Effect of silver diamine fluoride and potassium iodide on shear bond strength of composite resin to caries affected dentin

(IN VITRO STUDY)

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Dedication

I sincerely dedicate this work to the soul of my father

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List of abbreviations

SDF	Silver Diamine Fluoride
WHO	World Health organization
FDA	Food Drug Administration
KI	Potassium Iodide
GIC	Glass Inomer Cement
DEJ	Dentino Enamel Junction
MMP	Matrix Metalo Proteinase
Non-CD	Non Cariogenic Discoloration
CD	Cariogenic Discoloration
FTIR	Afourier transform infrared imaging
EPMA	Electron probe micro analysis
Mg	Magnesium
Ca	Calcium
P	Phosphorus
ART	A traumatic restorative technique
RI-GIC	Reinforced glass inomer cement
SSC	Stainless Steel Crown
PPM	Part Per Million
$AgNO_3$	Sliver Nitrate
$AgNH_3$-NO_3	Ammonical Silver nitrate
AgF	Silver Fluoride
Ag^+	Silver Ion
Ag	Metallic Silver
DNA	Deoxyribonucleic Acid
SBS	Shear Bond Strength

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Abstract

Silver diamine fluoride (SDF) solution gains popularity in clinical practice. Little known whether its combination with potassium iodide (KI) will affect adhesion to dentin and does KI reverse silver diamine fluoride staining

Aim: the aim of this study was to investigate the effect of silver diamine fluoride and potassium iodide treatment on the bond strength of composite resin to artificial caries affected dentin and effect of KI on dentin discoloration caused by SDF.

Material and methods: 90 dentin samples prepared of 2mm thickness were prepared from extracted human molars and divided into three groups(n=30) based on dentin surface treatment as follows:(1) SDF pretreatment of dentin ;(2)SDF+KI pretreatment of dentin;(3) dentin without treatment color assessment was recorded. Composite resin was built on all samples and shear bond strength was tested.

Result: pretreatment of affected dentin with SDF, SDF+KI increased SBS and statically significant. Potassium iodide following SDF masked discoloration of affected dentin caused by SDF.

Conclusion: pretreatment of affected dentin with SDF, SDF+KI doesn’t adversely affect shear bond strength (SBS) of composite resin and it was statically significant and treatment of affected dentin with KI immediately after SDF treatment significantly reduced the discoloration caused by SDF.

Key words: silver diamine fluoride, potassium iodide, affected dentin, discoloration, shear bond strength

Chapter 1

Introduction

1. Introduction

Dental caries defined as a localized, pathological process due to multiple factors, that cause softening and destruction of the dental hard tissues proceeding to the formation of cavities on the tooth surface and it continues to be a prevalent disease all over the world .(1)

In recent years, the development of restorative materials and advancement in our conception of the caries process have created the capability to practice in consideration of a minimally invasive dentistry philosophy. (2) The concept of minimum intervention is based on performing management with as little of dental tissue loss as possible without causing any destruction to the adjacent healthy tooth tissues .(3)

Dentin caries lesion is comprising of two different layers: an outer layer which is called infected dentin and an inner layer called affected dentin.(4) The outer layer has been regarded as being highly demineralized and exhibiting irreversible denatured collagen fibrils with an obvious disappearance of cross-linkages, whereas the inner layer is not infected with bacteria and is partially demineralized and physiologically remineralizable .(5)

Caries-affected dentin should be preserved in clinical treatment based on the philosophy of minimally invasive dentistry. Consequently, caries-affected dentin other than normal dentin has commonly been the bonding substrate in clinical settings. (6)

Dental caries continues to remain a global health problem, despite various advancements in the dental care. As the philosophy of caries management has changed from a surgical approach to a medical model, and managing caries as a disease. (7) A variety of chemical agents have been developed with the aim of arresting dentin caries. (8)

Silver containing compounds have proved to be successful antimicrobial agents, with one of these compounds being silver diamine fluoride (SDF). SDF was introduced by Yamaga *et al.,* in 1960's .[9]

Recent studies reported that topical application of SDF can be considered a cost effective, simple and non-invasive technique for caries management.[10-12] Also Laboratory studies reported that SDF exhibited a high anti-bacterial effect on cariogenic biofilm [13] and inhibited the effect of matrix metallo-proteinase .[14]

SDF action can increase mineral density of the carious enamel lesions and the micro- hardness of the carious dentin lesions.[15,16] A literature review reported that SDF is considered safe and an effective caries preventive agent that seems to meet the criteria of the WHO millennium goals and the FDA US institute .[17]

Demineralized dentin occurred due to acid produced by cariogenic biofilm. SDF application is recommended as a mean to inhibit further dentin demineralization and collagen degradation in addition to promoting remineralization.[18-19] Despite its benefits, SDF application is often clinically limited due to formation of dark stains within tooth structure caused by silver deposition that can lead to esthetic concern.[11]

SDF has a major adverse effect which represented in production of the black stain or discoloration of the underlying tooth structure because of the reaction of SDF products with tooth tissues and because of this inherent property, it has not been widely accepted by patients with aesthetic concerns.[20] Two alternative approaches have been suggested to minimize this side-effect. One of them is to use a saturated potassium iodide (KI) solution, which can react with residual silver ions, to eliminate the staining effect .The other alternative is to apply GICs or composites over SDF to mask the stained carious lesion and as a direct restoration after application of SDF .[21]

The clinical success of restorative materials depends upon a good adhesion with dentinal surface to resist various dislodging forces acting within the oral cavity. [22] These forces are measured in terms of compressive strength, tensile strength, and shear strength. Shear bond strength is the resistance to forces that slides restorative material past tooth structure and for that it assumes much importance to the restorative material clinically because of the fact that the major dislodging forces at the tooth restoration interface have shearing effect.[23] Therefore, higher shear bond strength implies better bonding of the material to tooth.

Though compressive and tensile strengths are important parameters to be evaluated but in the present study, we have evaluated shear bond strength as it assumes much importance to the restorative material clinically because of the fact that the major dislodging forces at the tooth restoration interface have shearing effect .[23]

On the other hand, authors postulated that there is insufficient evidence to show the effect of the application of KI after SDF treatment on the bond strength of composite on caries-affected dentin. [24]

So, the objectives of this study are to measure and compare the shear bond strength of composite resin to carious dentin before and after treatment with a 38% silver diamine fluoride and potassium iodide (SDF+KI)

Chapter 2

Literature Review

2. Literature Review

2.1. Overview of tooth structures

The human teeth develop and take their position into the jaw following a highly organized process. [25] The teeth consist of an outer part, which is known as enamel for the part around the crown and cementum for the part surrounding the root surface. The cementum is involved in the attachment of the tooth with the surrounding bone. Teeth are composed of three different mineralized tissues which are cementum, dentin, and enamel. [26] Dentin is softer and more flexible than the enamel and therefore it has a supportive role. The applied forces from the enamel are transferred to dentine through the dentino-enamel junction (DEJ).[26 The pulp lies in the center of the tooth and contains nerves and the blood supply of the tooth and is usually not mineralized. [25, 26]

2.2. Histology of dental enamel

The enamel is a highly mineralized tissue and is considered to be the hardest tissue in the human body produced by enamel-forming cells called ameloblasts during amelogensis process.[27] Enamel consists of well organized hydroxyapatite crystallites, which form the enamel prisms. [27] This process has a first stage of enamel deposition followed by a second stage, which is enamel maturation. [28]

Several enamel matrix proteins are involved in the mineralization of the enamel where the vast majority of those proteins (90%) belong to the amelogenin group, while the rest of them are proline-rich, non-amelogenins, tuftelin or other serum proteins. [27]

2.3. Histology of dentin

Dentin is a hydrated biological complex structure and is considered a mineralized connective tissue. (29, 30) It is composed of 50 w/w % of calcium deficient apatite. Dentin is formed by odontoblasts derived from the ectomesenchymal cells. (31 These cells are responsible for the development of the predentin matrix, which contains type I collagen. The organic part of dentin represents 30 w/w %. which mainly formed of proteases, proteoglycans, non-collagenous proteins such as dentine sialoproteins, bone-morphogenic proteins, phosphoryns and insulin-like growth factors. (32) Various enzymes are incorporated into human dentin and are responsible for the degradation of dentine collagen matrix proteins including type I collagen. (33)

After the deposition of primary dentin at the time of tooth development, odontoblasts continue to gradually deposit secondary dentin throughout life if their functioning ability remains undisrupted by external factors. It is believed that in the presence of any injury-like challenges the so-called reactionary dentine is produced, not only by the surviving odontoblasts, but also by other cells that can be found in the subsequent zone, if more severe changes occur, pulp-derived stem or progenitor cells differentiate into mineralized dentine matrix-producing odontoblast-like cells and they deposit the reparative dentin. (34)

Another important characteristic of the dentine is the presence of the dentinal tubules which may vary in number and size, depending on the area of the tooth, with lower density near the dentine-enamel junction (DEJ) and highest number as well as larger diameter near the pulp.(30) They are formed by the mineralization mechanism of odontoblast cells and represent tracks that start from the DEJ or cementum up to the pulp chamber. (30)

Throughout life, the human dentition may exposed to various tooth disorders among them dental caries.

2.4. Dental Caries

2.4.1. Definition

The term dental caries is being used to describe both the clinical manifestation of caries as well as the carious lesion .[35] Fejerskov 1997 stated that dental caries reflects the symptoms of the disease, either it is past or ongoing .[36] Generally, demineralization or destruction of dental hard tissues as a result of bacteria comes under the term dental caries. [36] However, there are different stages of tooth decay that can distinguished, and might afford different treatment approaches. Most commonly, dental caries starts from enamel and the initial lesion may appear as a small white lesion or chucky appearance where demineralization has occurred with undamaged surface, which with more caries spreading into dentin, cavity formation may be found. In cases of no visible cavity formation, such dentinal lesions are referred to as hidden caries lesions. [37]

2.4.2 .Prevalence

Dental caries is a multifactorial, sugar and plaque-dependent chronic disease that affects many individuals and it is considered to be one of the most common chronic diseases affecting the populations around the globe.[38,39] The prevalence of oral diseases has a considerable economic impact on health care provision across the world with dental caries affecting over 80 % of the population in many countries which has a significant influence on quality of life due to pain and discomfort, as well as implications for systemic health.[40,41]

A decline in caries has been observed in most industrialized countries over the past 20 years which are attributed to effective use of fluorides, together with changing lifestyles and improved self-care practices. While in developing countries, little, if any, importance is given to preventive or restorative dental care and teeth are often left untreated or even extracted to relieve pain or discomfort .[42,43]

Overall, 50 % of children have one or more decayed primary teeth by the end of toddler age. Healthy teeth in childhood have an important role in the eruption of healthy permanent teeth, healthy nutrition, and one's aesthetic appearance. [44, 45] The World Health Organization (WHO) has represented the early childhood caries as a worldwide problem with a prevalence of between 60 and 90%. [46, 47]

2.4.3. Aetiology of dental caries

Dental caries is undoubtedly a disease that can be prevented. [40] One of the main factors responsible for the development of dental caries is the biofilm created in the tooth surface. [38] The biofilm, known as dental plaque, if left on the teeth, can lead to the disturbance of the balance between pathological and protective factors in the oral cavity and subsequently to demineralization of the enamel and creation of the caries cavity. [38]

Factors associated with dental caries etiology include the increased consumption of sugars and inadequate exposure to fluoride. [48, 49] Salivary secretion rate can also play an important role. [36] Recent studies are also investigating the impact of genes in caries susceptibility, Matrix metalloproteinase (MMPs) and their inhibitors have been implicated in the dental caries process and the levels of heritability have been shown to reach 40 % to 60%. [50] dental caries is a dynamic process in which the bacteria residing the biofilm causes a drop in the pH of the oral cavity due to acid production by fermentation process leading to the dissolution of hydroxyapatite of enamel and dentine surfaces. [51-53]

2.4.4. Caries into enamel

The occlusal surface of the teeth is highly affected by dental caries due to the presence of pits and fissures which act as plaque accumulating shelter due to the difficulty to disturb the biofilm formation and plaque removal.(54) Occlusal discoloration can be seen on the pits and fissures of teeth as an early sign of dental caries. Which is known as non- cariogenic discoloration (Non-CD). Non-CD refers to the attachment of staining chromogens to sound tooth surfaces, while Cariogenic discoloration (CD) on the other hand, represents the discoloration of porous structures due to bacterial metabolites and mineral loss from the enamel surface. (54)

When the caries process is initiated in the enamel, mineral loss takes place, starting from the surface of the tooth. Specifically, if dental plaque remains in the tooth surface without being removed for two weeks, the "white-spot lesion" can be seen in the enamel surface. If this lasts for a longer period of time such as three to four weeks , then the enamel surface presents a more opaque and matte lesion, visible even without air-drying of the surface. (55) White or brown opacities can be observed on the occlusal surfaces as a result of the difference in the refractive index between the sound and carious areas of the tooth. (54)

2.4.5 Caries into dentine

Histologically and clinically, the caries lesion of the dentin has been characterized as having two layers. The first layer is called "the infected zone". This is the outer zone of the lesion which stains with caries-detector dye where the dentin is found highly demineralized and the collagen is denatured and heavily infected with bacteria.

The second one, which lies beneath the infected zone, is characterized as the "affected zone". In the affected zone, which does not stain with a caries-detector dye, the dentin is demineralized, however the collagen is still intact and minimally infected. [37]

2.4.6. Characteristic features of caries-affected dentin

2.4.6.1. Inorganic phase

This mineral phase of dentin is mainly composed of carbonate-rich hydroxyapatite. The dentinal caries process consists of dynamic, repeated periods of demineralization and remineralization.[55] A Fourier-transform infrared imaging (FTIR) study has shown that the mineral phase of caries affected dentin is less crystalline and has a lower mineral content than normal dentin.[56] Micro-Raman spectroscopy investigation has suggested that the relative intensity of the mineral carbonate decreased dramatically in caries-affected dentin.[57] Electron probe microanalysis (EPMA) revealed that caries-affected dentin, as well as caries-infected dentin showed much lower magnesium (Mg) content compared with intact dentin, although the densities of calcium (Ca) and phosphorus (P) in caries affected dentin were relatively similar to intact dentin .[58] The reduction in Mg content in dentin starts before the commencement of a decrease in Ca and P content in dentinal caries.[59,60] Changes in Mg content could be the first sign of carious demineralization and may indicate a loss of peritubular dentin matrix. Moreover, mineral crystals in caries-affected dentin are scattered and randomly distributed, with larger apatite crystallites and wider inter crystalline spaces compared with intact dentin .[61]

2.4.6.2. Organic phase

The dentin organic matrix contains different extracellular proteins, such as type I collagen, proteoglycans, dentin phosphoproteins and sialoprotein. Changes in dentin organic matrix associated with caries have been reported. [62]

In the inner layer (caries-affected dentin), the general pattern of amino acid composition shows no significant differences from intact dentin [62]. In addition, the reducible intermolecular covalent cross-links of the collagen are partly shifted to the precursor form, thus leading to decreased cross-links-but this change is reversible, and the 67- nm cross-bands of the collagen fibrils remain. These results support the idea that caries-affected dentin is remineralizable. [63]

Continuous deposition of minerals within the lumen of the tubules will lead to their occluding which render the refractivity of this layer similar to that of the intertubular dentin and give transparent layer. [63]

2.4.6.3.Water content

the water content of normal dentin is approximately 10%, whereas that of caries-affected dentin shows a higher value, which varies from 14% to 53% [64]

2.4.7. Recurrent caries

The term recurrent caries is used in order to describe the caries developed in the margins of a restoration. This lesion occurs after the initial caries has been removed and the cavity has been filled with a restorative material. It is therefore referred to as secondary caries lesion. [65]

Some approaches have been proposed over the years for prevention from secondary caries lesions. Placing the margins of the restoration in an area that would be easily accessed by the toothbrush in order to maintain appropriate oral hygiene has been one of these approaches for many years. More recently though, the approaches lean towards fluoride releasing restorative materials, which have been proposed for the prevention of secondary caries in the margins of restorations. [66]

2.5. Management of dental caries

Complete removal of the carious demineralized dentine followed by the restoration of the cavity with filling materials has been the traditional way of managing dental caries for a long period of time. [67] The conventional methods can lead to unnecessary tooth structure loss and greater risk of pulp involvement or symptoms of pulpitis following restoration. [68] While non-vital teeth have been shown to be more prone to fractures. [69] Further Limitations of the more invasive approach include the need to use local anesthesia, hand pieces for the caries removal and highly trained dental professionals .[70]

With the development of new dental restorative materials and advances in adhesive dentistry, a better understanding of the caries process and the tooth’s potential for remineralization and changes in caries prevalence and progression, the management of dental caries has developed from G.V. Black’s extension for prevention to minimally invasive.[3]

This concept includes early detection of lesions; individual caries risk assessment; nonsurgical interventions; and a modified surgical approach that includes delayed restoration, lesser tooth preparations with modified cavity designs and adhesive dental materials and repair rather than replacement of failing restorations aiming to preservation of natural tooth structure.[3] Several approaches such as a Stepwise excavation, partial caries removal, a traumatic Restorative Technique (ART) the Hall Crown Technique and SDF are increasingly more evidence based. According to these approaches only part of the caries lesion is being removed, while the harder more intact caries is left behind in order to avoid pulp exposure. [68, 71, 72]

2.5.1. Stepwise excavation technique

In stepwise excavation the soft carious dentine is removed from the margins and as much as possible also removed from the cavity, with caution in order to avoid exposing the pulp. The remaining lesion is covered with an antimicrobial material usually calcium hydroxide and a few months later the cavity is accessed again and the remaining dentine is reviewed. (67)

Hayashi et al., 2011 in their research found that stepwise excavation is effective for pulp preservation in extremely deep caries and leads to a high clinical success rate, the remaining lesion was found hard and remineralised in most of the cases and pulp vitality was preserved .(73)

2.5.2. A traumatic Restorative Technique (ART)

A traumatic Restorative Technique (ART) was firstly introduced by the dentist Jo Frencken in 1985, Tanzania (Frencken et al., 1996). (74) It was implemented in order to overcome the above-mentioned disadvantages of the conventional more invasive approaches of caries management. The concept behind this technique is that the carious dentine is removed with the use of excavators (hand-instruments) only, followed by restoration with adhesive materials, such as composite, GIC or RM-GIC (Tyas, 2000). This results in a more conservative way of managing the carious lesion, and preserving the maximum amount of sound tooth structure. (75)

Adequate sealing of the remaining, intact, remineralisable dentine is important in order to prevent mineral loss out of the lesion and acid penetration from the bacteria of the biofilms. (69)

2.5.3 The Hall Technique

The Hall Technique has been another minimally invasive approach of restoring the primary teeth .The Hall technique is a conservative alternative treatment of carious primary molars developed by Dr. Norna Hall in the 1980s. The Hall technique uses stainless steel crowns (SSC) to seal over carious lesions on primary molars using glass ionomer cement with no caries removal, no crown preparation, and no local anesthesia. (76)

The technique had initially caused controversy due to the lack of understanding how leaving all the carious tissues and the associated bacteria below a crown could lead to favorable outcomes. (76) Nowadays, there is evidence that can explain the above results along with the results of other minimally invasive techniques based on the fact that caries concept has moved from that of an infectious disease, towards that of a biofilm driven disease.(77)

According to Hall Technique, when a carious primary tooth has no clinical or radiographic symptoms, the tooth can be sealed with a preformed metal crown without the prior removal of caries from the cavity. Space can be created with the use of an orthodontic separator and the crown is placed without prior use of a hand piece or local anesthesia. It has been shown that sealing the caries below the preformed metal crown can slow down the progress of the lesion .(71)

2.5.4. Fluoride agents for caries management:

Fluoride is commonly and widely used to prevent and even arrest caries. As a low-cost and easily operated treatment, the professionally applied topical fluoride was approved for preventing dental caries and remineralizing early enamel caries and even arrest dentine caries.The modern caries-management philosophy has changed from the traditional surgical approach to a medical model, which includes the use of fluoride therapy and antimicrobial agents. (78)

Rather than focusing on restorative care, the bacterial infection should be considered, develop an effective strategy to treat the bacterial component of caries, and prevent further infectivity which can be facilitated with the use of fluoride agents. Sodium fluoride is one of the most common fluoride agents used for promoting the remineralization of enamel and dentine. Sodium fluoride varnish containing 2.26% (22,600 ppm) fluoride is known to be effective in caries prevention and has been used for this purpose for decades .[79]

Sodium fluoride varnish is considered one of the most effective means of delivering fluoride for two reasons. First, it allows a high-concentration application of fluoride and hence minimizes the amount to be ingested. Second, the varnish theoretically prolongs the contact time of the fluoride to the tooth surfaces. Thus, the slow release of fluoride can avoid the immediate loss of fluoride after application. The American Dental Association recommends that high-risk patients should receive fluoride varnish applications at three to six months intervals .[80]

The topical application of 5% sodium fluoride varnish remineralised early enamel caries and white spot lesions [81] Although a complete understanding of the mechanism of fluoride action in dental caries is still being researched, it has been found that fluoride application on tooth surface produces calcium fluoride-like globules. [82] These globules are stabilized by protein phosphate and are fairly insoluble in the mouth. They act as a reservoir of fluoride at neutral acidity (pH). The dissolution rate of these globules increases when the pH is lowered during cariogenic challenges. Fluoride is released, which increases the saturation of calcium and phosphate ions in plaque fluid by lowering the solubility constant of the calcium and phosphate ions. [82] It was reported that sodium fluoride helps to prevent the dissolution of calcium and phosphate from the tooth mineral and/or increases the rate of remineralsation or reprecipitation of the lost minerals and hence Fluoride can remineralize caries at early stages by forming Fluor- apatite and being incorporated into the demineralized enamel. [83]

2.5. 5. Caries management by silver compounds

Historically the use of silver in dentistry ages back to China in 659 A.D. [84] It was used not only for its material properties, but also for the long-known antimicrobial effects Silver has been accepted as an antimicrobial material for thousands of years. People in ancient Mexico used silver to make containers for storing water and food. A Roman pharmacopoeia written in 69 B.C. mentioned the use of silver as a disinfectant. [84] Since the 1800s, silver (Ag) has been used both in dentistry and medicine for its anticaries, antimicrobial and antirheumatic properties. In the 1900s, silver compounds were popular treatments for tetanus and rheumatism and before antibiotics were invented, clinicians attempted to treat colds and gonorrhea by utilizing silver compounds before antibiotics were invented .[85] In the 1930s, penicillin and other antibiotics appeared and health professionals discovered that antibiotics were superior to silver compounds for their efficacy of fighting infections and their easy of manufacture. Owing to these reasons, research and clinical interest in silver greatly reduced. [86] However, in the 1970s, interest in silver compounds reappeared, due to the emergence of antibacterial resistance of some antibiotics. Silver is again favored as an antimicrobial agent due to its broad spectrum, low toxicity and lack of cross-spectrum bacterial resistance. [87, 88]

Silver compounds, such as silver nitrate ($AgNO3$), and silver sulphadiazine have been used as topical antibacterial agents for controlling skin infections encountered in burns and chronic ulcers. Silver sulphadiazine has even become the gold standard in topical burn treatment. [88]

In dentistry, silver compounds have been used as early as the 1840s, when silver nitrate was used for reducing the incidence of caries in the primary dentition. Later it was used as a caries preventing agent for permanent molars, a cavity sterilizing agent and as a dentine desensitizer. In the 1960s, silver was advocated to combine with fluoride as an anticaries agent presumably for a combined beneficial effect. However, the clinical application of silver fluoride compounds has been limited due to the black staining associated with caries lesions. [16]

2.5.6. Silver nitrate

Silver nitrate is one of the most common silver salts and has antibacterial properties which have been widely used in medicine. Silver nitrate solution is a colorless and odorless solution which used as a cauterizing agent in medicine for treating burned wounds, umbilical granulomas and warts. [89]

In the late 19th century, silver nitrate was used to treat venereal disease. [90] A solution of 1% silver nitrate was used as eye drops for newborn babies to protect their eyes from the transmission of gonorrhea from mothers during birth. [90] It has long been a common antimicrobial agent for medical use because of its broad spectrum of antibacterial activity, lack of bacterial resistance, and low toxicity.[88] However, the use of silver nitrate became subsidiary when penicillin and other antibiotics were introduced in the 1950s. The use of $AgNO_3$ was reported in the 1840s and appears to be the first silver compound used for arresting caries. [91,92] It was claimed that in vitro $AgNO_3$ could interact with ivory to form a barrier, which might have a caries preventing effect on dentine surfaces.[93] In 1917, a simple procedure of generating metallic silver was reported, and was later known as Howe's ammoniacal silver nitrate solution ($AgNH_3NO_3$). Metallic silver within Howe's solution was believed to penetrate into affected dentine, and have an antibacterial effect. [94] And based on this phenomena it became a popular cavity sterilization agent although it was not proven clinically, it was even advocated for endodontic treatment of unmanageable cases. [95]

Howe's solution was used up to the 1950s; however, doubts of its clinical efficacy and possible adverse effects on the pulp were mentioned by several researchers. The observed claims were that ammoniacal silver nitrate had a self-limiting action and stained only carious dentine thereby not affecting the vitality of the pulp. [96-98]

2.5.7. Silver fluoride

It is a neutral colored solution having silver ions and fluoride ions. It is highly alkaline PH: 11. No significant difference was found in the bacterial-inhibiting potency among $AgNO_3$, AgF and electronic-generated silver ion. [99] The major inhibitory product is the silver ion and no other anions. It was also reported that AgF rapidly lethal to Streptococcus mutans at a concentration of 200 ppm while at 20 ppm, 3–4 h were required.[99]

2.5.8 .Silver diamine Fluoride (SDF)

2.5.8.1. Historical Over View of SDF

Till late 1960s and 1970s, SDF was not much exposed to other parts of the world other than Japan,it was approved for use as a therapeutic agent in Japan in the 1960s. [100] it has also been used in Argentina, Australia, Brazil and China for many years to treat dental caries. In 2014, the US Food and Drug Administration (FDA) cleared the first SDF product for use in the USA. [16]

Since 1969, SDF has been used to arrest caries of the primary teeth in children, prevent pit and fissure caries of the erupting permanent molars and prevent root caries in elderly people.[101] Apart from caries management, SDF is also used to treat tooth hypersensitivity and to sterilize infected root canals.[102]

2.5.8.2. Composition

Silver diamine fluoride (SDF), is a colorless alkaline solution containing diamine-silver ion and fluoride ion. Diamine-silver ion is a complex with two ammonia molecules attached to a silver ion, which makes it more stable and less oxidizing than silver ion. (11) The combination of silver and fluoride in an alkaline solution has a synergistic effect in arresting dentine caries, which makes SDF different from other fluoride agents. (101) SDF can inhibit demineralization and preserve the collagen in dentine from degradation. (102) It was reported that SDF exhibited a significant increase in micro hardness of the underneath tooth structure due to the presence of the high levels of calcium and phosphorus in the outmost surface layer of the SDF arrested dentine caries lesion. (29,30) Additionally, SDF can react with calcium and phosphate ions to produce fluoro- hydroxyapatite with reduced solubility, which is considered as one of the main factors in arresting caries.(31)

2.5.8.3 Mechanism of action of SDF

The exact role and the mechanism of action of SDF are still unclear. The possible mode of action might be associated with its interaction with tooth tissue, as well as its antibacterial ability on cariogenic bacteria which reduces the growth of cariogenic bacteria. (103) The silver ion is bactericidal due to incorporation of silver ions which have bactericidal effect, furthermore, the SDF can also remineralize both enamel and dentine caries. The possible mode of action of SDF for arresting caries may be attributed to its inhibition of mineral demineralization, promotion of mineralization and protection of the collagen matrix from degradation (103).

2.5.8.4. Actions of SDF on cariogenic bacteria

Silver ions (Ag+) are expected to have antibacterial effects whereas metallic silver (Ag or Ag^0) is relatively inert. However, metallic silver can interact with moisture in the oral environment and subsequently release silver ions which are the crucial point for the antibacterial effects on pathogenic organisms. (93) Silver ions have been suggested to have the following three main antibacterial effects: destruction of cell wall structure; denaturation of cytoplasmic enzyme and inhibition of microbical DNA replication. (104)

Silver ions can bind with disulphide in membrane proteins; thereby allowing easy penetration through membranes. (105) it is also reported that silver ions can bind with negatively-charged peptidoglycans in the bacterial cell wall, and disrupt membrane transport functions which in turn leads to cellular distortion and loss of viability. (106) Silver ions can bind to sulfhydryl groups of cysteine which is essential for enzymes activities. (107) such interactions with cysteine could inhibit enzyme activities, disrupt metabolic processes and eventually cause death of the microbe. (108)

In dentistry, silver compounds were reported to oxidize thiol groups, thus reduce acidogenicity of dental plaque. (109) In addition to that silver ions can also attach to guanine, which is a major component of DNA, thus disable the replication ability of bacteria. (110)

2.5.8.5. Effects of SDF on tooth tissues

According to Shimizu, 1974 when SDF is applied on dentin, its permeability reduced and electric resistance enhanced. He also reported that silver and its compounds from SDF application blocked the diffusion of acid and invasion of microorganisms into the dentinal tubules. (111) additionally, obturation of the dentinal tubules decreased the surface area of dentin, which may be attacked by caries. It has also been seen that the use of 38% SDF repressed demineralization and preserved collagen from degradation in demineralized dentin. [112] The other mechanisms could be the cariostatic action of products produced by reaction between SDF and minerals of the tooth. The fluoride improved the resistance of the dentin to the acid and reduced its penetration into inner dentin. [113] when SDF is applied to dentin under in vivo conditions, its fluoride ions penetrated to a depth of 50–100 μ. [114]

It has been proved that SDF reacts with hydroxyapatite of tooth to release calcium fluoride and silver phosphate, resulting in hardening of affected dentin. The silver phosphate that is formed on the tooth is insoluble to acid attacks. The calcium fluoride formed as a reaction product becomes a pool of fluoride ions for the formation of fluorapatite. [115] it was also proved that fluoride ions enhances calcification of tooth, and restores lattice imperfection. [116] and improves the crystallinity of Hydroxyapetite. [117] the anti-enzymatic actions of the reaction products between SDF and organic component of the tooth can be the next mechanism of action for caries arrest. Its antibacterial properties arise from inhibition of the enzyme activities and dextran induced agglutination of cariogenic strains of Streptococcus mutans. [118] Resistance of dentin to trypsin increased when SDF was applied on tooth surface. [119] Also, a study reported that resistance to collagenase and trypsin for dentin proteins increased after treating the tooth with SDF. [120]

2.6. Bonding to caries affected dentin:

Dentin adhesive systems have dramatically developed during the past decades. In a Prepared cavity for an adhesive composite restoration, large areas of the cavity floor are composed of caries-affected dentin after removal of caries-infected dentin, not normal dentin. [121] Caries-affected dentin is different in morphological, chemical and physical characteristics from normal dentin. Therefore, caries-affected dentin still has problems as bonding substrate compared with normal dentin. As it was confirmed previously, caries-affected dentin produces lower bond strength and poor quality of the hybrid layer than normal dentin. In addition, when the adhesive interface of caries-affected dentin exposed to oral environment, the poor quality of the hybrid layer would compromise the longevity of the composite restoration due to hydrolysis of the resin and collagen fibrils. The improvement of bonding potential to caries-affected dentin could lead to reinforcement of tooth-composite restoration complex. (121) As minerals are lost from the dentin matrix during the carious process, its volume is replaced by water. On the other hand, permeability of caries-affected dentin decreases due to occlusion of the tubules, Tagami et al., 1992 found young carious molars were only 14% as permeable as young normal dentin and suggested that the transparent layer would be effective in decreasing permeability. (122)

Caries-affected dentin produces lower bond strengths than normal dentin, regardless of the type of adhesive system.(123) Cohesive failure of specimens in dentin increases in resin bonded caries-affected dentin. A reduction in the cohesive strength of caries-affected dentin would be one of the reasons for lower bond strength values to caries-affected dentin compared with normal dentin. On the other hand, Wei *et al.*,2008 demonstrated that when analyzing the effect of dentin type normal and caries-affected dentin on bond strength after removing the variance for which hardness accounted as a covariate, it was found that the condition of dentin had a significant effect on bond strength: even if normal and caries-affected dentin had similar intertubular hardness, bond strength to caries-affected dentin would still be significantly lower than to normal dentin. (124)

The change in chemical and morphological characteristics of caries affected dentin would be also reasons for the lower bond strength. The hybrid layers created to caries-affected dentin are thicker than those of normal dentin, because caries affected dentin is more susceptible to the acid etching due to partially demineralization, resulting in the formation of a deeper demineralized zone. [58]

The treatment of dental tissues prior to adhesive restorative procedures is an extremely important step in the bonding protocol and determines the clinical success of restorations. Dentin substrate is a complex structure which can influence the bonding of restorative systems; therefore, bonding to dentin surface is a greater challenge than to enamel surface. [137] The bond between dentin and composite is more micromechanical than chemical .[125] Preparation with rotating instruments produces a smear layer which contains hard particles, blood, bacteria and saliva . Acid etching dissolves the smear layer, demineralize the peritubular and intertubular dentin and exposes the collagen matrix. [126] The demineralized dentin is infiltrated by resin monomers to create a hybrid layer after their polymerization.[127]So, to create the hybrid layer, it is necessary to remove the smear layer and demineralize the superficial dentin layer. Etching exposes the collagen fiber network of the dentin matrix, thereby permitting infiltration of bonding agents into the spaces between fibers. The fibers are engulfed and the complex fiber–resin is polymerized providing improved micromechanical retention of resin polymers.[128] The bond strength of adhesive systems is one of the major factors to be considered in the placement of composite resins.[129]Adhesion of restorative materials to dental substrates is a desirable property because it is closely related to the prevention of material dislodgement and marginal leakage.[130]An effective adhesion to tooth structure is important to withstand the stresses resulting from polymerization shrinkage, thus retention and marginal integrity of restorations are preserved.[129]

The bonding mechanism of composite resin to acid-etched dentin is well known and understood to be micromechanical .[131,132]The formation of a hybrid layer and resin tags is essential to the establishment of a strong bond at the dentin level.[133] and may be achieved by complete dissolution of the smear layer and demineralization of intertubular and peritubular dentin by means of acid etching, resulting in an exposed collagen matrix which is infiltrated by resin that polymerizes in situ.[132,134]

The development of adhesive technology has revolutionized restorative dentistry. Dental adhesive systems are commercially categorized into generations reflecting the handling technique or advances in formulations. [135] for dental adhesives bonding to dentine, there are two main approaches. One is depending on to completely remove the smear layer and superficial demineralized tissues by a strong acid, and the other is to partially dissolve and incorporate the smear layer into the adhesive interface by a mild or intermediate acid. Therefore, two main categories of adhesives, are known as etch-and-rinse and self-etch systems, are commercially available.[136] In the etch-and-rinse system, before application of primer and adhesive, an acid is used to etch the dental substrate and then followed by rinsing with water. In contrast, in the self-etch system, the acid etching and rinsing with water step is omitted, and a mild or intermediate acid is used to partially dissolve and modify the smear layer, and in both systems, adhesion is achieved by micromechanical retention to the underlying etched dental substrates. [136] an additional chemical bonding between dental substrates and adhesives can be observed in the self-etch system. [56, 57]

2.7. Effect of SDF and KI on bonding

The treatment of dental tissues prior to adhesive restorative procedures is an important step in the bonding protocol and determines the clinical success of restorations. Dentin is a complex structure which can influence the bonding of restorative systems. [137]

Knight *et al.,* 2006 evaluated the effect of SDF and KI on the bond strength of auto cure glass ionomer cement to dentin and found that application of SDF/KI following by washing away of the precipitate and air drying, created bond strengths that were not significantly different to conditioned samples while leaving the precipitate Agf/KI on the dentin surface significantly reduced the bond strength of auto-cure glass ionomer cement to dentin. [20]

Another study by Quock *et al.,* 2012 concluded that there was no significant difference between the self etch and etch and rinse bond strengths for the control groups with no SDF treatment and the groups treated with 38% SDF solution. [2]

As concluded by Wu *et al.,* 2016 dentin pretreating with 38 % silver diamine fluoride does not affect the bonding strength of composite resin to dentin. The fracture patterns suggested that bonding strength might be stronger between the adhesive and the SDF-applied dentin. Their data suggested that SDF can be used as a dentin pretreatment prior to resin restoration possibly contributing to secondary caries prevention in primary teeth. [138] A Study by Selvaraj et al. , 2016 showed that pretreatment of dentin with SDF/KI minimized nanoleakage at the resin-dentin interface without adversely affecting the bond strength of resin composite to dentin and may enhance adhesive resin bonding. [139] Koizumi et al., 2016 concluded that all dentin surfaces treated with SDF/KI prior to bonding showed a significant weakening in bond strength. [140]

Lutgen *et al.,* 2018 in their study evaluated micro tensile shear bond strength to sound human dentin treated with SDF for three adhesive systems following four different SDF application protocols SDF demonstrated a negative effect on bonding. [141] and the severity of which strongly correlated with the application protocol used. Rinsing after SDF application led to improved bond strength compared to non-rinsing groups. Removal of the superficial layer of SDF treated dentin recovered bond strength values similar to those observed for controls for multi-step adhesive protocols. [141]

Jiang *et al.,* 2020 mentioned that no firm conclusion can be drawn on the effect of SDF application on the bond strength of dentin to adhesives due to lack of a standard way to prepare specimen, including the SDF application protocol which was probably the reason to explain the variation. [142]

Evaluation of the micro-shear bond strength of total etch adhesives to pretreated dentin with SDF or SDF/KI and evaluation of the mode of bond failure under scanning microscope on a study performed by Sakr, 2020 concluded that pretreatment of dentin with either SDF or SDF/KI showed non-significant effect on micro-shear bond strength of resin composite to dentin. [143]

2.8. The anti-staining potential of KI

Previous clinical studies on SDF reported that it was common to have black stain on the arrested caries lesions which may cause an aesthetic concern. [144,145] it has been suggested that by applying a saturated solution of potassium iodide (KI) immediately after the application of silver fluoride, staining of the dentin caries lesion can be minimized while the caries arrest effect of silver fluoride is not affected. The proposed explanation is that the iodide ions from the KI solution will react with the excess silver ions from the silver fluoride solution to form a precipitate of silver iodide. [145]

The Study which carried by Miller *et al.,* 2016, assessed if there was a definite difference in staining of restorations in silver diamine fluoride treated teeth, with or without the subsequent application of potassium iodide (KI) the authors reported that there was no significant differences between the two groups. So they concluded that the application of potassium iodide after silver diamine fluoride on caries-affected teeth may improve initial esthetic appearance, but after placement of a glass ionomer restoration, potassium iodide did not seem to result in any significant difference in staining. [146]

Nguyen *et al.,* 2017 found that treatments of teeth with KI solution after SDF treatment significantly reduced the discoloration caused by SDF. [147]

Zhao *et al.,* 2017 found that SDF + KI treatment caused a perceptible staining at the restoration margin, but the intensity was less than that with purely SDF treatment. Silver ions in the SDF solution can blacken the tooth structure. It was suggested that the KI solution can react with SDF to form a bright yellow solid compound (silver iodide) and this reaction could reduce the excess free silver ions which result in the black staining Although the bright yellow precipitates can be seen after the application of KI, the staining of tooth surfaces could still be detected in SDF + KI treatment group. [148]

While KI was supposed to remove the staining caused by SDF, its effect has not been previously quantified. One possible explanation may be that the amount of the applied KI solution was not sufficient to produce an excess of free silver ions remaining. Besides that, silver iodide is considered to be highly photosensitive which can dissociate into metallic silver and iodine by exposure to light. Moreover, in the long term, it was not effective in preventing discoloration of the restoration margin, but could reduce staining compared to that of SDF. (138)

Patel *et al.,* 2018 concluded that the onset of black staining occurred within two minutes, was noticeable after five minutes, and increased in value for up to 6 h post application, use of KI immediately after SDF application resulted in no noticeable staining of the carious dentin or surrounding enamel and no significant differences were evident in the staining potential between the different SDF concentrations (38% and 12%), the root surface and cementum were found to stain darker and more readily when compared with the coronal enamel surface.(149)

Zhao *et al.,* 2019 in their study approved that the immediate application of KI solution after SDF treatment can reduce dentine discoloration caused by SDF. (6)

Garg *et al*., 2019 in their case reports confirmed that the application of KI helped to reverse staining caused by SDF to a large extent but restoration margins was still to be at risk of discoloration. They concluded that KI can help enhance the esthetic outcome by stain reduction, thus making SDF a mainstream choice for preventing caries. (150)

2.9. Color of the tooth

A tooth consists of multiple layers. Enamel and dentin have different optical properties. Dentin is high in value, Chroma, and fluorescence, and enamel is translucent and is low in Chroma and value. Generally speaking, enamel allows light to pass through and then it hits the dentin where dentin will reflect, absorb, or refract it. Therefore the color of a tooth is affected by both of these two structures but predominantly by dentin. (151)

2.9.1. Color systems

1. Munsell Color Order System:

One of the oldest available color order systems is the Munsell color order system. It was created in 1905 by Albert H. Munsell, who is considered the father of modern color classification. He was the first to separate color uniformly and independently into the three dimensions of hue, value, and Chroma and illustrate it systematically into three dimensional space. (152)

Parameters of color

The hue is the main component of color; it is what is usually referred to by the name of a color. It is derived from the three main primary colors: red, yellow, and blue that cannot be created by mixing other colors. (153)

Chroma refers to the saturation or intensity of the color. High Chroma refers to color that is intense and rich; low Chroma to color that appears faded and dull. (153)

Value refers to the brightness of a color and expressed as the lightness or darkness of the color. (153)

2. The CIE System

This system is developed by the International Commission on Illumination (Abbreviated CIE for its French name, Commission Internationale de l'éclairage) It is the most widely used system for color specification. Its principles are used for designing color measurement instruments and conversion of spectrophotometric readings to color parameters The First CIE color specification was introduced in 1931.(154)

3. CIE LAB

One of the most-used color spaces introduced by the CIE in 1976 is the CIE L*a*b*. [153] Three axes of the CIE LAB color space are the L* vertical axis and the* and b* horizontal axes with the neutral scale located in the center of the space. The L* represents the lightness/darkness of a color. It ranges from 0-100, where 0 is black and 100 is white.

The a* axis represents the relative redness-greenness of the color.

A positive value represents a shift towards red, and a negative value represents a shift towards green. The b* axis represents the relative yellowness-blueness of the color. A positive value represents a shift towards yellow, and a negative value represents a shift towards blue. Any color could be plotted in the color space by values of its three points. [153,155]

4. Color Difference Evaluation

The CIE LAB attributes can be used to calculate the color difference (ΔE) between two specimens. It can be calculated using the following equation: ΔECIELAB = (ΔL*2 + Δa*2 + Δb*2) ½ Where ΔL* is the difference in L values between the two specimens, Δa* is the difference in a values between the two specimens, and Δ b* is the difference in b values between the two specimens. [154,155]

The present study evaluated color measurement according to the CIE LAB color space.

2.9.2. Color Measurement devices

Color measurement devices are widely used as an objective method for Standardizing and quantifying color Such as colorimeters, Spectroradiometers, and spectrophotometers. Colorimeters provide color measurements in terms of three wavelengths of the visible spectrum.[155] On the other hand spectrophotometers measure color in all wavelengths of the spectrum, which renders them useful for absolute color measurements and color difference measurements. ([153]) Spectrophotometers are widely used to measure surface colors. The Spectrophotometer measures colors based on reflectance by calculating the ratio of reflected wavelengths of the target object to the wavelengths reflected from a white standard reference at intervals of 5, 10, or 20 nm of the visible spectrum. They are more stable and are the instruments of choice for surface color measurements. They can be used for evaluation of color difference. [(155)]

Chapter 3

Aim of the study

3. Aim of the study

This in vitro study was performed to investigate the effect of silver diamine fluoride (SDF) and Potassium Iodide (KI) treatment on the Shear bond strength (SBS) of composite resin to artificial caries affected dentin.

Objectives:

The objectives of the study were to investigate:

1. The effect of SDF and KI on bond strengths of composite resin bonded to artificial caries affected dentin.
2. The effect of (KI) potassium iodide on dentin discoloration caused by SDF application.

Chapter 4

Materials and Methods

4. Materials and Methods
4.1. Materials:

The materials and Armamentarium used in the study are presented in tables (1) & (2)

Table 1: materials used in the study

Material	Main component	Manufacture, lot No.	Applications
Adper Easy One universal-etching adhesive system	HEMA,Bis GMA,Methylacrylated phosphoric esters,1,6 hexanediol dimethacrylate, methacrylate functionalized polyalkenoic acid, silica filler ethanol, water, initiators, stabilizers.	3MESPE,Seefeld,Germany 406582.	The bottle was agitated and bond was applied onto dentin surfaces, After exposing to a gentle air stream, the adhesive was light cured for 10 seconds.
Filtek Z250 Microhybrid. Resin composite.	Resin matrix:Bis-GMA,UDMA,Bis-EMA Filler: zirconia/silica0.01-3.5µm, 60vol%-84wt%.	3MESPE, ST. Paul,MN,USA N210989.	±2mm light cured for40s at 600Mw/cm$^{2.}$
Silver diamine fluoride SDF.	38% Ag (NH3)2F Silver, Fluoride, Ammonia.	Mumbai 400 054 India.	Dentin surface treated with SDF using Micro brush.
Demineralized Solution.	2.2 µm Calcium Chloride, 2.2 NaH2PO4,5.05M acetic acid with PH4.4 adjusted with 1M KOH.	Chemical laboratory at faculty of pharmacy, Mansoura university, Egypt.	All samples immersed in demineralized solution for 7days.
Saturated Potassium Iodide(KI).	Potassium iodide A.R Assay 99.5% M.W 166.o1.	P21057/5.	Applied immediately after SDF.
Artificial saliva.	1 gram sodium carboxymthyle cellulose, 4.3 gram Xilotol, 0.1 gram potassium chloride, 40 milligram potassium phosphate, 1 milligram potassium thiocyanate and 100 milliletre de-ionized water.	Prepared at Chemical laboratory at (Faculty of PharmacyMansoura University, Egypt).	The specimens were stored in artificial saliva for one day.

Table 2: Armamentarium used in the study

N0.	Type	Manufacture	Uses
1.	Carbide abrasive paper 220-240 grit.	Federation of European products, Paris, France.	Teeth ground occlusally under water coolant to obtain a flat dentin surface.
2.	Low speed motorized drill.	2200-2800RPM, Impact drill, 19pcs CHINA.	Teeth ground occlusally under water coolant to obtain a flat dentin surface.
3.	Diamond coated disc.	Ernst Leitz GmbH,Wetzler,Germany.	Teeth cut perpendicular to long axis (2mm thickness).
4.	Light cure device	Cordless light emitting diode (LED) COXO DB-686 Latte fashan COXO medical instrument united kingdom): wave length420=480nm with light power: ≥1200WLCM2.	For light curing of the adhesive and composite resin.
5.	A computer controlled material testing machine.	Model, 3345; Instron Industrial products,Norwood,USA.	Shear bond strength Testing.
6.	Spectrophotometer.	Portable Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany.	For color assessment.

Figure1: Etching gel

Figure 2: Bonding system

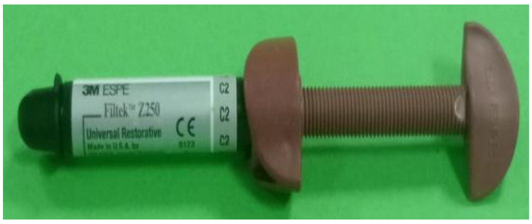


Figure 3: Composite resin

Figure 4: Silver diamine fluoride

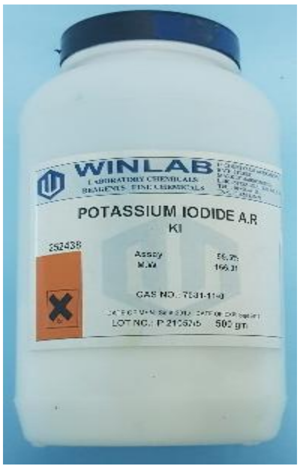


Figure 5: Potassium Iodide (KI)

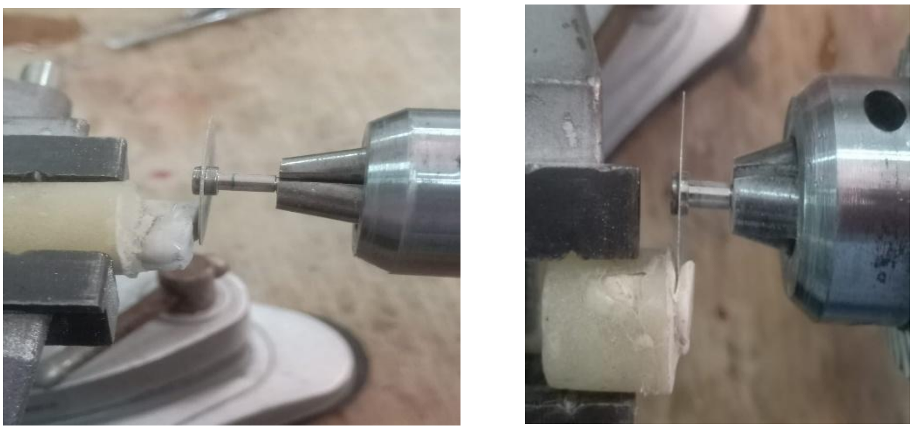
4.2 Methods

4.2.1 Sample collection

Sixty intact, non-carious extracted human molars were collected from dental polyclinic to be used in this study. Teeth were debrided from soft tissue with scaler. The teeth were stored in 0.5% Chloramine-T solution at room temperature up to one month till use.

4.2.2 .Sample preparation

1. Each tooth was mounted in acrylic resin up to the level of bifurcation area.
2. Each tooth was ground occlusally with silicone carbide abrasive paper 220-240 grit mounted in mandrill attached to low speed motorized drill under water coolant to remove the whole enamel surface and to obtain a flat dentin surface (Fig 6. (a&b)



(a) **(b)**

Figure 6 (a&b) :

a. Initial tooth grinding with silicon carbide abrasive paper.

b. Final stage of tooth grinding.

3. Sixty dentin discs (2mm thickness) were cut perpendicular to long axis of the tooth with low speed motorized coated disc.

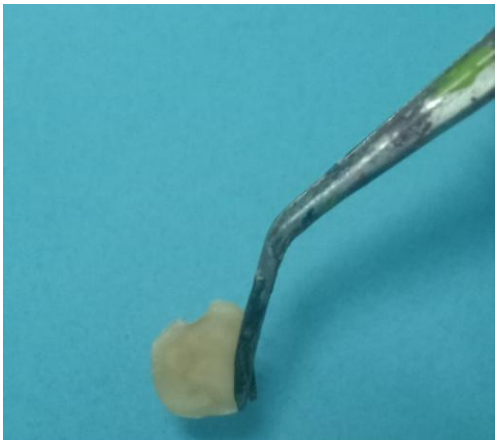


Figure 7: Dentin disc.

Figure 8: Sample thickness measured with APT

4. Each sample was embedded in a mold filled with cold-cure acrylic resin up to the level of 5mm from the sample thickness. Fig :(9, 10, 11)

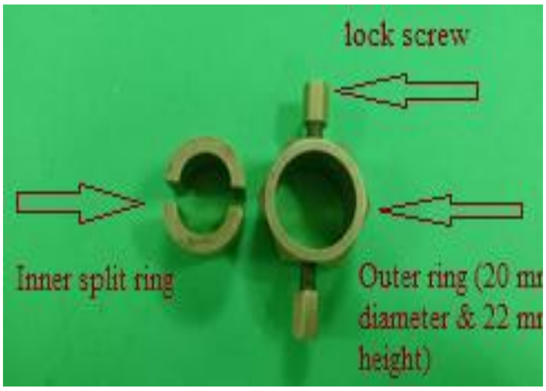


Figure 9: Parts of the metal mold used in the study

Figure 10: Mould after assembly

Figure 11: Sample of the dentin embedded in acrylic after removed from the mould.

4.2.3. Polishing of dentin sample

The surfaces of the dentin slices were polished with silicone carbide abrasive paper with different grits in ascending manner under running water.

(a) (b)

Figure 12:(a&b) a**.** Silicone abrasive paper

b**.** dentin slice polished

4.2.4. Surface demineralization

All samples were immersed in demineralized solution with ph 4.4

For 7 days. (Fig.13)

Figure 13**:** Demineralized solution.

4.2.5. Sample grouping

The 60 samples were allocated to three equal groups according to type of treatment with (n=20).

Group 1: A total number of 20 dentin specimens (n=20) were used and treated with SDF

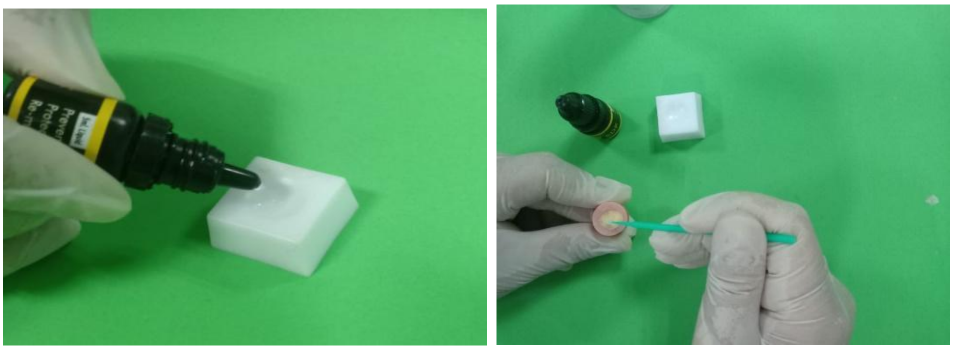
Group 2: A total number 20 dentin specimens (n=20) were treated with SDF followed by KI.

Group 3: Control group in which a total number 20 dentin specimens (n=20) were used with no treatment.

4.2.6. Material application

4.2.6.1. For SDF application (Group 1) fig. (14)

The demineralized dentin surfaces of all the specimens were treated with a 38% SDF.



(a) (b)

Figure 14: (a&b) SDF application

a. SDF was dispensed in aplastic dippen dish
b. Application of SDF on dentin sample using micro brush

4.2.6.2. For SDF+KI application, (Group 2) the demineralized surface was treated will be with SDF+KI. 38% SDF was applied to dentin slice using micro brush, immediately followed by a saturated KI solution until acreamy white solution turned clear. Then the reaction was washed off with distilled water. Fig. (14,15)

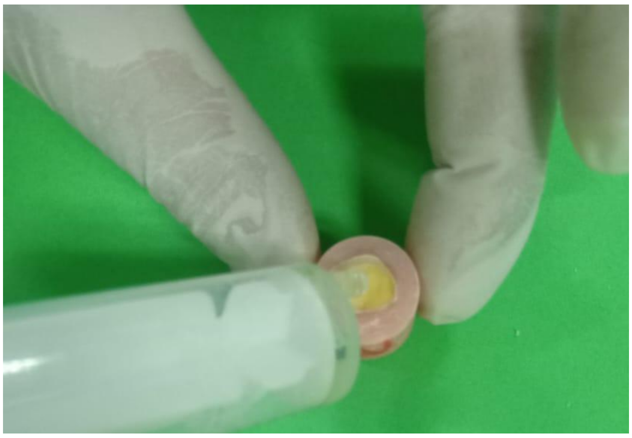


Figure 15: Saturated KI solution applied to dentin dis

4.2.6.3. Group 3 negative control group, the demineralized surface underwent water rinsing for few seconds.

4.3 Testing methods

4.3.1. Color assessment

Color assessments of dentine samples of all three groups were performed after one-day immersion in the artificial saliva.

The specimens' colors were measured using a portable Reflective spectrophotometer, fig 16 (a&b) the aperture size was set to 4 mm and the specimens were exactly aligned with the device. A white background was selected and measurements were made according to the CIE L*a*b* color space relative to the CIE standard illuminant D65. The color changes (ΔE) of the specimens were evaluated using the following formula:

$\Delta ECIELAB = (\Delta L*2 + \Delta a*2 + \Delta b*2)$ ½

Where: L* = lightness (0-100), a* = (change the color of the axis red/green) and b* = (color variation axis yellow/blue)

Figure: 16 (a&b)

a. Portable Reflective Spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany

b .Color measurement

4.4. For bond testing

4.4.1. Material application

All the dentin samples were treated with self-adhesive bonding system according to its manufacturer instructions. A Teflon mold with 2-mm height and 4-mm diameter were placed on the treated dentin surface and the composite material was packed inside. A glass slide was placed on the top of the Teflon mold under a steady pressure and photo -cured. Fig. (17-21)

Figure 17.

Figure 18.

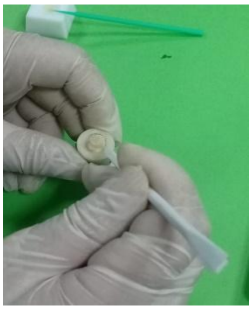


Figure19.

Figure 17**:** Etching of dentin sample with 37% phosphoric acid.

Figure 18**:** Dentin sample treated with bonding.

Figure 19: Composite application.

Figure 20: Photo cured of the composite resin.

Figure 21**:** The prepared Sample after removal of Teflon mould.

4.4.2. Shear Bond Strength Test procedure

A circular interface shear test was designed to evaluate the bond strength. All samples were individually and horizontally mounted on a computer controlled materials testing machine (Model 3345; Instron Industrial products, Norwood, USA) with a loadcell of 5 KN and data were recorded using computer software (Bluehill Lite; Instron Instruments). Samples were fixed in specially designed sample holder [rectangular metal block with central hole for sample housing] secured to the lower fixed compartment of testing machine by tightening screws. Shearing test was done by compressive mode of load applied at dentin-resin interface using a mono-beveled chisel shaped metallic rod attached to the upper movable compartment of testing machine traveling at cross-head speed of 0.5 mm/min. The load required to debonding was recorded in Newton.

Shear bond strength calculation:

The load at failure was divided by bonding area to express the bond strength in Mpa: $\tau = P / \pi r2$

Where: τ = shear bond strength (Mpa) P = load at failure (N))

π = 3.14 and r = radius of resin disc (mm)

Figure 22: Composite bonded to dentin sample mounted on testing machine Instron machine

4.4.3. Data Analysis

Data analysis was conducted using SPSS software (version 25).Summery statistics such as mean, standard deviation, minimum and maximum observations were used to describe the distribution of shear bond strength and color changes. Since data was not normally distributed, Kruskal Wallis test was applied to compare the three interventions used in the present study. Value for all statistical test was set at0.05 as a significant level.

Chapter 5

Results

5. Results

The purpose of this study was to determine the effect of SDF on the bonding efficacy of commonly used adhesive material for restorative procedures. SDF application protocols were investigated to determine which protocol resulted in the greatest bond strength. The next sections of results cover of the three interventions in terms of bonding strength, lightness and color changes.

5.1. Shear bond strength

Table 1 presents summary statistics of shear bond strength results (MPa) measured for all groups. The data were graphically drawn in figure 1. For ***control group*** the mean ± SD values were (***3.43± 1.61***) with minimum value (1.70 MPa) and maximum value (5.37 MPa), while for ***SDF treated group*** the mean ± SD values were (***6.11± 2.24*** MPa) with minimum value (2.35 MPa) and maximum value (8.43 MPa). The average values for ***SDF +KI treated group*** were (***6.06***± ***2.07*** MPa) with minimum value (2.99 MPa) and maximum value (8.32 MPa). Table 1 also shows the comparison of shear bond strength among study groups It was found that ***SDF treated group and SDF +KI treated group*** recorded a higher shear bond strength than that of the control group. The difference ***was statistically significant (p=0.026)***

Table 3: Descriptive statistics of shear bond strength results for all groups

		Control	SDF	SDF+KI	P value
N	Valid	8	10	10	
	Missing	2	0	0	
Mean		3.4343	6.1051	6.0600	
Std. Deviation		1.61021	2.23973	2.06728	0.026*
Minimum		1.70	2.45	2.99	
Maximum		5.37	8.43	8.32	

Kruskall wallis test was used to compare average values for study groups.

*; significant ($p<0.05$)

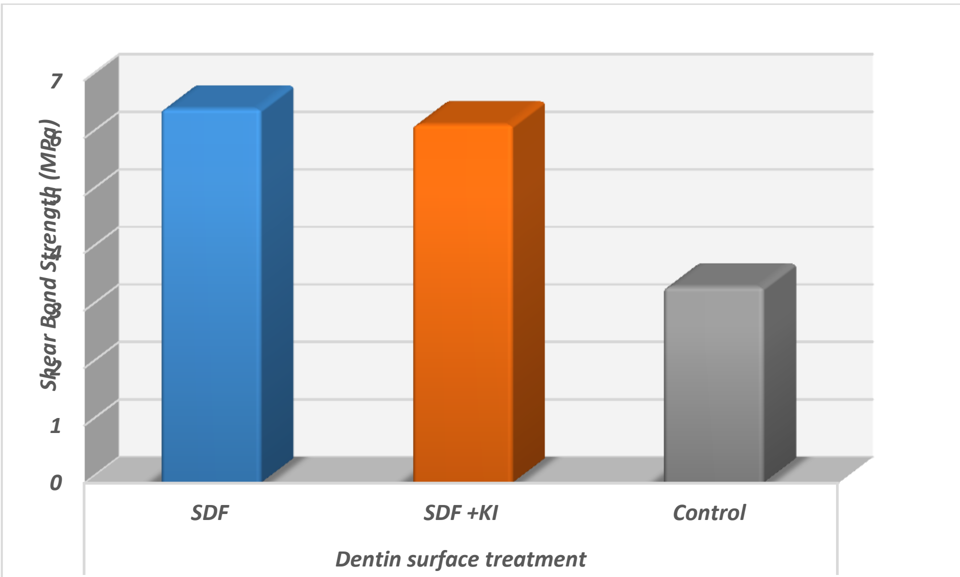


Figure 23: A column chart comparing shear bond strength mean values as function of dentin surface treatment type ranked from higher to lower

5.2. for Color assessment:

-Translucency (lightness-darkness) (ΔL):

(ΔL) results (Mean±SD) for all groups are summarized in table 2 and depicted in figure 2. The L* values of 0 to 100 represent a black and a white reference, respectively (Paravina, 2004). This coordinate is a measure of lightness-darkness of the material. Positive L* relates to the amount of lightness and negative values relate to darkness of the specimen. The greater the L* is, the lighter the specimen.

It was found that control group and ***SDF*** group recorded the most negative translucency change mean value (-3.08 ± 3.10 (ΔL)) and (-2.74 ± 3.34) respectively. On the other hand, SDF ***+KI*** group recorded the lowest translucency change mean value (-1.37 ± 5.96 (ΔL)). However, the differences were not statistically significant as indicted by (p=0.226)

Table 4: Comparison of translucency change mean values as function of dentin surface treatment type

	N	***Mean***	***Std. Deviation***	***P value***
SDF	***30***	***-2.7417***	***3.34855***	***0.226***
CONTROL	***30***	***-3.0800***	***3.10043***	
SDF+KI	***30***	***-1.3733***	***5.96900***	

-Redness-greenness change (∆a)

Redness-greenness change (∆a) results (Mean±SD) for all groups are summarized in table: 5. The a* values represent the redness-greenness (Paravina, 2004). Positive a* relates to the amount of redness and negative values relate to greenness of the specimen.

It was found that ***SDF*** group recorded statistically significant highest redness-greenness change mean value (1.95 ± 1.84 ∆a) followed by ***SDF +KI*** group (1.51 ± 2.53 ∆a) while ***control*** group recorded the lowest statistically significant redness-greenness change mean value (0.12 ± 1.78 ∆a) as indicted by one-way ANOVA followed by Tukey's post-hoc tests (p=<0.003, TURKY , p<0.05).

Table: 5 Comparison of redness-greenness change mean values as function of dentin surface treatment type

	N	*Mean*	*Std. Deviation*	*RANK*	*P VALUE*
SDF	***30***	***1.9533***	***1.84461***	***A***	***0.003***
CONTROL	***30***	***.1233***	***1.77874***	***B***	
SDF+KI	***30***	***1.5067***	***2.53934***	***A***	

Same letter in the same column indicating non-statistically significant difference (p > 0.05).
ns; non- significant (p>0.05) *; significant (p<0.05)

- Chroma (yellowness-blueness) change (∆b)

Chroma (yellowness-blueness) change (Δb) results (Mean±SD) for all groups are summarized in table: 6. the b* values represent the yellowness–blueness (Paravina, 2004). b* coordinate is a measure of the chroma along the yellow-blue axis. Positive b* values relate to the amount of yellowness, while negative values relate to blueness of the specimen

It was found that ***SDF +KI*** group recorded statistically significant highest chroma change mean value (8.55±3.87 Δb) followed by SDF group (2.21± 3.14 Δb) and ***control*** group, which recorded the lowest statistically significant chroma change mean value (1.84± 5.50 Δb) as indicted by one-way ANOVA followed by Tukey's post-hoc tests (p=<0.0001 <0.05) - in tables 6.

Table 6: Comparison of chroma change mean values as function of dentin surface treatment type

	N	Mean	Std. Deviation	***RANK***	***P VALUE***
SDF	30	2.2100	3.14485	***A***	<0.0001
CONTROL	30	1.8467	5.50835	***A***	
SDF+KI	30	8.5533	7.01716	***B***	

Same letter in the same column indicating non statistically significant difference (p > 0.05).
ns; non-significant (p>0.05) *; significant (p<0.05)

- ***Color changes*** test results measured in (ΔE)
- **(N.B. the clinically perceivable ΔE = 3.7)**

It was found that ***SDF +KI*** group recorded statistically significant highest color change mean value (11.91±4.95 ΔE) followed by ***control*** group and SDF groups (6.74±3.03 ΔE & 5.84± 2.44 ΔE), respectively. The difference between groups was significant (p=<0.0001, turkey <0.05).In table 7: and figure 24

Table7: Comparison of color change mean values as function of dentin surface treatment type

	N	Mean	Std. Deviation	Rank	P value
SDF	30	5.8403	2.44576	A	<0.0001
CONTROL	30	6.7613	3.02741	A	
SDF+KI	30	11.9087	4.95894	B	

- Same letter in the same column indicating non-statistically significant difference (p > 0.05). ns; non-significant (p>0.05) *; significant (p<0.05)

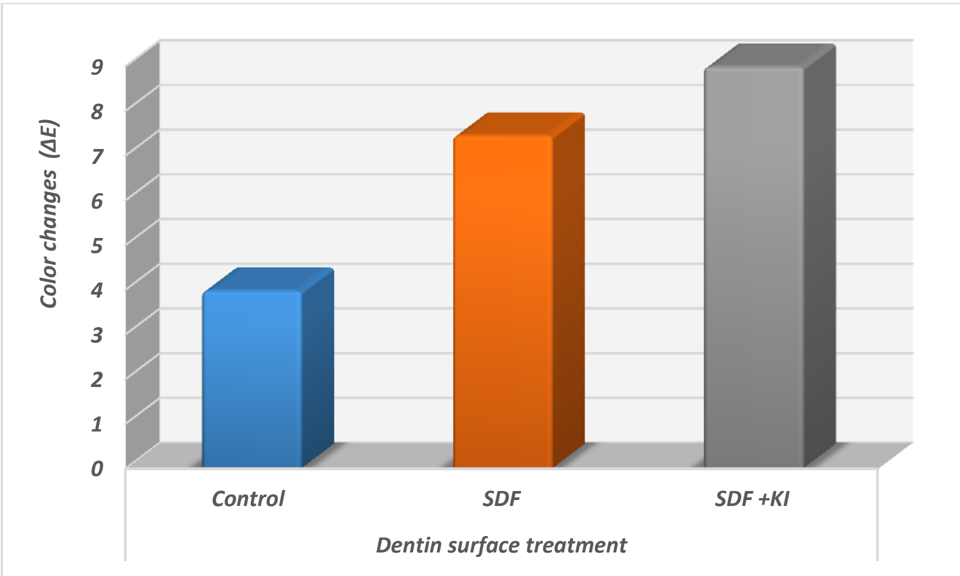


Figure 24: A column chart comparing color change mean values as function of dentin surface treatment type

Chapter 6
DISCUSSION

6. DISCUSSION:

Dental caries is the most common oral health problem worldwide affecting over 80% of the population in many countries and affects their quality of life.[38)] Dental caries is a multifactorial disease that is caused by host, bacteria and environmental factors. [(158)] The bacteria metabolize sugar and produce lactic acid that dissolves the calcium and phosphate in the tooth causing demineralization which occurs in the enamel or dentin of the tooth structure. [(159)]

The management philosophy of dental caries has been changed over the last century. Traditionally this process needed a purely surgical “drill and fill” approach, with the G.V. Black cavity design and the “extension for prevention” principles as its cornerstone [(160)]. However, an improved understanding of the pathophysiological processes of dental caries in recent years has led to the development of the Minimal Intervention Dentistry (MID), which emphasizes the critical importance of preserving the integrity of the natural tooth structure and adopts a biological approach in the management of caries lesions [(161-163)]. One such approach has been attributed to Nishino et al. [(164)], who described the caries-arresting properties of silver diamine fluoride (SDF) in 1969. A primary mechanism of the caries-arresting effect of SDF is its microbicidal effect on cariogenic biofilm [(165,166)]. The antimicrobial activity of SDF is mainly attributed to its elemental silver content. There are several ways in which silver exerts its antimicrobial effect. The clinical application of SDF has been rather limited to date. The main barrier appears to be the discoloration of arrested carious lesions associated with the application of SDF [(167)] due to obvious aesthetic reasons [(168)]. The staining that follows application of SDF is due to the precipitation of silver phosphate (Ag_3PO_4) [(100,168),]. To overcome this issue and expand the clinical use of SDF, Nguyo *et al.*, 2017 have proposed a method to overcome the staining due to SDF [(147)]. It demands the application of a layer of potassium iodide (KI) over the initial layer of SDF, which then reacts with the free silver ions in SDF and prevents the formation of silver phosphate precipitate. Since then, several studies have reported that the application of KI following SDF forms a yellow silver iodide precipitate and prevents black staining of teeth. [146-148] Detsomboonrat , et al.,2021 observed a significant immediate reduction in staining due to SDF by application of KI in a dose dependent manner. [169] Hence our study was performed to evaluate the influence of silver diamine fluoride on shear bond strength of composite resin to caries affected dentine and to assess the effect of (KI) potassium iodide on dentin discoloration caused by SDF application test the two objectives. A total of ninety intact non carious human molars were used in this study. The teeth divided into three groups. Each group consisted of 30 (n=30) based on the dentin surface treatment as follows: for Group 1: dentin specimens surfaces were treated with SDF. Group 2: dentin specimens were treated with SDF followed by KI. -Group 3: (Control): was without treatment. Color assessments of all the samples were performed after one day of immersion into artificial saliva using a portable reflective spectrophotometer.

For testing the shear bond strength; the shear bond strengths of all the dentin samples bonded to composite resin after performing the color assessment was tested by using Instron machine. Ongoing through the results we found that:
For shear bond strength measurement: the finding showed that the SDF treated group recorded the highest shear bond strength followed by SDF+KI group while control group recorded the lowest shear bond strength. The difference between all groups was statistically significant.

From this result it was observed that the bond strength of composite resin was not effected by application of SDF, or SDF/KI to artificial caries affected dentin. Our results were in parallel with several studies including:

Knight et al., 2006 evaluated the effect of SDF and KI on the bond strength of auto- cure glass ionomer cement to dentin and found that application of SDF/KI following by washing away of the precipitate and air drying, created bond strengths that were not significantly different to conditioned samples. Leaving the precipitate caused by Agf/KI reaction on the dentin surface significantly reduced the bond strength of auto-cure glass ionomer cement to dentin. [20]

Another report by Quock et al., 2012 concluded that there was no significant difference between the self-etch and etch and rinse bond strengths for the control groups with no SDF treatment and the groups treated with 38% SDF solution. [2]

As concluded by *Wu et al.,* 2016 dentin pretreating with 38 % silver diamine fluoride does not affect the bonding strength of composite resin to dentin. The fracture patterns observed suggest that bonding strength might be stronger between the adhesive and the SDF-applied dentin. Their data suggested that SDF could be used as a dentin pretreatment prior to resin restoration possibly contributing to secondary caries prevention in primary teeth. [138] A study by Selvaraj *et al.* , 2016 showed that pretreatment of dentin with SDF/KI minimized nanoleakage at the resin-dentin interface without adversely affecting the bond strength of resin composite to dentin and may enhance adhesive resin bonding. [139]

Lutgen *et al.,* 2018 in their study evaluated micro tensile shear bond strength to sound human dentin treated with SDF for 3 adhesive systems) and phosphoric acid-etching following 4 different SDF application protocols SDF demonstrated a negative effect on bonding and the severity of which strongly correlated with the application protocol used. Rinsing after SDF application led to improved bond strength compared to non-rinsing groups. Removal of the superficial layer of SDF treated dentin recovered bond strength values similar to those observed for controls for multi-step adhesive protocols SBT and CSE. [141]

Jiang *et al.,* 2020 mentioned that no firm conclusion can be drawn on the effect of SDF application on the bond strength of dentin to adhesives due to lack of a standard way to prepare specimen, including the SDF application protocol which was probably the reason to explain the variation. (142)

On the other hands, our study was disagreed with Sakr, 2020 who reported that pretreatment of dentin with either SDF or SDF/KI showed non-significant effect on micro-shear bond strength of resin composite to dentin. (143) Furthermore Koizumi *et al;* 2016 concluded that all dentin surfaces treated with SDF/KI and then bonded showed a significant weakening in bond strength. (140)

The parameters for color assessment in this study for ΔL which denoted translucency (lightness-darkness) summarized in table: 4 showed that the control group and SDF group recorded the most negative translucency change mean value (-3.08±3.10 ΔL) and (-2.74±3.34) respectively while the SDF+KI group recorded the lowest translucency mean value (-1.37±5.96).

For Δa illustrated the redness-greenness where the Redness-greenness change (Δa) results (Mean±SD) for all groups are summarized in table (5). The a* values represent the redness-greenness (Paravina, 2004). Positive a* relates to the amount of redness and negative values relate to greenness of the specimen.

It was found that ***SDF*** group recorded statistically significant highest redness-greenness change mean value (1.95 ± 1.84 Δa) followed by ***SDF +KI*** group (1.51 ± 2.53 Δa) while ***control*** group recorded the lowest statistically significant redness-greenness change mean value (0.12 ± 1.78 Δa) as indicted by one-way ANOVA followed by Tukey’s post-hoc tests ($p=<0.003$, Tukey , $p<0.05$).

On the other hand for Chroma changes Δb which is represented a measure of the Chroma along the yellow-blue axis,it was found that ***SDF +KI*** group recorded statistically significant highest chroma change mean value (8.55±3.87 Δb) followed by SDF group (2.21± 3.14 Δb) then the ***control*** group, which recorded the lowest statistically significant chroma change mean value (1.84± 5.50 Δb)

So, on comparing of color changes mean values as function of dentin surface treatment type using one-way ANOVA followed by Tukey's post-hoc tests indicated that ***SDF +KI*** group recorded statistically significant highest color change mean value (11.91±4.95 ΔE) followed by ***control*** group and SDF groups (6.74±3.03 ΔE & 5.84± 2.44 ΔE), respectively. The difference between groups was significant (p=<0.0001, turkey <0.05). Previous clinical studies on SDF reported that it was common to have black stains on the arrested caries lesions which may cause an aesthetic concern. (144,145) It has been suggested that by applying a saturated solution of potassium iodide (KI) immediately after the application of silver fluoride, staining of the dentin caries lesion can be minimized while the caries arrest effect of silver fluoride is not affected. (145,146) The proposed explanation is that the iodide ions from the KI solution will react with the excess silver ions from the silver fluoride solution to form a precipitate of silver iodide. (145)

Nguyen et al, 2017 found that treatments of teeth with KI solution after SDF treatment significantly reduced the discoloration caused by SDF. (147)

Zhao etal, 2017 found that SDF + KI treatment caused a perceptible staining at the restoration margin, but the intensity was less than that with purely SDF treatment. Silver ions in the SDF solution can blacken the tooth structure. It was suggested that the KI solution can react with SDF to form a bright yellow solid compound (silver iodide) and this reaction could reduce the excess free silver ions which result in the black staining. (148)

While KI was supposed to remove the staining caused by SDF, its effect has not been previously quantified. One possible explanation may be that the amount of the applied KI solution was not sufficient to lead to an excess of free silver ions remaining. Besides that, silver iodide is considered to be highly photosensitive which can dissociate into metallic silver and iodine by exposure to light. Moreover, in the long term, it was not effective in preventing discoloration of the restoration margin, but could reduce staining compared to that of SDF. [138]

Patel et al., 2018 concluded that the onset of black staining occurred within two minutes, was noticeable after five minutes, and increased in value for up to 6 h post application, use of KI immediately after SDF application resulted in no noticeable staining of the carious dentin or surrounding enamel and no significant differences were evident in the staining potential between the different SDF concentrations (38% and 12%), the root surface and cementum were found to stain darker and more readily when compared with the coronal enamel surface.[149]

Zhao *et al.,* 2019 in their study approved that the immediate application of KI solution after SDF treatment can reduce dentine discoloration caused by SDF. [6] Also Garg *et al.,* 2019 in their case report confirmed that the application of KI helps to reverse staining caused by SDF to a large extent but restoration margins was still to be at risk of discoloration. They concluded that KI can help enhance the esthetic outcome by stain reduction, thus making SDF a mainstream choice for preventing caries. [150]

A study by Miller *et al,* 2016 to assess if there was a definite difference in staining of restorations in silver diamine fluoride treated teeth, with or without the subsequent application of potassium iodide (KI) the author reported that there was no significant differences between the two groups. So they concluded that the application of potassium iodide after silver diamine fluoride on caries-affected teeth may improve initial esthetic appearance, but after placement of a glass ionomer restoration, potassium iodide did not seem to result in any significant difference in staining. [146]

Study limitation

The limitation of our study was that it was done in a lab setting which is completely different from oral environment especially for color assessment.

The high expenses of this research since it had been performed in private dental Lab in Egypt.

Chapter 7
Conclusions and Recommendations

7.Conclusions

- There were statically significant difference between the values of shear bond strength of all the test groups.
- Bonding of composite resin to affected dentin surface treated with SDF or SDF+KI did not compromised the value of shear bond strength.
- Bonding of composite resin to affected dentin without any surface treatment showed the lowest shear bond strength values.
- For color assessment there were significant difference between all the test groups regarding color change. Treatment of dentin surface with KI solution after SDF treatment significantly reduced the discoloration caused by SDF.

Recommendations

- The effectiveness of this combination SDF/KI treatment should be clinically proved.
- If caries can be arrested with this non-invasive treatment, a low cost treatment may be more acceptable and practical for areas without full dental operatories or for low-income patients with limited access to comprehensive dental care.
- The ammonic odor created during SDF treatment should be disclosed to the patient.

Chapter 8

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Chapter 9

Appendices

Effect of silver diamine fluoride and potassium iodide on shear bond strength of composite resin to caries affected dentin

(IN VITRO STUDY)

تـأثير فلوريد الفضة ثنائي الامين ويوديد البوتاسيوم علي قوة الترابط بين المركب الراتنجي والعاج المتأثر بالتسوس

دراسة مختبرية

By

Ghalia Omron Farag Ejakah

Proposal

Submitted In partial fulfillment of requirements for the degree of Master Science

In

Conservative and Endodontic

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Introduction

Dental caries continues to remain a global health problem ,even though various advancement have been done in dental care .the concept of the caries management has been changed from a surgical approach to a medical approach. Caries has been managed as a dental disease which cause a destruction of hard dental tissue. (1)

A variety of chemical agents have been developed as attempts to seize dentine caries .(2)Recently Silver diamine fluoride has been introduced to dental practitioners as one of the chemical agents to stop the development of dental caries for its antibacterial activity.(3)Many recent studies showed that the topical application of SDF can be considered a cost effective, simple and non –invasive technique for caries management.(4-6)

Furthermore laboratory studies recorded that SDF exhibited a high rank effect as anti-bacterial effect on cariogenic biofilm and inhibited the effect of matrix metallo-proteinase. (6, 7) Also, reported that the SDF enhanced mineral density of the carious enamel lesions and the micro hardness of the carious dentin lesions. (8-10)

A literature review reported that SDF is considered a safe and effective caries preventive agent that means it can match to the criteria of the World Health Organization (WHO) millennium goals and the US Food and Drug Administration (FDA).(11)

SDF is recommended as a mean to inhibit further dentin demineralization and collagen degradation which produced by cariogenic biofilm and promote dentin demineralization. (12, 13)

Although of its great benefits SDF application is often clinically limited in use due to formation of dark stains within tooth structure which leads to esthetic concern. (14) This stain is caused by silver deposition on the dentin surface because of this adverse effect the SDF is not well tolerated by patients with esthetic concern.

Two alternatives have been suggested to minimize this side-effect, one is to use a saturated potassium iodide (KI), which can react with residual silver ions, to eliminate the staining effect, and the other alternative is to apply GICs or composites over to mask the stained caries lesion. (15)

The restorative material's adhesive strength is best represented by shear bond (SBS) which defined as the maximum stress that a material can withstand before failure in a shear mode of loading.(15)

An in vitro study indicated that the SDF has no bond strength of composite resin to dentin. Furthermore it was reported that the type of adhesive etch and rinse vs self-etch does not affect the adhesion of composite resin to dentin in teeth treated with SDF. (16)

Furthermore it was reported that the pretreatment of dentin surface with SDF/KI minimized nanoleakage at the resin-dentin interface without adversely affecting the bond strength of resin composite to dentin.(16)

Aim of the study

This in vitro study will be performed to investigate the effect of silver diamine fluoride (SDF) and potassium iodide (KI) treatment on shear bond strength (SBS) of composite resin to artificial caries affected dentin.

To investigate:

1-Effect of potassium iodide (KI) on dentin discoloration caused by SDF application.

2-Effect of SDF and KI on shear bond strength of composite resin bonded to artificial carries affected dentin.

Materials and methods

1-materials

-Sixty sound human extracted molars will be collected from polyclinic to be used in this study.

-38% Silver diamine fluoride (SDF).

-Demineralized solution.

-Saturated potassium iodide (KI).

-Dentin adhesive.

-Composite resin.

2. Methods of the study

2:1. Sample collection

In this study sixty sound molars teeth will be collected, with exclusion of teeth with cracks and caries or restoration.

2:2 Sample preparation

The teeth will be thoroughly cleaned with ultrasonic scaler and slurry pumice to remove all soft tissue remnants, calculus and plaque and then will be stored in normal saline at room temperature.

The occlusal surface will be grained to remove enamel structure and to expose fresh dentin surface.

Sixty dentin slices with 2mm thickness will be prepared with especial disk.

Magnified lenses will be used to ensure complete removal of enamel.

Each sample will be embedded in a mould filled with cold –cure acrylic resin up to level 5mm from the sample thickness.

The surfaces of all dentin slices will be polished with micro-fine sanding paper under running water.

All the samples will be immersed in demineralized solution for 7 days.

2:3 sample grouping

The sixty samples will be allocated to three equal groups according to type of treatment with (n=20).

-For group1: A total number 20 dentin specimens (n=20) will be used.

This group will be treated with SDF.

-For group 2: A total number 20 dentin specimens (n=20) will be treated with SDF followed by KI.

-For group 3: A control group in which a total number 20 dentin specimens (n=20) will be used with no treatment.

2.4. Material application

2.4.1. For SDF application (group 1)

The demineralized dentin surface of all the specimens will be treated with a38% SDF solution using a micro brush.

2.4.2. For SDF+KI application (group 2)

The demineralized surface will be treated with SDF+KI.38% SDF will be applied to dentin slices using micro-brush, immediately followed by saturated KI solution until a creamy white solution turned clear. The reaction will be washed off with distilled water.

2.4.3. Negative control group, **Group3** the demineralized surface will receive water application only.

3-Testing methods

3.1. Color assessment Color assessment of dentin samples will be performed after 1-day immersion in the artificial saliva. The color of the treated dentin surface will be assessed using Spectrophotometer.

3.2 .For bond testing

3.3.1. Material application

All the dentin samples (n=60) will be treated with adhesive system according to its manufacturer instructions.

Then, the treated samples will be bonded with photo-cure composite resin.

A Teflon mould with 4 mm height and 3 mm diameter will be placed on the treated dentin surface and the composite material will be packed inside. A glass slide will be placed on the top of the Teflon mould under a steady pressure and photo-cured.

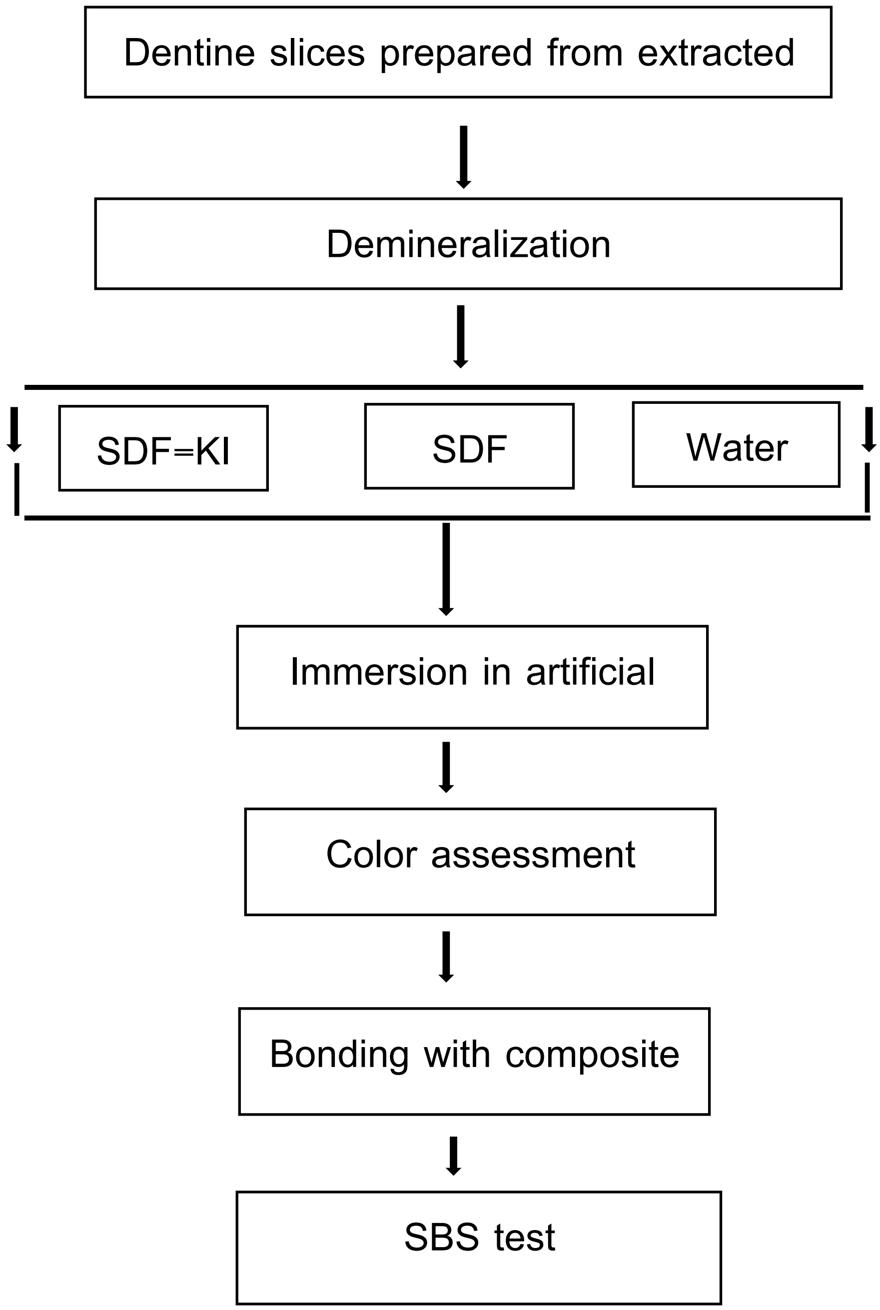
3.3.2. Shear bond strength testing

A circular interface shear test will be designed to evaluate the bond strength. All samples will be individually and horizontally mounted on a universal testing machine.

Samples will be secured to the low fixed compartment of testing machine by tightening screws .shearing test will be done by compressive mode of load applied at dentin substrate-resin interface amono-beveled chisel shaped metallic rod attached to the upper movable compartment of the testing machine travelling at cross-head speed of 0.5 mm/min. the load required to debonding will be recorded in the Newtons.

The shear bond strength will be calculate as follow: the load at the failure will be divided by bonding area to express the bond the bond strength in MPa

STUDY DESIGN



Sample grouping

Treatment / Material	SDF G1 n = 30	SDF/KI G2 n =30	Control G3 n=30	Total
Color masking(M	G1M	G2M	G3M	90
Bond strength (S)	G1S	G2M	G3M	90
	60	60	60	180

Statistical analysis:

The results of the study will be tabulated and statistically analysis.

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تـأثير فلوريد الفضة ثنائي الامين ويوديد البوتاسيوم علي قوة الترابط بين المركب الراتنجي والعاج المتأثر بالتسوس

دراسة مختبرية

قدمت من قبل :

غالية عمران فرج اجعاكة

تحت اشراف :

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ملخص

الاهداف: الغرض من هذه الدراسة هو فحص تاثيرفلوريد ثنائي الفضة ويوديد البوتاسيوم علي قوة الرابط الراتنجى بين مركب الراتنج وعاج الاسنان المتأثر بالتسوس ودراسة تأثير يوديد البوتاسيوم علي التصبغ الناتج عن استعمال فلوريد ثنائي الفضة

المواد والطرق المستعملة: تم تجميع 90 اسنان سليمة من العيادات المجمعة وحفظت في محلول كلورامين0.5% لمدة شهر كل ضرس تم قص كل طبقة المينا للحصول علي سطح مستو من العاج سمكه 2سم ثم غرزت في اكريلك رزين كل العينات وضعت في محلول ازالة المعادن ثم قسمت الي ثلاث مجموعات حسب المعالجة كالتالي: المجموعة 1:عولجت بفلوريد الفضة ثنائى الامين ,المجموعة 2: فلوريد ثنائى الفضة+يوديد البوتاسيوم ,المجموعة 3: لا شيء. كل العينات تم قياس التغير في اللون ثم كل العينات تم معالجنها بالمركب الراتنجي حسب المواصفات المتبعة وتم قياس قوة الربط الراتنجي بين العاج المتأثر بالتسوس مركب الراتنج ,كل البيانات جمعت وحللت احصائيا.

النتائج:علاج العاج المتاثر بالتسوس بفلوريد الفضة ثنائي الامين متبوعا بيوديد البوتاسيوم زاد من قوة الربط بين المركب الراتنجي وعاج الاسنان المتاثر بالتسوس بفارق ذو اهمية,كذلك استعمال يوديد البوتاسيوم كان له تأثير في أخفاء التصبغ الناتج عن استعمال فلوريد الفضة ثنائى الامين.

الاستنتاج: استخدام فلوريد ثنائى الفضة ويوديد البوتاسيوم لم يكن له تاثير معاكس علي قوة الربط الراتنجى بين المركب الراتنجى وعاج الاسنان المتأثر بالتسوس واستعمال يوديد البوتاسيوم قلل من التصبغ الناتج عن استخدام فلوريد الفضة ثنائى الامين.

الكلمات الدالة:فلوريد الفضة ثنائى الامين,يوديد البوتاسيوم,عاج الاسنان المتأثر بالتسوس,قوة الربط الراتنجي,التصبغ.

تأثير فلوريد الفضة ثنائي الامين ويوديد البوتاسيوم علي قوة الترابط بين المركب الراتنجي والعاج المتأثر بالتسوس

دراسة مختبرية

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قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في العلاج التحفظي

جامعة بنغازي

كلية طب وجراحة الفم والأسنان

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