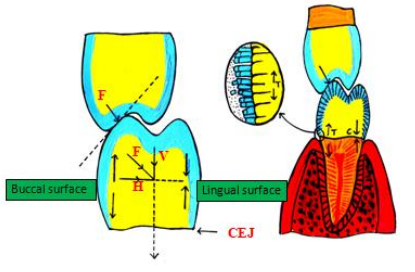

Fig.3. Diagrammatic represention of forces at cuspal inclines (F) resolved into horizontal (H) and vertical component (V) acting on tooth.

Types of abfraction

Grippo described five types of enamel abfraction and ten types of dentin abfraction.[4]

Enamel abfration

- **Hairline cracks-** visible minute cracks accentuated with transmitted light.
- **Striations –** irregular horizontal bands of enamel that have abfracted due to molecular breakdown, termed as "molecular slip planes", or lines of luder.
- **Saucer-shaped –** an abfraction entirely within enamel.
- **Semilunar -** these are crescent shaped lesion.
- **Cusp tip invagination –** depression seen on occlusal surface of molars and bicuspids, seen as invagination into dentin.

Dentin abfractions

- **Gingival –** deep, sharp angular notches at gingival margin on facial surface referred as Mc Coy notches.
- **Circumferential -** completely around cervical portion of teeth
- **Multiple –** two or more grooves on one surface.
- **Sub gingival –** groove or notch below the gingival.
- **Lingual –** occurs on lingual surface near CEJ, either horizontal or angular.
- **Interproximal -** seen on rotated teeth.
- **Alternate –** abfraction occurs on a tooth but adjacent one is unaffected.
- **Angular –** an abfractive lesion seen at 45 degrees angle.
- **Crown margin –** abfractive lesion beneath prosthetic crowns.
- **Restorative margins –** occurs gingival to all types of restorations without signs of tooth brush abrasion.

Factors influencing abfraction

Hereditary composition of enamel, dentin and the bond strength of the hydroxyapatite crystal structures within the tooth influences the severity of abfraction lesions. Mandibular premolars have the highest risk for developing wedge shaped defects, followed by the maxillary premolars. Anatomical disadvantage of premolars such as the furcation adjacent to the cervical region, marked grooves on root and crown, as well as cervical constriction of the crown and low crown volume makes premolars more susceptible to abfraction .[19,20,21]

Abfraction lesions are commonly seen on facial aspect, but the lingual surfaces also should be affected. Katranji, Misch, and Wang reported that the thickness of the bone is consistently greater on the lingual than on buccal side.[22] When subjected to lateral forces acting from a facial to a lingual direction, tooth begins to tip lingually and must bend at the fulcrum, but cannot move bodily due to the thickness of the bone. This leads to the lingual CEJ area coming under compression and the facial

CEJ area under tension. Conversely, if the force acts from a lingual to a facial direction, the tooth can more likely tip bodily because of lesser bone volume/thickness on the facial and thus tensile stresses are not concentrated at the lingual CEJ to cause abfractive lesions.[23]

The location, frequency, duration of tooth contact determines the type and characteristics of the abfraction. Tall teeth with long roots and only cusp tip function tend to flex more than flat teeth with multiple contact points. Abfractions are less likely to occur on a tooth with diminished periodontal support, and if it does occur, must be more apically located. Vandana KL et al reported that with decreasing periodontal support, the location of the highest stress concentration tended to shift away from CEJ towards the apical dentin region.[24] Rees JS investigated the effect of occlusal restoration on the stress profile in the cervical region of a lower second premolar using two dimensional finite element stress analysis and concluded that the weakening effect of cavity preparation may contribute to the development of non-carious cervical tooth loss.[25]

The risk of developing abfractions increases with age, due to longstanding exposure to the risk factors, representing this pathology as a chronic condition.[20, 26] The increased risk of abfractions in tilted teeth can be explained by the altered occlusal contacts.[20] Occlusally restored teeth with inlays exhibited increased estimated risk of developing abfractions. Occlusal facets of scores 1 to 3 (method of ***Hugsons et al***) showed a significant effermation of abfractions. Reduced Hunter -Schreger band packing density in the cervical regions of the crown increases the risk of developing abfraction lesions in cervical region.[27]

Biomechanics of a class V cavity

Dislodgement of class V restorations is most common especially in area of stresses. According to earlier concepts, dislodgement of class V restoration is due to the pulling forces of sticky foods. The extrusion of a class V amalgam restoration was attributed to delayed expansion of amalgam due to water contamination. Heymann et al. in 1991 have suggested a tooth flexure theory to explain increased risk of failure of class V restorations. Gabel was the first to consider the effect of biomechanical forces on disruption of class V restorations. If the restoration is placed on tension side, tooth- restoration interface at the occlusal margin tends to open up and a wedge shaped defect is created between the tooth and the restoration (Fig 4a). If restoration is placed on compression side of tooth, restoration will move out of the cavity because of pressure applied onto it[28,29,30](Fig 4b).

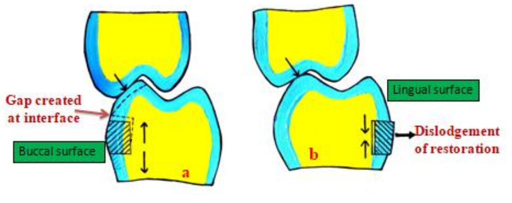

Fig. 4 (a & b) Biomechanics of class V restoration

Clinical characteristics of abfractions

Lee and Eakle described the characteristics of lesions that may result from tensile stresses[6]. Abfractions result in wedge shaped, irregular lesions, with well defined edges. These lesions are deeper than their width. Their internal angle can be sharp or more rounded[31].

Contributing factors causing erosion or abrasion can modify the clinical appearance of abfraction by making the angles less sharp and the outline broader and more saucer-shaped[32]. The size of the wedge defect is proportional to the intensity and frequency of the tensile forces applied to teeth**.** Magnitude of tensile stress is determined by the distance between the applied force and fulcrum[33].

Number of lesions that can develop on the same tooth depend upon the number of directions of lateral forces. If there are two differently directed lateral forces acting on the same tooth, the final lesion would be a combination of two lesions generated by each of the two forces. According to McCoy, lesions have sheen or polished glassy appearance. This characteristic appearance is explained by the fact that teeth are composed of collagen and when collagen is compressed, electricity is produced. Positive ions are emitted through focal points of high stress resulting in the polished effect.

Diagnosis

Complete medical and dental history and careful clinical examination are crucial to establish diagnosis of abfraction. Evaluation for any gastro-esophageal reflux disease, eating disorders, and dietary habits, occlusion, parafunction and oral habits including occupational and ritual behaviours plays a role in diagnosis. As abfraction is multi-factorial in nature, evaluation of all contributing factors should be done to differentiate abfraction from other NCCLs. Characteristic wedge shaped lesions and association of contributing factors gives a clue pointing to abfraction lesion. Sometimes the contributing factors leading to erosion or abrasion can alter the clinical manifestations of these lesions, by making the lesions appear more saucer shaped with blunt angles and broader outlines. Moreover, abfraction lesions may appear deeper than wider depending upon the stage of progression and related etiological factors.

Management of abfraction

Various treatment modalities for abfraction lesions have been proposed. Some modalities are designed specifically for abfraction lesions and others are used for NCCLs of all etiologies. The first and the foremost step in the treatment of abfraction lesions are diagnosis and removal of causative factor. Detailed history should be taken on aspects of brushing habits, parafunctional habits and dietary habits, gastric disturbances, drugs**,** radiotherapy, salivary gland dysfunction and work related exposure to acidic environments**.**

Monitoring of abfraction

When abfractive lesions are asymptomatic and are not affecting the esthetics and are shallow in depth (less than 1 mm), simply monitor them at regular intervals (e.g. six-monthly). Standardized intra-oral photographs, study models and measuring lesion dimensions are all potential approaches to monitor abfraction lesions.[33] A novel method of determining the activity of abfraction lesions over time is to undertake a scratch test. A number 12 scalpel blade is used to superficially scratch the tooth surface. Visual observation of the scratch will give an indication of the rate of the tooth structure loss. Loss of scratch definition or loss of the scratch altogether signifies active tooth structure loss.[34]

Occlusal adjustments

Theoretical evidences from finite element analysis studies shows associations between occlusal interferences and abfraction lesions, and between loading direction (influenced by cusp inclines) and unfavorable tensile stresses. Therefore, occlusal adjustment has been advised to prevent their initiation and progression and to minimize failure of cervical restorations. Occlusal adjustments may involve altering cuspal inclines, reducing heavy contacts, and removing premature contacts.[35] If occlusal adjustment is not done, restoration will then be subjected to the same bending movements as the unrestored abfraction, leading to marginal breakdown and dislodgment of restoration.

Lateral occlusal contacts present on the abfracted tooth can be determined with both the T-Scan and double sided Accufilm™ articulating paper. T- Scan provide information about how long, the abfracted tooth is in contact with opposing tooth during excursive movement. Patient is instructed to close completely on the sensor, holding teeth together[36] and direct the patient to make an excursion to the side of the abfracted tooth that is in need of restoration. Black side of Accufilm™ will mark occlusal contacts at complete mandibular closure. Red side of the Accufilm™ marks occlusal contacts during excursion movements. Adjustment is done by completely removing the red track marks, while leaving the full closure contact black marks. This process is repeated until only the black closure contact marks are present on the involved tooth. However, Wood et al reported that reducing occlusal load in lateral excursion movements does not appear to prevent the progression of abfraction.[37] Currently, there is a lack of evidence to support the trend that occlusal adjustment would alter the forces applied to tooth structure.

Restorative procedures

Isolation is mandatory in restoring abfraction lesion. Isolation can be achieved by various techniques like, rubber dam, gingival retraction cords, and in some cases gingival surgery may be required to expose the gingival margin of the cavity.[35] Restorative material used for NCCLs should resist flexural forces efficiently and should be able to withstand degradation due to erosion, tooth brush abrasion and it should be able to bond effectively to dentin and cementum. Traditionally, amalgam, direct gold, porcelain crowns were used.

Presently composites, compomers, glass-ionomers cement (GIC), resin modified glass ionomers (RMGIC) and a combination of glass-ionomer and composite in sandwich technique are frequently used.

The advantages of using glass ionomer cement as class V restorative material includes its biocompatibility, fluoride release, good bonding, and coefficient of thermal expansion closer to that of the tooth. Lambrechts et al showed that retention rate for glass-ionomer cement restorations is between 90 to 100% after three years of clinical evaluation.[38] Hence, GICs are the material of choice to be used in the cervical area. But limitations of GIC in class V restorations are high solubility during initial setting and low wear resistance. Ichim et al (2007) reported fracture and dislodgment induced failure of cervical GIC restorations at the cervical margin under parafunctional loads. It also shows that prior to fracture the GIC restorative material undergoes strain softening, which in turn introduces damage and weakens the materials involved.[39]

The limitations of conventional GICs are overcome by resin-modifed GICs (RMGICs). Adeleke et al reported that retention rate at the end of twelve months for RMGIC was 91.0% and resin composite was 74.1%. The high retention rate for RMGIC can be attributed to better chemical bonding to tooth and less stress and gap formation from thermal expansion and contraction.[40] Brackett et al conducted a study to compare the clinical performance of a polyacid-modified resin-based composite and a resin-modified glass-ionomer restorative material in abfraction lesions over 1 year and found that the retention rate was 84% with compomer and 100% with RMGIC.[41]

Indira priyadarshini et al reported high retention rates with RMGIC and Ketac Nano restorations when compared to Giomer, in non carious cervical lesions. This may be due to low elastc modulus of Ketac Nano and RMGIC when compared to Giomer. Materials with low elastic modulus are intended to flex with the tooth and better resist the cervical flexure in NCCLs without debonding.[42] Bollu et al compared microleakage in cervical cavities restored with nano- ionomer, resin modified glass ionomer and giomer and found the least microleakage score for nano-ionomer, while giomer exhibited the highest microleakage score.[43] Srirekha et al reported that when nano-RMGIC was taken into consideration, it developed least stresses in the cervical region of tooth with and without occlusal restoration. This may be due to low modulus of elasticity of nano-RMGIC that allows deformation and flexing of the material under occlusal loading.[44]

Vandelwalle and Vigil recommend that NCCLs suspected of being caused primarily by abfraction, should be restored with a microfilled resin composite that has a low modulus of elasticity, as it will flex with the tooth without compromising retention.[45] Flowable composites are recommended in NCCLs due to their low modulus of elasticity that exhibits more flexibility under occlusal stress in the cervical areas.[46] Shaalan et al reported from their meta-analysis that flowable composites acts as stress absorbers and allow the material to be more flexible to occlusal stress and prevent dislodgement of restoration.[47] However, long term clinical studies are sparse and thus should be conducted to evaluate performance of various restorative materials for abfraction lesions.

Conclusion

The critical aetiological factors of tooth wear appear to be the mechanisms of stress, chemical degradation and friction. Understanding these mechanisms, their possible interactions and manifestations enables to diagnose this complex, multifactorial aetiology of these tooth surface lesions. By taking thorough history and careful evaluation, a successful diagnosis can be arrived and an effective treatment planning be instituted.

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